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CHAKACHAMNA HYDROELECTRIC PROJECT
INTERIM FEASIBILITY ASSESSMENT REPORT

VOLUME I
SECTIONS 1-10
APPENDIXES TO SECTIONS 4.0 & 8.0

BECHTEL CIVIL & MINERALS INC.

ENGINEERS – CONSTRUCTORS

MARCH 1983

ALASKA POWER AUTHORITY

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CHAKACHAMNA HYDROELECTRIC PROJECT
INTERIM FEASIBILITY ASSESSMENT REPORT
MARCH 1983

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INTRODUCTION

ALASKA POWER AUTHORITY

ANCHORAGE ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

INTERIM FEASIBILITY ASSESSMENT REPORT, MARCH, 1983

1.0 INTRODUCTION

This report has been prepared in accordance with the terms of Contract 82-0294 dated August 3, 1981 between the State of Alaska/Department of Commerce and Economic Development/Alaska Power Authority and Bechtel Civil & Minerals, Inc. in connection with services for performing interim feasibility assessment studies of the Chakachamna Hydroelectric Project. As its title indicates, the report is of an interim nature. It is based upon previously published information regarding the project, and on data acquired and derived during a study period extending from the fall of 1981 to December 1982. Its objectives are to summarize the information derived from the studies, to provide a preliminary evaluation of alternative ways of developing the power potential of the project, to define that power potential, and to report on the estimated cost of construction, and to provide a preliminary assessment of the effects that the project would have on the environment.

The initial engineering, geological, and environmental studies were conducted during the fall of 1981, and the findings of these studies were summarized in an interim report dated November 30, 1981. Although the data

collected and study period up to that time were rather limited by the short time base, some rather clear indications emerged as to the manner in which it was considered that development of the project should proceed.

One aspect that became evident was that a much more extensive and populous fishery uses the waters in the project area than had been earlier realized or anticipated. This led to an amendment of the above mentioned contract in which the requirements for completion of the feasibility report and application to the Federal Energy Regulatory Commission for a license to construct the project were deleted from the scope of work. Continuing studies of the fishery in the waters of the project area were authorized as were the development of conceptual designs for fish passage facilities at the outlet of Chakachamna Lake plus the preparation of estimates of their construction costs and those of the McArthur tunnel assuming that it could be excavated by tunnel boring machine.

As may be seen by reference to Figure 1-1, Chakachamna Lake lies in the southern part of the Alaska Range of mountains about 85 miles due west of Anchorage. Its water surface lies at about elevation 1140 feet above mean sea level.

The project has been studied and reported upon several times in the past. The power potential had been estimated variously from about 100,000 kw to 200,000 kw firm capacity, depending on the degree of regulation of the outflow from Chakachamna Lake and the hydraulic head that could be developed.

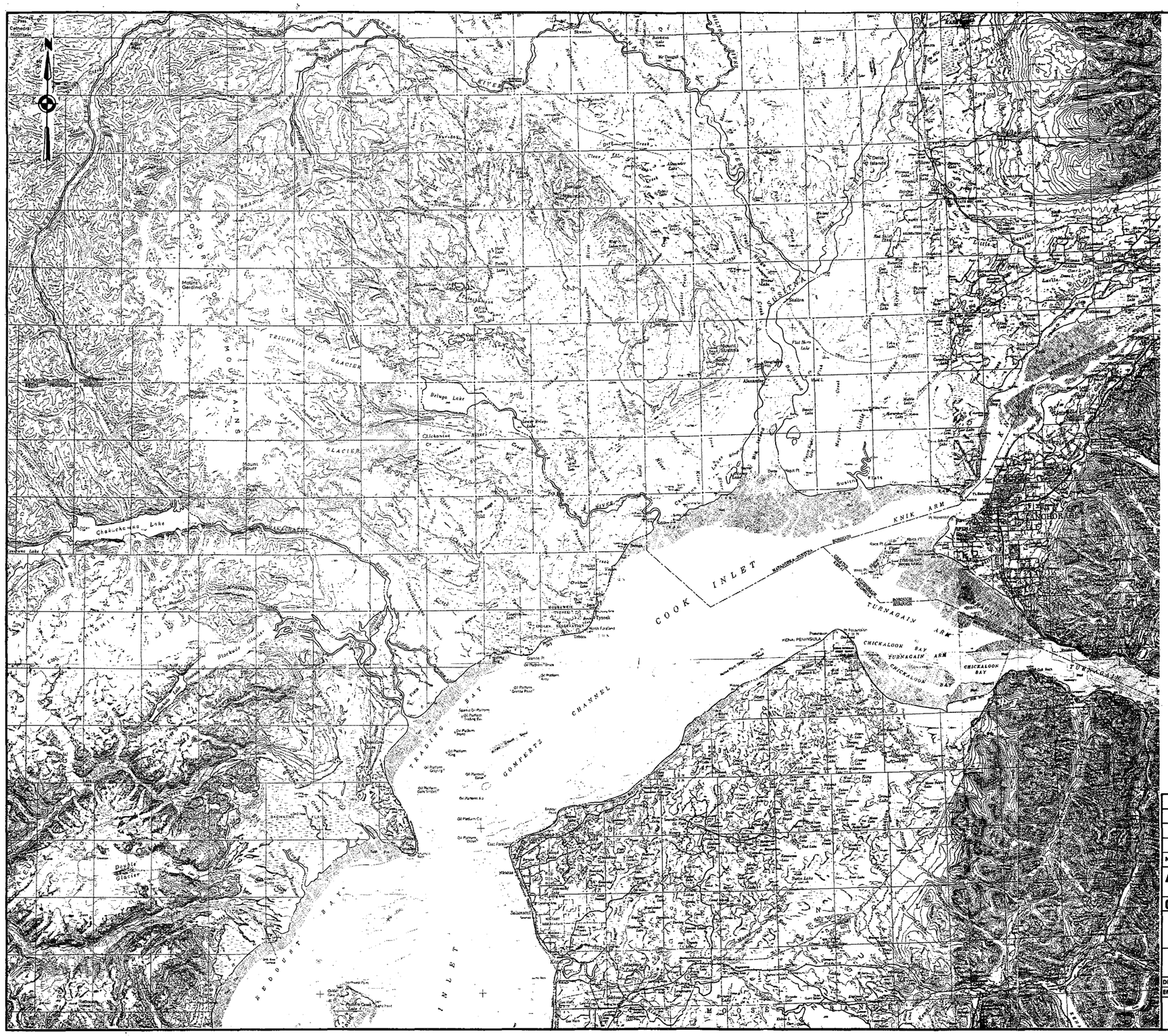
Two basic alternatives can be readily identified to harness the hydraulic head for the generation of electrical energy. One is by a twelve mile tunnel more or less parallel to the valley of the Chakachatna River. This river runs out of the easterly end of the lake and descends to about elevation 400 feet above sea level where the river leaves the confines of the valley and spills out onto a broad alluvial flood plain. A maximum hydrostatic head of about 740 feet could be developed via this alternative.

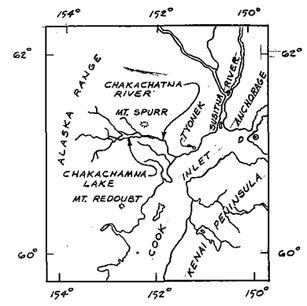
The other alternative is for development by diversion of the lake outflow through a ten mile tunnel to the valley of the McArthur River which lies to the southeast of the lake outlet. A maximum hydrostatic head of about 960 feet could be harnessed by this diversion. Various means of development by these two basic alternatives are discussed in the report on the basis of the present knowledge of the site conditions.

The 1982 environmental studies confirmed the importance of the fishery using waters in the project area and expanded the data base concerning it. The basic elements of the recommended mode of development were conceived, these being for development via the McArthur River with a concrete lined machine bored tunnel and with fish passage facilities that would permit fish to ascend into the lake or to travel downstream from the lake into the Chakachatna River. Three samples of rock collected from the surface, two from the general vicinity of the proposed power intake site at Chakachamna Lake and one from near the powerhouse site by the McArthur River, were tested in The Robbins Company laboratory at Kent, Washington. The results indicated that the rock sampled,

would be suitable for boring, but since the test data from samples taken at the surface can sometimes be misleading, and since no geological studies have yet been performed along the planned tunnel alignment, it must be assumed at the present time that the tunnel can be bored and additional geological studies will be needed before it can be firmly recommended that the tunnel be bored by machine. The rock test data was used for guidance in estimating the cutter penetration rate in assessing the estimated cost of excavating the tunnel by boring machine.

For the assessment of environmental factors and geological conditions in the project area, Bechtel retained the services of Woodward-Clyde Consultants.





VICINITY MAP

4 0 4 8

SCALE : 1" = 4 MILES

NOTES:

1.) TOPOGRAPHY IS FROM USGS QUADRANGLE MAPS

2.) VERTICAL DATUM IS MEAN LOWER LOW WATER

3.) HORIZONTAL GRID IS UNIVERSAL TRANSVERSE MERCATOR PROJECTION, 1927 NORTH AMERICAN DATUM

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

LOCATION PLAN

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED Richfield
ENGR SUPV Richfield	PROJ ENGR JM	APP'D RZ

JOB No.	DRAWING No.	REV.
14879	FIGURE 1-1	B

SUMMARY

2.0 SUMMARY

2.1 Project Layout Studies

The studies evaluated the merits of developing the power potential of the project by diversion of water southeasterly to the McArthur River via a tunnel about 10 miles long, or easterly down the Chakachatna Valley either by a tunnel about 12 miles long or by a dam and tunnel development. In the Chakachatna Valley, few sites, adverse foundation conditions, and the nearby presence of an active volcano made it rapidly evident that the feasibility of constructing a dam there would be questionable. The main thrust of the initial studies was therefore directed toward the tunnel alternatives without consideration of raising the lake level above the present outlet channel invert, taken as El. 1128, and a minimum drawdown of the water level to El. 1014.

Two alignments were studied for the McArthur Tunnel. The first considered the shortest distance that gave no opportunity for an additional point of access during construction via an intermediate adit. The second alignment was about a mile longer, but gave an additional point of access, thus reducing the lengths of headings and also the time required for construction of the tunnel. Cost comparisons and economic evaluation nevertheless favored the shorter 10 mile 25 foot diameter tunnel.

The second alignment running more or less parallel to the Chakachatna River in the right (southerly) wall of the valley afforded two opportunities for intermediate

access adits. These, plus the upstream and downstream portals would allow construction to proceed simultaneously in 6 headings and reduce the construction time by 18 months less than that required for the McArthur Tunnel. Economic evaluation again favored a 25 foot diameter tunnel running all the way from the lake to the downstream end of the Chakachatna Valley.

If all the controlled water were used for power generation, the McArthur Powerhouse could support 400 MW installed capacity, and produce average annual firm energy of 1752 GWh. The effects of making a provisional reservation of approximately 19% of the average annual inflow to the lake for instream flow requirements in the Chakachatna River were found to reduce the economic tunnel diameter to 23 feet. The installed capacity in the powerhouse would then be reduced to 330 MW and the average annual firm energy to 1446 GWh.

If a small rock dike were to be constructed at the outlet of the lake and the maximum lake level is raised to the natural maximum, El. 1155, this would allow 72 feet lake drawdown to accommodate fish passage facilities. If the tunnel diameter remained 23 feet to avoid excessive losses, then the installed capacity in the powerhouse would be 330 MW and the average annual firm energy 1301 GWh. The reduction in firm energy is due to the lesser volume of regulatory storage contained within the narrower range of lake level needed for gravity operation of the fish passage facilities.

For the Chakachatna Powerhouse, diversion of all the controlled water for power generation would support an installed capacity of 300 MW with an average annual firm energy generation of 1314 GWh. Provisional reservation of approximately 0.8% of the average annual inflow to the lake for instream flow requirements in the Chakachatna River was regarded as having negligible effect on the installed capacity and average annual firm energy because that reduction is within the accuracy of the present study.

The reasoning for the smaller instream flow releases considered in this alternative is discussed in Section 2.5.3.

2.2 Geological Studies

At the present level of study, the Quarternary Geology in the Chakachatna and McArthur Valleys has been evaluated and the seismic geology of the general area has been examined though additional work remains to be done next year. General observations as they may affect the project are as follows:

The move of ice of the Barrier Glacier toward the river may be gradually slowing. However, no material change in the effect of the glacier on the control of the Chakachamna Lake outlet is anticipated.

The condition of the Blockade Glacier facing the mouth of the McArthur Canyon also appears to be much the same as reported in the previous USGS studies.

There does not appear to be any reason to expect a dramatic change in the state of growth or recession of either of the above two glaciers in the foreseeable future.

Surface exposures on the left (northerly) side of the Chakachatna Valley consist of a heterogeneous mix of volcanic ejecta and glacial and fluvial sediments which raise doubts as to the feasibility of damming Chakachatna River by a dam located downstream of the glacier.

The rock in the right wall of the Chakachatna Valley is granitic, and surface exposures appear to indicate that it would be suitable for tunnel construction if that form of development of the project were found to be desirable.

No rock conditions have yet been observed that would appear to rule out the feasibility of constructing a tunnel between the proposed locations of an intake structure near the outlet of Chakachamna Lake and a powerhouse site in the McArthur Valley. It must be noted, however, that in the vicinity of the proposed powerhouse location in the McArthur Canyon, the surface exposures indicate that rock quality apppears to improve significantly with distance upstream from the mouth of the canyon.

The Castle Mountain fault, which is a major fault structure, falls just outside the mouth of the McArthur Canyon and must be taken into account in the seismic design criteria of any development of the

project whether it be via the McArthur or Chakachatna Canyons. Other significant seismic sources are the Megathrust Section of the Subduction Zone and the Benioff Zone.

2.3 Environmental Studies

2.3.1 Hydrology

Field reconnaissances were conducted in Chakachamna Lake, several of its tributary streams, the Chakachatna and McArthur Rivers. Records of mean daily flows were initiated in mid-August 1982 at the site of the previously operated U.S. Geological Survey gage site and in the Upper McArthur River downstream from the powerhouse location. Data collected and developed are typical of glacial rivers with low flow in late winter and large glacier melt flows in July and August.

The water level in Chakachamna Lake when measured in 1981 was elevation 1142 and is typical of the September Lake stage records in the 12 years preceding the major flood of August 1971. Lake bottom profiles were surveyed at the deltas of the Nagishlamina and Chilligan Rivers, and the Shamrock Glacier Rapids.

Reaches of the McArthur and Chakachatna Rivers vary in configuration from mountainous through meandering and braided. All except the most infrequent large floods are mostly contained within the unvegetated flood plan. Sedimentation characteristics appear to be typically those of glacial systems with very fine suspended sediments and substantial bed load transport.

2.3.2 Aquatic Biology

Field observations identified the following species in the waters of the project area:

Resident:	Rainbow trout	Artic grayling
	Lake trout	Slimy sculpin
	Dolly Varden	Ninespine stickleback
	Round Whitefish	Threespine stickleback
	Pygmy Whitefish	
Anadromous:	Chinook salmon	Pink salmon
	Chum salmon	Sockeye salmon
	Coho salmon	Dolly Varden
	Eulachon	Rainbow smelt
	Longfin smelt	Bering cisco

Salmon spawning in the Chakachatna River drainage and its tributaries occurs primarily in tributaries and sloughs. A relatively small percentage of the 1982 estimated escapement was observed to occur in mainstem or side-channel habitats of the Chakachatna River.

The largest salmon escapement in the Chakachatna drainage was estimated to occur in the Chilligan and Igitna Rivers upstream of Chakachamna Lake. The escapement of those sockeye in 1982 was estimated to be approximately 41,000 fish, or about 70 percent of the escapement within the Chakachatna drainage. Chakachamna Lake is the major rearing habitat for these sockeye. It also provides habitat for lake trout, Dolly Varden, round whitefish, and sculpins.

In the McArthur River over 96 percent of the estimated salmon escapement occurred in tributaries during 1982. The estimated escapement of salmon of all species was slightly greater in the McArthur than the Chakachatna drainage. Other anadromous fish including eulachon, Bering cisco, longfin smelt and rainbow smelt have been found in the McArthur River.

The contribution of salmon stocks originating in these systems to the Cook Inlet commercial catch is presently unknown. Although some commercial and subsistence fishing occurs, the extent to which the stock is exploited is also not known.

Rearing habitat for juvenile anadromous and resident fish is found throughout both rivers, although the waters within the Chakachatna River canyon below Chakachamna Lake and the headwaters of the McArthur River do not appear to be important rearing habitat. There appears to be extensive movement of fish within and between the two drainages, and seasonal changes in distribution have also been noted.

2.3.3 Terrestrial Biology

On the basis of their structural and species compositions, eight types of vegetation habitats were delineated. These range from dense alder thickets in the canyons to vast areas of coastal marsh. The riparian communities are the most prevalent varying from rivers with emergent vegetation to those with broad flood plains scattered with lichen, willow and alder.

Evaluation of wildlife communities in the project area identified seventeen species of mammals. Moose, coyote, grizzly bear and black bear ranges occur throughout the area.

Birds also are abundant, fifty-six species having been identified with the coastal marshes along Trading Bay containing the largest diversity.

None of the species of plants, mammals and birds that were found are listed as threatened or endangered although in May 1981 it was proposed that the tule whitefronted goose, which feeds and may nest in the area, be considered for threatened or endangered status.

2.3.4 Human Resources

These studies were organized into the following six elements:

Archaeological and historical resources
Land ownership and use
Recreational resources
Socioeconomic characteristics
Transportation
Visual resources

Many contacts were made with both State and Federal Agencies and native organizations, as well as a limited reconnaissance of the project area.

No known cultural sites have been identified and the field reconnaissance indicates that the proposed sites for the power intake and powerhouses have a low potential for cultural sites.

Land owners in the area comprise federal, state, and borough agencies, Native corporations and private parties. Land use is related to resource extraction (lumber, oil and gas), subsistence and the rural residential village of Tyonek.

Recreational activity takes place in the project area, but with the exception of Trading Bay State Game Refuge, little data is available as to the extent or frequency with which the area is used.

Regional data on population, employment and income characteristics are relatively good. Employment level and occupational skill data are limited and need to be developed together with information on local employment preferences.

Transportation facilities in the area are few and small in size. There are airstrips at Tyonek and on the shoreline at Trading Bay. A woodchip loading pier is located near Tyonek. Several miles of logging roads exist between Tyonek and the mouth of the Chakachatna Valley; many of these roads and bridges are being removed as timber activities are completed in specific areas. The Chakachatna River was bridged near its confluence with Straight Creek until 1982. There is no permanent road linking the project area with any part of the Alaska road system.

The project area's scenic characteristics and proximity with BLM lands, Lake Clark National Park and the Trading Bay State Game Refuge make visual resource management a significant concern.

2.4 Economic Evaluation

The studies demonstrate that the project offers an ecomonically viable source of energy in comparison with the 55.6 mills/kWh which is the estimated cost of equivalent energy from a coal fired plant, apparently the most competitive alternative source. Taking that figure as the value of energy, the Chakachamna Hydroelectric Project could begin producing 400 MW at 50% load factor (1752 GWh) in 1990 at 37.5 mills/KWh if all stored water is used for power generation. If approximately 19 percent of the water is reserved for instream flow release to the Chakachatna River, the powerplant could still produce 330 MW at 50% load factor (1446 GWh) at 43.5 mills/KWh, which is still significantly more economical than the coal fired alternative. Assuming that the power tunnel were to be machine bored, if the maximum pool level of the lake is raised to El. 1155 and can be drawn down to El. 1083, the powerplant will produce 330 MW (1301 GWh) at 44.5 mills/KWh with 45% load factor. In all the cases above, the powerhouse would be located on the McArthur River. A powerhouse on the Chakachatna River as described in the report is barely competitive with the alternative coal fired source of energy.

2.5 Technical Evaluation and Discussion

Several alternative methods of developing the project were identified and reviewed in 1981. Based on the analyses performed in 1982, the most viable alternative has been identified for further study. That is Alternative E in which water would be diverted from Chakachamna Lake to a powerhouse located near the McArthur River.

2.5.1 Chakachatna Dam Alternative

The construction of a dam in the Chakachatna River Canyon approximately 6 miles downstream from the lake outlet, does not appear to be a reasonable alternative. While the site is topographically suitable, the foundation conditions in the river valley and left abutment are poor as mentioned earlier in Section 2.2. Furthermore, its environmental impact specifically on the fisheries resource will be significant although provision of fish passage facilites could mitigate this impact to a certain extent.

2.5.2 McArthur Tunnel Alternatives A, and B

Diversion of flow from Chakachamna Lake to the McArthur Valley to develop a head of approximately 900 feet has been identified as the most advantageous as far as energy production at reasonable cost is concerned.

The geologic conditions for the various project facilities including intake, power tunnel, and powerhouse appear to be favorable based on the limited 1981 field

reconnaissances. No insurmountable engineering problems appear to exist in development of the project.

Alternative A, in which essentially all stored water would be diverted from Chakachamna Lake for power production purposes could deliver 1664 GWh of firm energy per year to Anchorage and provide 400 MW of peaking capacity. Cost of energy is estimated to be 37.5 mills per KWh. However, since the flow of the Chakachatna River below the lake outlet would be adversely affected, the existing anadromous fishery resource which uses the river to gain entry to the lake and its tributaries for spawning, would be lost. In addition the fish which spawn in the lower Chakachatna River would also be impacted due to the much reduced river flow. For this reason Alternative B has been developed, with essentially the same project arrangement except that approximately 19 percent of the average annual flow into Chakachamna Lake would be released into the Chakachatna River below the lake outlet to maintain the fishery resource. Because of the smaller flow available for power production, the installed capacity of the project would be reduced to 330 MW and the firm energy delivered to Anchorage would be 1374 GWh per year. The estimated cost of energy is 43.5 mills per KWh. The cost estimate included an allowance for facilities for downstream flow release and for passage of fish at the lake outlet. Layouts of these facilities were not prepared. Obviously, the long term environmental impacts of the project in this Alternative B are significantly reduced in comparison to Alternative A.

2.5.3 Chakachatna Tunnel Alternatives C and D

An alternative to the development of this hydroelectric resource by diversion of flows from Chakachamna Lake to the McArthur River is by constructing a tunnel through the right wall of the Chakachatna Valley and locating the powerhouse near the downstream end of the valley. The general layout of the project would be similar to that of Alternatives A and B for a slightly longer power tunnel.

The geologic conditions for the various project features including intake, power tunnel, and powerhouse appear to be favorable and very similar to those of Alternatives A and B. Similarly no insurmountable engineering problems appear to exist in development of the project Alternative C, in which essentially all stored water is diverted from Chakachamna Lake for power production, could deliver 1248 GWh of firm energy per year to Anchorage and provide 300 MW of peaking capability. Cost of energy is estimated to be 52.5 mills per KWh. While the flow in the Chakachatna River below the powerhouse at the end of the canyon will not be substantially affected, the fact that no releases are provided into the river at the lake outlet will cause a substantial impact on the anadromous fish which normally enter the lake and pass through it to the upstream tributaries. Alternative D was therefore proposed in which a release of 30 cfs is maintained at the lake outlet to facilitate fish passage through the canyon section into the lake. In either of Alternatives C or D the environmental impact would be limited to the Chakachatna River as opposed to Alternatives A and B in which both the Chakachatna

and McArthur Rivers would be affected. Since the instream flow release for Alternative D is less than 1% of the total available flow, the power production of Alternative D can be regarded as being the same as those of Alternative C at this level of study (300 MW peaking capability, 1248 GWh of firm energy delivered to Anchorage). Cost of power from Alternative D is 54.5 mills per KWh.

The cost of energy from Alternative D is 25% greater than that for Alternative B and E and is close to the cost of alternative coal-fired resources. Therefore, it was decided to concentrate further studies on the McArthur River alternatives.

2.5.4 Alternative E

In the development of Alternative B, no specific method was developed for release of instream flows into the Chakachatna River immediately downstream from the lake outlet, and no specific facilities were developed for the passage of upstream and downstream migrant fish at the lake outlet. Instead a lump sum cost allowance was provided to cover these items for Alternative B.

However, in Alternative E which is a refinement of Alternative B, development by tunnel to the McArthur River, specific facilities for providing instream flow releases and fish passage facilities were developed and incorporated into the proposed project structures. To facilitate the arrangement of these facilities, it became evident that a more limited reservoir drawdown was essential. The range of

reservoir level adopted was maximum level El. 1155 near the historical maximum level, and minimum level El. 1083 to permit gravity discharge of water through the facilities at the lowest operating water level.

With this operating range in the reservoir and with an installed capacity of 330 MW, the project can produce 1301 GWh per annum at a 45% load factor. If a 50% load factor were to be retained, the installed capacity of the powerhouse would reduce to approximately 300 MW, which would reduce the overall project cost by about 5-10%. However, at this stage of the project development, such a refinement was not considered warranted, and the same installed capacity as developed for Alternative B was retained for Alternative E, i.e. 330 MW. Significant project data for Alternative E are set forth in Table 2-1.

Alternative E is also based on the power tunnel being driven by a tunnel boring machine which resulted in a significant reduction in cost compared with conventional "drill and shoot" methods previously adopted for Alternatives A through D. In addition, the power tunnel profile in Alternative E was modified to a uniform grade from the intake at Lake Chakachamna to the powerhouse in the McArthur valley. The estimated cost of energy is 44.5 mills per kWh.

It should be noted that the significant saving in tunnel cost for Alternative E, as compared with Alternative B, is offset by the increased cost of the fish passage facilities and slightly lower energy production, thereby yielding a firm energy cost slightly higher for Alternative E than for Alternative B.

TABLE 2-1

RECOMMENDED ALTERNATIVE E

PROJECT DATA

Chakachamna Lake	
Maximum water level, natural conditions, (ft.)	1,155
Minimum water level, natural conditions, approx. (ft.)	1,128
Surface area at elevation 1155 (sq. mi.)	27
Total volume at elevation 1155 (Ac. ft.)	4,483,000
Drainage area (sq. mi.)	1,120
Average annual inflow, 12 years (cfs)	3,606
Correlated average annual inflow, 31 years (cfs)	3,781
Reservoir Operation	
Normal maximum operating water surface elevation (ft.)	1,155
Normal minimum water surface elevation (ft.)	1,083
Active storage (Ac. ft.)	1,105,000
Dike	
Type	Overflow rockfill
Length, (ft.)	600
Crest elevation (ft.)	1,177
Maximum height (ft.)	49
Volume (Cu. yd.)	250,000
Spillway	
Type	Free overflow
Crest elevation (ft.)	1,155
Discharge capacity (cfs)	55,000
Power Tunnel	
Type	Circular, concrete lined
Diameter, internal (ft.)	24
Hydraulic capacity (cfs)	7,200
Surge chamber (Dia. x Ht. Ft.)	48 x 450

TABLE 2-1 (cont'd)

Penstock	
Number/Type	1-Circular, concrete lined 4-Circular, steel lined
Diameter, internal (ft.)	
Concrete lined	24
Steel lined	10
Powerhouse	
Type	Underground
Cavern size (L x W x H Ft.)	250 x 65 x 130
Turbines	4 Vertical Francis
Generators	Synchronous
Unit output (MW)	82.5
Maximum net head (ft.)	938
Minimum net head (ft.)	866
Maximum discharge (cfs)	7,200
Distributor centerline elevation (ft.)	190
Installed capacity (MW)	330
Average annual firm energy (GWh)	1,301
Average annual secondary energy (GWh)	290
Load factor	.45
Fish Passage Facilities	
Maximum release (cfs)	1,094
Minimum release (cfs)	343
Fish passage tunnel (L x W x H Ft.)	7800 x 18 x 20
Economic Parameters	
Estimated total cost $ billion	1.31
Cost of energy (mills per kWh)	44.5
Cost per installed kW ($)	3,985
Construction period (Mos.)	76

PROJECT DEVELOPMENT STUDIES

3.0 PROJECT DEVELOPMENT STUDIES

3.1 Regulatory Storage

The existing stream flow records show a wide seasonal variation in discharge from Chakachamna Lake with 91 percent of the annual discharge occurring from May 1 through October 31 and 9 percent from November 1 through April 30 when peak electrical demands occur. The storage volume required to regulate the flow has been reported to be in the order of 1.6 million acre-feet (USBR, 1962). The elevation of the river bed at the lake outlet has been reported as 1127-1128 feet (Giles, 1967). This elevation is thought to have varied according to the amounts and sizes of solid materials deposited in the river bed each year by the melting toe of the glacier, and the magnitude of the annual peak outflow from the lake that is available to erode the solid materials away and restore the river channel.

The above-mentioned volume of regulatory storage can be developed by drawing down the lake by 113 feet to Elevation 1014. The original studies performed in 1981 adopted such a reservoir operating range in developing project alternatives A, B, C and D. However, when the 1982 studies for development of suitable fish passage facilities at the lake outlet were initiated, it became evident that a lake drawdown to El. 1014 was not suited to the provision of such facilities. Therefore a modified range of reservoir operating level was adopted as discussed below.

If the maximum lake level is raised to El. 1155 and 72 feet drawdown is considered, then a regulatory storage of 1,105,000 acre-feet is provided with increase in head. Although previous studies of the project have discredited the possibility of locating a control structure at the lake outlet because its left abutment would have lain on the toe of the Barrier Glacier, it is believed that a relatively low dike with 27 feet of hydraulic head plus freeboard could be constructed and maintained at this location. This is discussed further in Section 3.5.1.

The Barrier Glacier ice thickness was measured in 1981 by the USGS using radar techniques. The data has not yet been published but verbal communication with the USGS staff has indicated that the ice depth is probably 500-600 feet in the lower moraine covered part of the glacier near the lake outlet. Thus it would appear that the outlet channel from the lake may be a small gravel and boulder lined notch in a deep bed of ice.

3.2 Chakachatna Dam

The possibility of gaining both storage and head by means of a dam on the Chakachatna River was first posed in 1950 by Arthur Johnson (Johnson, 1950) who identified, though was unable to inspect, a potential dam site about 6 miles downstream from the lake outlet. Three years later, during the 1953 eruption of Mount Spurr, a mud flow descended the volcano slopes and temporarily blocked the river at this location, backing it up for about 4 miles until it overtopped the debris dam. At this location, the river today is

still backed up almost 2 miles despite the occurrence of the August 1971 lake breakout flood estimated to have peaked at about 470,000 cubic feet per second (Lamke, 1972). This flow is about twenty times larger than the maximum daily discharge that occurred during the 1959-1972 period of record.

Examination of aerial photographs taken after the 1953 eruption between 1954 and 1981 indicate that subsequent mud flows, though of smaller magnitude, may have occurred but probably did not reach the river. The source of this activity has been Crater Peak, an active volcanic crater on the southerly flank of Mount Spurr. It lies directly above and in close proximity to the postulated dam site and thus poses serious questions on the safety of this site for construction of any form of dam. At this location, generally from about 6 miles to 7 miles downstream from the lake outlet, the river is confined within a canyon. Both upstream and downstream, the valley substantially widens and does not appear to offer any topographicaly feasible sites for locating a dam.

Within the canyon itself, conditions are rather unfavorable for siting a dam. Bedrock is exposed on the right abutment, making this the most likely site for a spillway, but the rock surface dips at about 40-degrees toward the river channel. At this location, the peak discharge of the probable maximum flood calculated according to conventional procedures would be in the order of 100,000 cubic feet per second. The crest length of a spillway would have to be in the order of 200 feet and siting it on the steeply dipping

right abutment rock surface would be difficult and costly.

Surface examination of the left abutment conditions, as discussed in section 5.2.3.2 of this report, indicates that they consist of deep unconsolidated volcanic materials. These would require a deep diaphragm wall or slurry trench cutoff to bedrock, or an extensive upstream foundation blanket to control seepage through the pervious materials lying on this abutment. Very high costs would also be attached to their construction.

The presence of the volcano and its potential for future eruptions accompanied by mud flows as well as pyroclastic ash flows is probably the overriding factor in discrediting the feasibility of constructing a dam in this canyon location. Consequently, this concept has been temporarily set aside from further consideration at the present stage of the studies, and the main thrust has been directed toward development by gaining regulatory storage by drawing down the lake water level and diverting water from a submerged intake in Chakachamna Lake through a tunnel to the McArthur river, or through a tunnel to the mouth of the Chakachatna Valley, as discussed in the next two sections of this report.

3.3 McArthur Tunnel Devlopment

3.3.1 Alternative A

Initial studies have been directed toward development by means of a tunnel to the McArthur River that would

maximize electrical generation without regard to release of water into the Chakachatna River for support of its fishery. Two arrangements have been studied, the first being a tunnel following an alignment about 12 miles long designated Alternative A-1 and shown in Figure 3-1. This alignment provides access for construction via an adit in the Chakachatna Valley about 3 miles downstream from the lake outlet.

As discusssed in section 9.0 of this report, the tunnel would be 25 feet internal diameter and concrete lined throughout its full length.

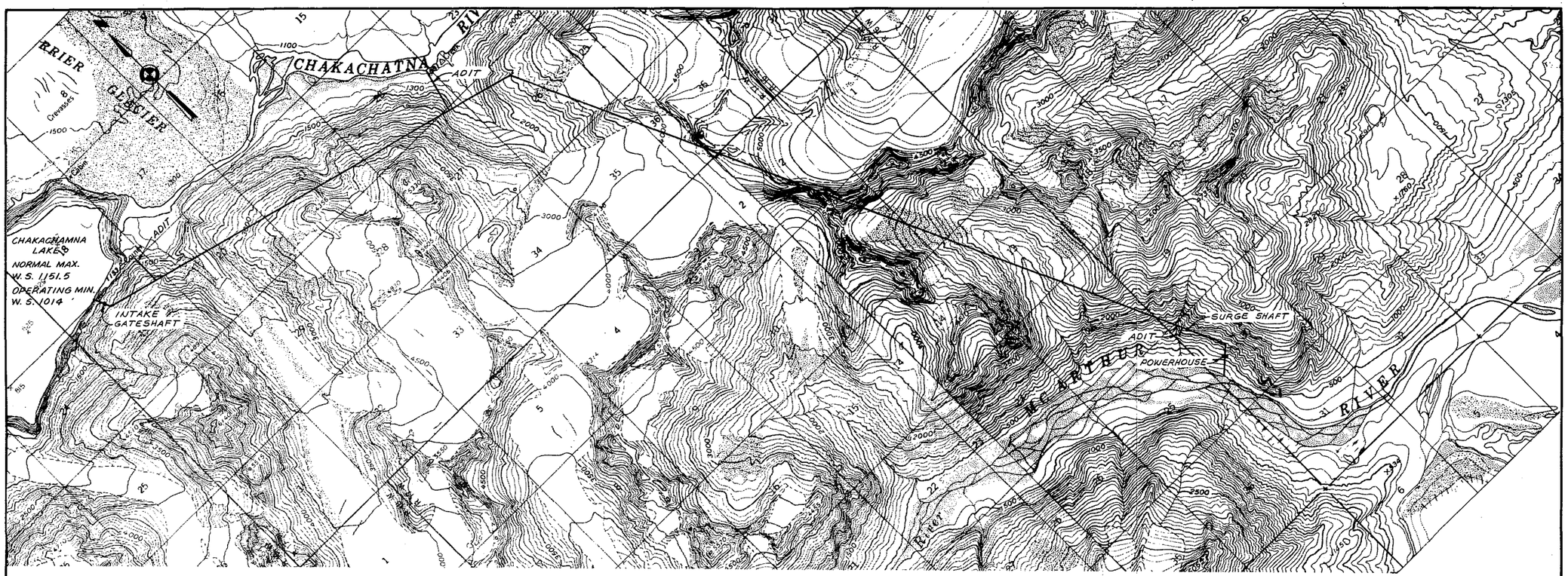
The second tunnel studied is designated Alternative A-2 and follows a direct alignment to the McArthur Valley without an intermediate access adit as shown on Figure 3-2. As further discussed in Section 9.0 of this report, this tunnel would also be 25 feet diameter and concrete lined.

Although the tunnel for Alternative A-1 is about 1 mile longer than that for Alternative A-2, it would enable tunnel construction to proceed simultaneously in four headings thus reducing its time for construction below that required for the shorter tunnel in Alternative A-2. Nevertheless, the studies show that the economics favor the shorter tunnel and no other significant factors that would detract from it have been identified at this stage of the studies. Therefore the direct tunnel route was adopted and all further references in the report to Alternative A are for the project layout with the direct tunnel shown on Figure 3-2.

Typical sketches have been developed for the arrangement of structures at the power intake in Chakachamna Lake and these are shown on Figure 3-4 with typical sections and details on Figure 3-5. Similarly, layouts have been developed for structures located beyond the downstream end of the tunnel. These include a surge shaft, penstock, manifold, valve gallery, powerhouse, transformer gallery, access tunnel, tailrace tunnel and other associated structures as shown on Figure 3-6.

For Alternative A, the installed capacity of the powerhouse derived from the power studies discussed in Section 4.0 of this report is 400 MW. For purposes of estimating costs, the installation has been taken as four 100 MW capacity vertical shaft Francis turbine driven units.

It is to be noted that the layout sketches mentioned above and those prepared for other alternatives considered in this report must be regarded as strictly typical. They form the basis for the cost estimates discussed in Section 8.0 but will be subject to refinement and optimization as the studies proceed. For example, the lake tapping for the power intake is laid out on the basis of a single opening about 26- feet in diameter. This is a very large underwater penetration to be made under some 150-170 feet of submergence, and the combination of diameter and depth is believed to be unprecedented. In the final analysis, it may prove advisable to design for multiple smaller diameter openings. The information needed to evaluate this is not available at the present time.



NOTES:

1) TOPOGRAPHY IS FROM USGS QUADRANGLE MAPS.
2) CONTOUR INTERVAL IS 100 FEET.
3) VERTICAL DATUM IS MEAN SEA LEVEL.
4) HORIZONTAL GRID IS UNIVERSAL TRANSVERSE MERCATOR PROJECTION, 1927 NORTH AMERICAN DATUM.
5) SEE FIGURES 3-4 AND 3-5 FOR GATE SHAFT DETAILS AND FIGURE 3-6 FOR SURGE TANK, PENSTOCK AND POWERHOUSE GENERAL ARRANGEMENT.

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

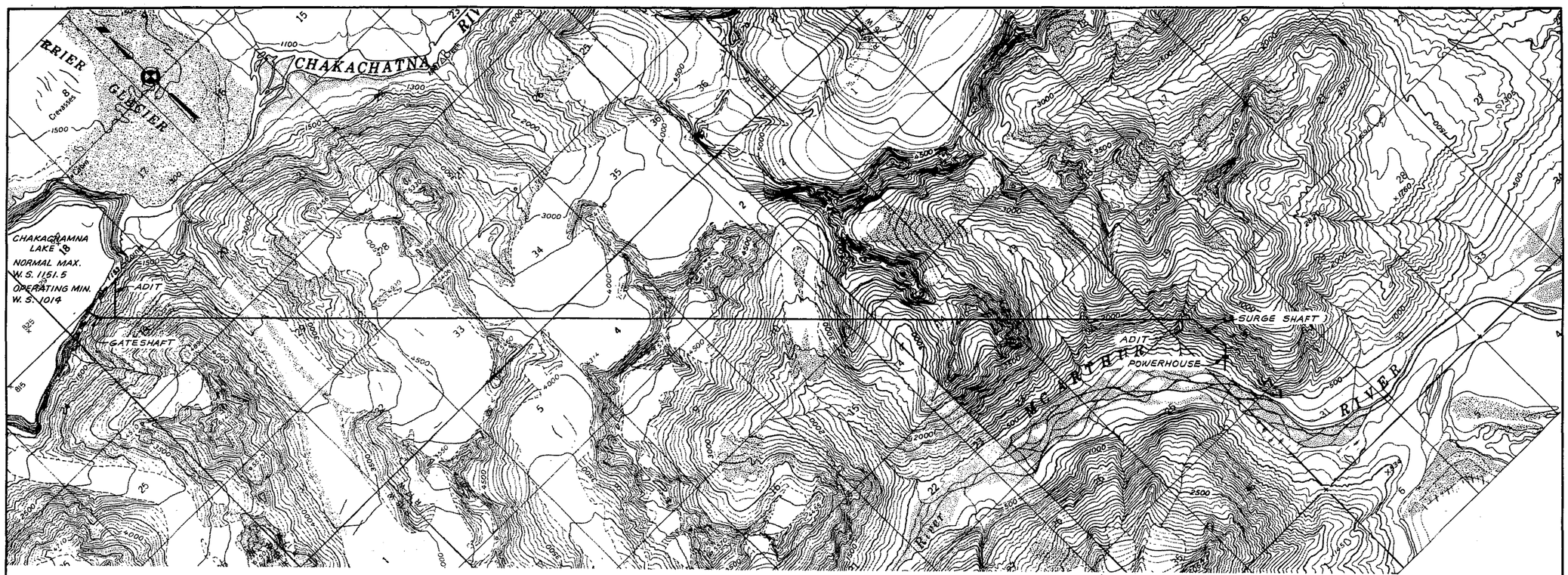
CHAKACHAMNA HYDROELECTRIC PROJECT

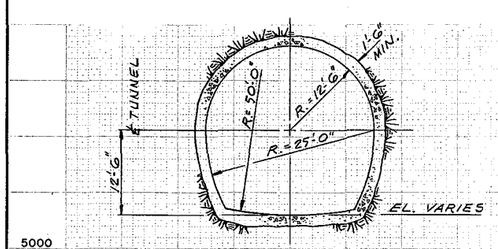
McARTHUR TUNNEL
ALTERNATIVE A-1

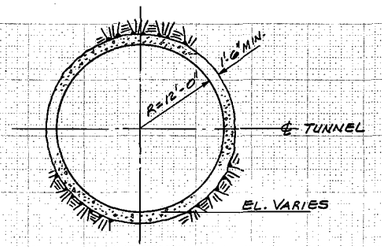
BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-1	

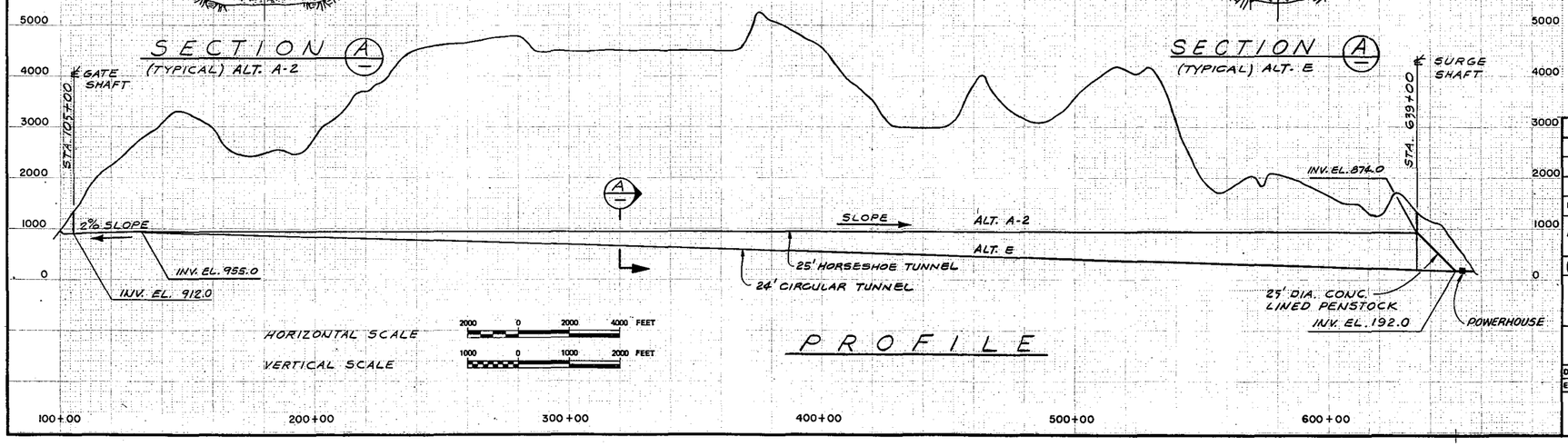






SECTION (A) (TYPICAL) ALT. A-2

SECTION (A) (TYPICAL) ALT. E



NOTES:

1. TOPOGRAPHY IS FROM USGS QUADRANGLE MAPS
2. CONTOUR INTERVAL IS 100 FEET
3. VERTICAL DATUM IS MEAN SEA LEVEL.
4. HORIZONTAL GRID IS UNIVERSAL TRANSVERSE MERCATOR PROJECTION, 1927 NORTH AMERICAN DATUM.
5. SEE FIGURES 3-4 AND 3-5 FOR GATE SHAFT DETAILS AND FIGURE 3-6 FOR SURGE TANK, PENSTOCK AND POWERHOUSE GENERAL ARRANGEMENT.

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

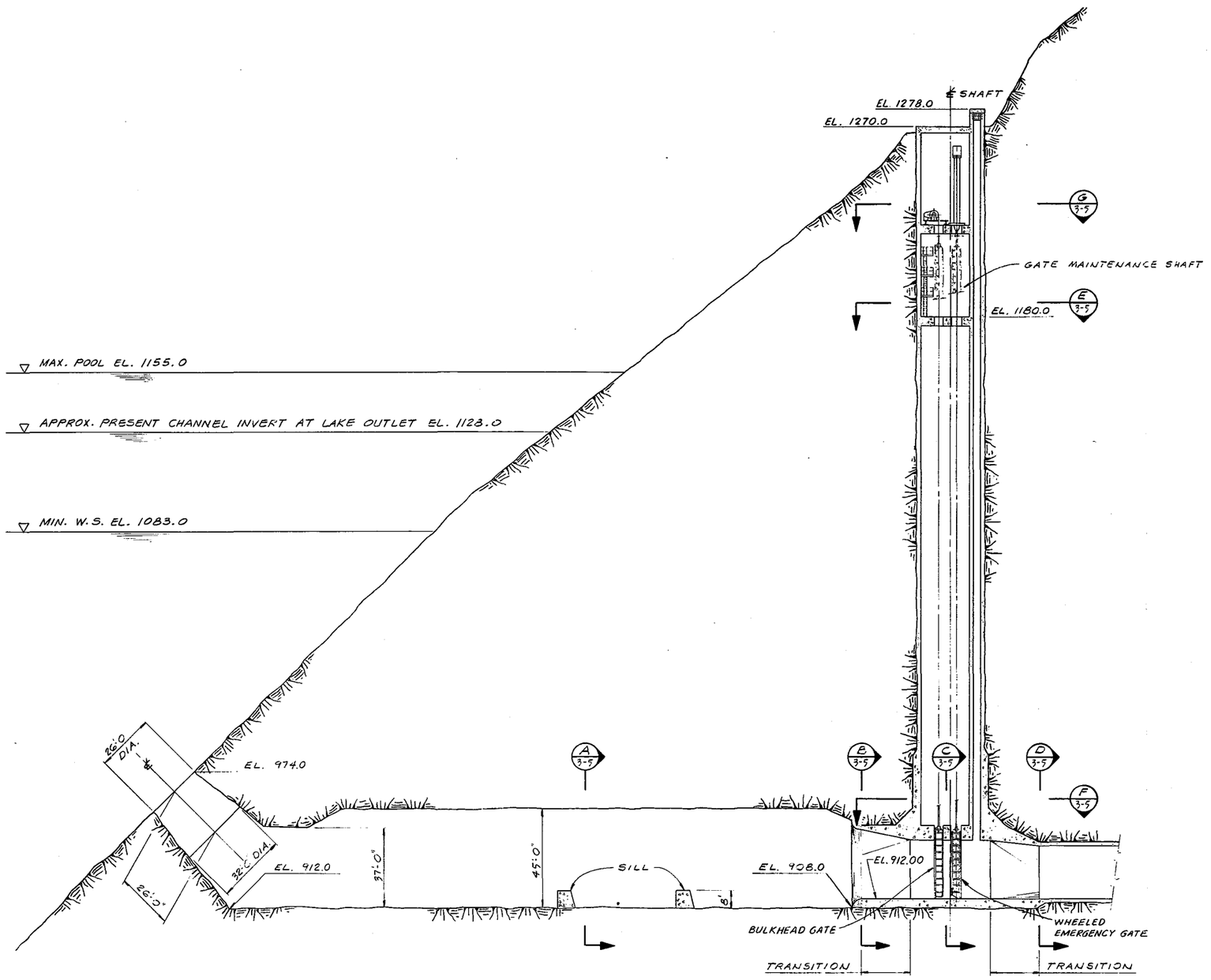
CHAKACHAMNA HYDROELECTRIC PROJECT

McARTHUR TUNNEL
ALTERNATIVES A-2 & E

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-2	



SECTIONAL ELEVATION

1" = 20'-0"

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

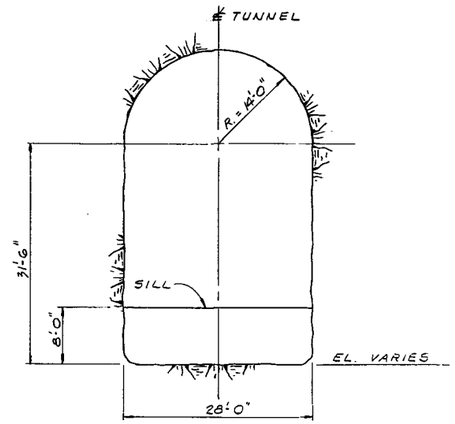
CHAKACHAMNA HYDROELECTRIC PROJECT

GATE SHAFT SECTION
SHEET-1

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN ARITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-4	



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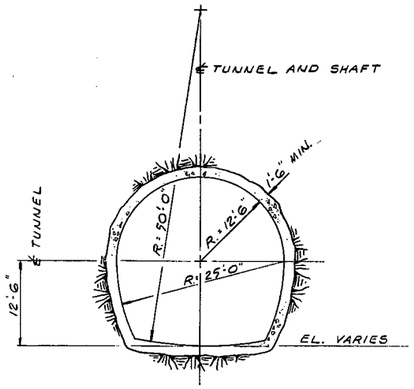

SECTION (D)
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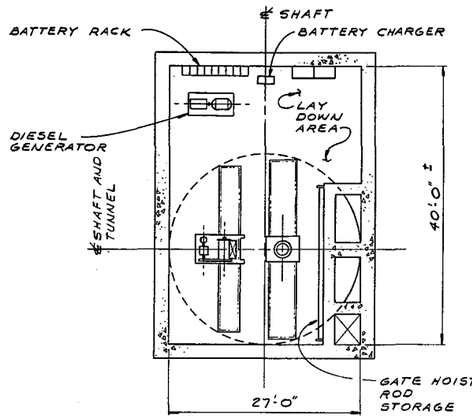

SECTION (G)
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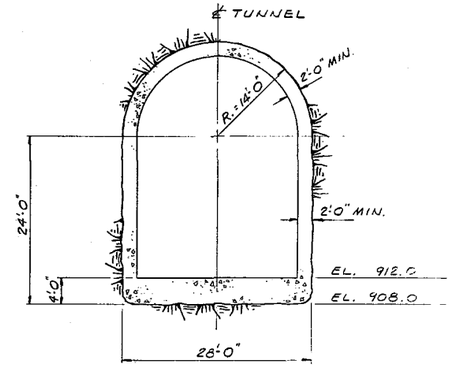

SECTION (B)
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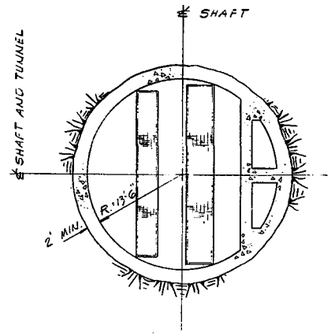
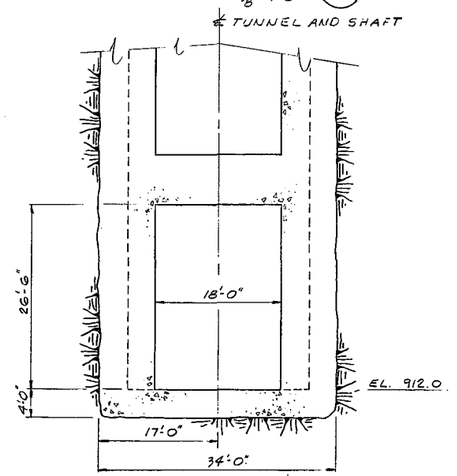
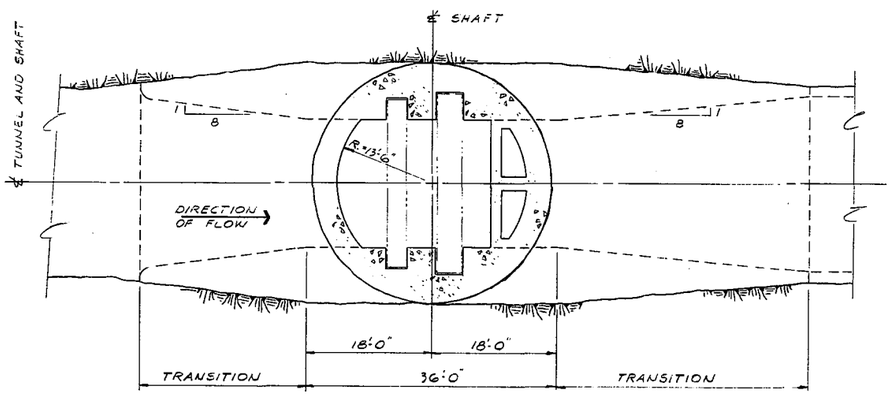


SECTION (E)
1/8" = 1'-0"



SECTION (C)
1/8" = 1'-0"



SECTION (F)
1/8" = 1'-0"

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ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

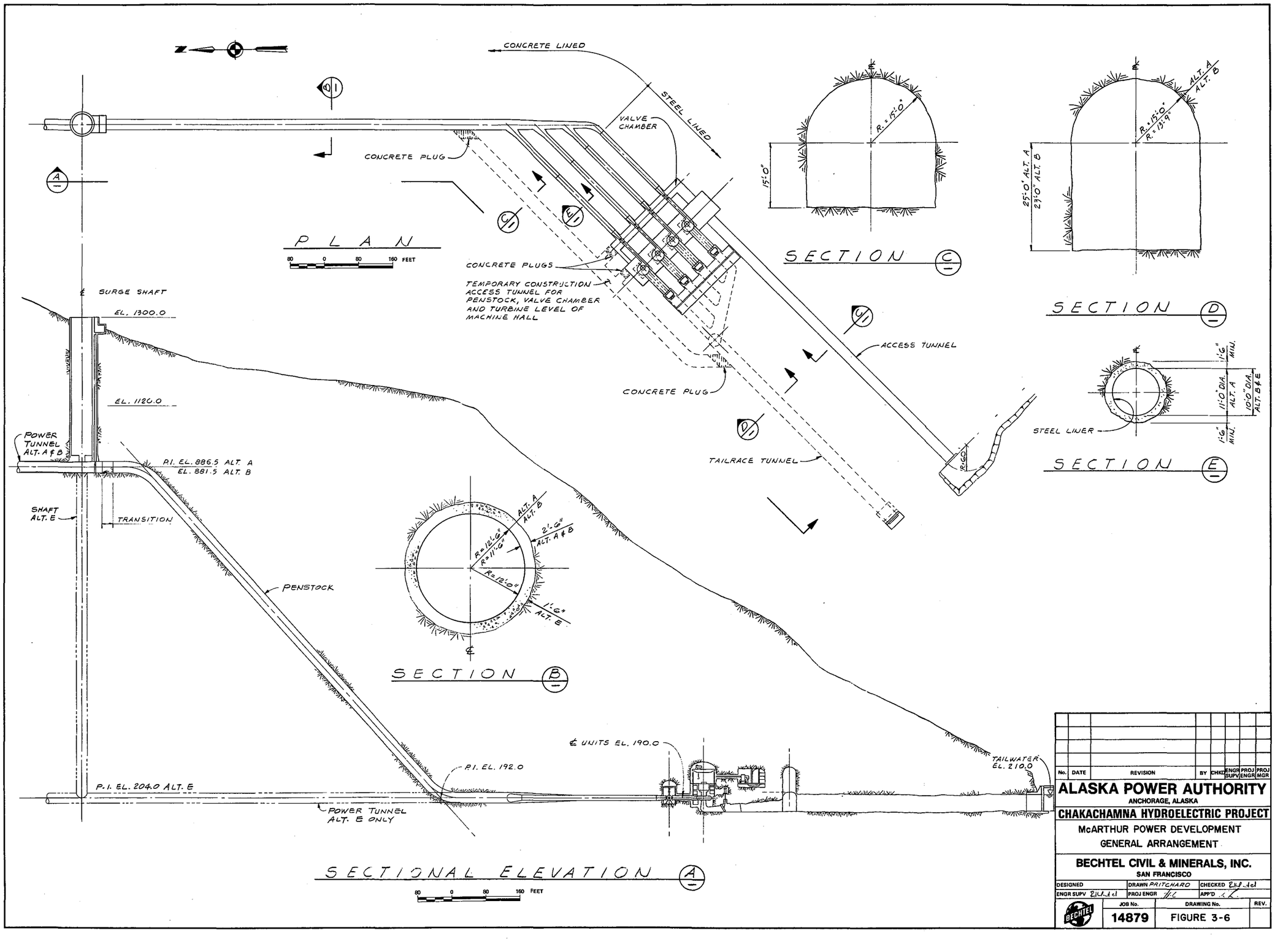
CHAKACHAMNA HYDROELECTRIC PROJECT

GATE SHAFT SECTIONS
SHEET-2

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-5	



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ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

McARTHUR POWER DEVELOPMENT
GENERAL ARRANGEMENT

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-6	

In similar vein, the penstock is shown as a single inclined pressure shaft descending to a four-branched manifold at the powerhouse level with provisions for emergency closure at the upstream end. Again, this is a very large pressure shaft, but the combination of pressure and diameter is not unprecedented in sound rock. Other considerations, such as unfavorable hydraulic transients in the manifold, or operational flexibility, may support the desirability of constructing a bifurcation at the downstream end of the tunnel with two penstocks, each equipped with an upper level shutoff gate, provided to convey water to each pair of turbines in the four-unit powerhouse. Such an arrangement would cost more than the single penstock shaft.

Turbine shutoff valves are shown located in a valve chamber separated from the powerhouse itself. Optimization studies should be made in the future to evaluate whether these valves can be located inside the powerhouse at the turbine inlets, or whether a ring gate type installation inside the turbine spiral cases might be preferable.

The powerhouse is shown as an underground installation. This appears to be the most logical solution for development via the McArthur River because of the steep avalanche and rock slide-prone slopes of the canyon wall. For the same reason, the transformers are shown in a chamber adjacent to the powerhouse cavern. A surge chamber is shown near the upstream end of the tailrace tunnel. It may prove more advantageous for this relatively short tailrace tunnel

to make it freeflowing in which case the tailrace surge chamber would not be required.

The object of the above comments is to point out some of the options that are available. The arrangement of structures shown provides for a workable installation. Because of the limited engineering studies performed to date, it is not to be regarded as the optimum or most economical. Optimization will be performed at a later date. The layout is a workable arrangement that gives a realistic basis on which to estimate the cost of constructing the project, and a separately identified contingency allowance is provided in the estimate to allow for costs higher than those foreseen at the present level of study.

3.3.2 Alternative B

This alternative considers what effect a tentative allocation of water to meet instream flow requirements in the Chakachatna River would have on the amount of energy that could be generated by Alternative A which would use all stored water for energy generation. The tentative instream flow schedule is discussed in Section 7.3.2 of this report. For diversion to the McArthur River, and reservation of water for instream flow releases, the tunnel diameter would be about 23 feet. Based on the power studies discussed in Section 4.0, the installed capacity of the powerhouse would be reduced to 330 MW. The tunnel alignment and basic layout of structures generally is the same as that shown for Alternative A in Figure 3-2. The diameters of hydraulic conduits and the dimensions of the 330 MW powerhouse would be smaller than for the

400 MW powerhouse in Alternative A and appropriate allowances for these are made in the cost estimates.

When the various alternative arrangements of the project were developed in the 1981 study, no specific plan had been developed for the provision of releases of flow into the Chakachatna River immediately downstream from the lake outlet nor for the provision of fish passage facilities at the lake outlet for upstream and downstream migrants. It was recognized that suitable structures would be difficult to develop and would be very expensive. It was also planned that, due to the presence of the glacier at the lake outlet, the fish passage facility would have to be constructed inside a tunnel within the massive rock mountainside forming the right side of the lake outlet. Since no plan for such facility had been developed at that stage of the studies, a provisional allowance of $50 million was shown in the estimate for fish passage facilities.

During the second phase of the study in 1982, the concept of fish facilities and operation of the lake has been further developed for this alternative and it is described at the end of this section as Alternative E, the recommended alternative.

3.4 Chakachatna Tunnel Development

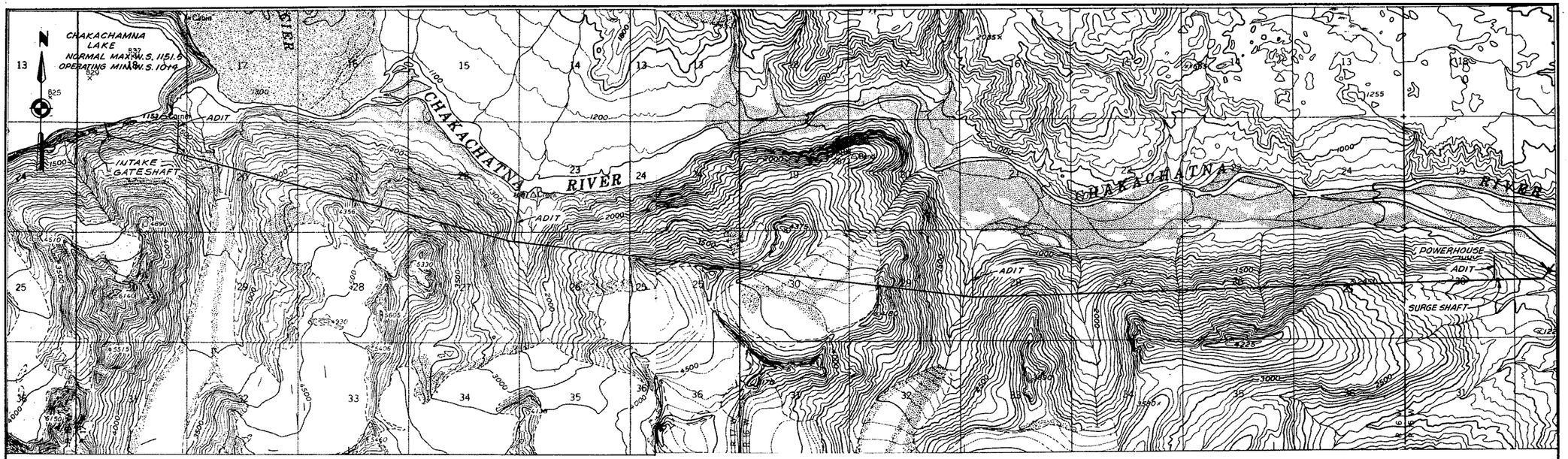
3.4.1 Alternative C

The initial studies of this alternative focused on development of the power potential by means of a tunnel roughly paralleling the Chakachatna River

without release of water for instream flow requirements between the lake outlet and the powerhouse where the water diverted for power generation would be returned to the river. The tunnel alignment is shown on Figure 3-3.

This alignment offers two convenient locations for intermediate access adits during construction. The first is about 3 miles downstream from the lake outlet in the same location as discussed in Section 3.3.1 above for Alternative A. The second adit location is about 7 miles downstream from the lake outlet. The total tunnel length in this arrangement is about 12 miles and the adits would make it possible for construction of the tunnel to proceed simultaneously in six different headings.

The arrangement of the power intake is essentially the same and in the same location as for Alternative A as shown on Figures 3-4 and 3-5. The tunnel is also 25 feet internal diameter, concrete lined, and penetrates the mountains in the right wall of the Chakachatna Valley. The arrangement for the surge shaft, penstock, valve gallery, powerhouse and asssociated structures is similar to that for development via diversion to the McArthur River but is modified to fit the topography and lower head. The layout is shown on Figure 3-7. The head that can be developed in Alternative C is roughly 200 feet less than in Alternatives A and B and the installed capacity in the powerhouse is only 300 MW as determined from the power studies discussed in Section 4.0 of this report.



PLAN

2000 0 2000 4000 FEET

NOTES:

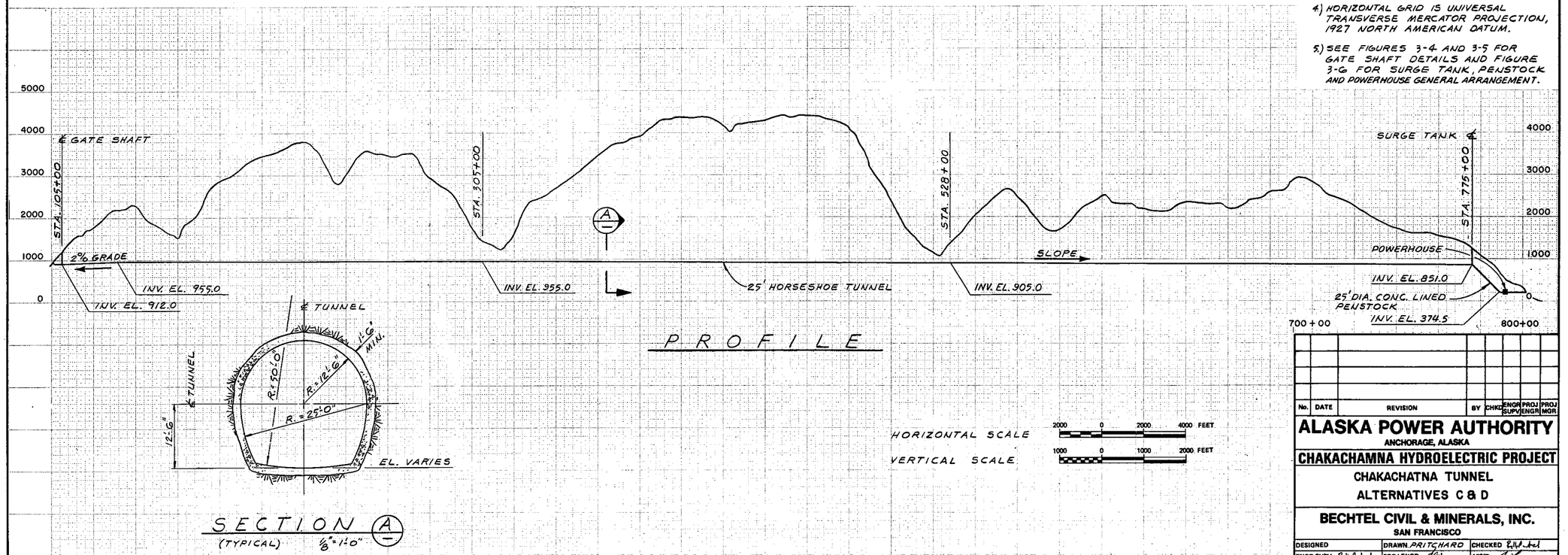
1.) TOPOGRAPHY IS FROM USGS QUADRANGLE MAPS.

2.) CONTOUR INTERVAL IS 100 FEET

3.) VERTICAL DATUM IS MEAN SEA LEVEL

4.) HORIZONTAL GRID IS UNIVERSAL TRANSVERSE MERCATOR PROJECTION, 1927 NORTH AMERICAN DATUM.

5.) SEE FIGURES 3-4 AND 3-5 FOR GATE SHAFT DETAILS AND FIGURE 3-6 FOR SURGE TANK, PENSTOCK AND POWERHOUSE GENERAL ARRANGEMENT.



PROFILE

SECTION A (TYPICAL) 1/8"=1'-0"

HORIZONTAL SCALE 2000 0 2000 4000 FEET

VERTICAL SCALE 1000 0 1000 2000 FEET

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ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

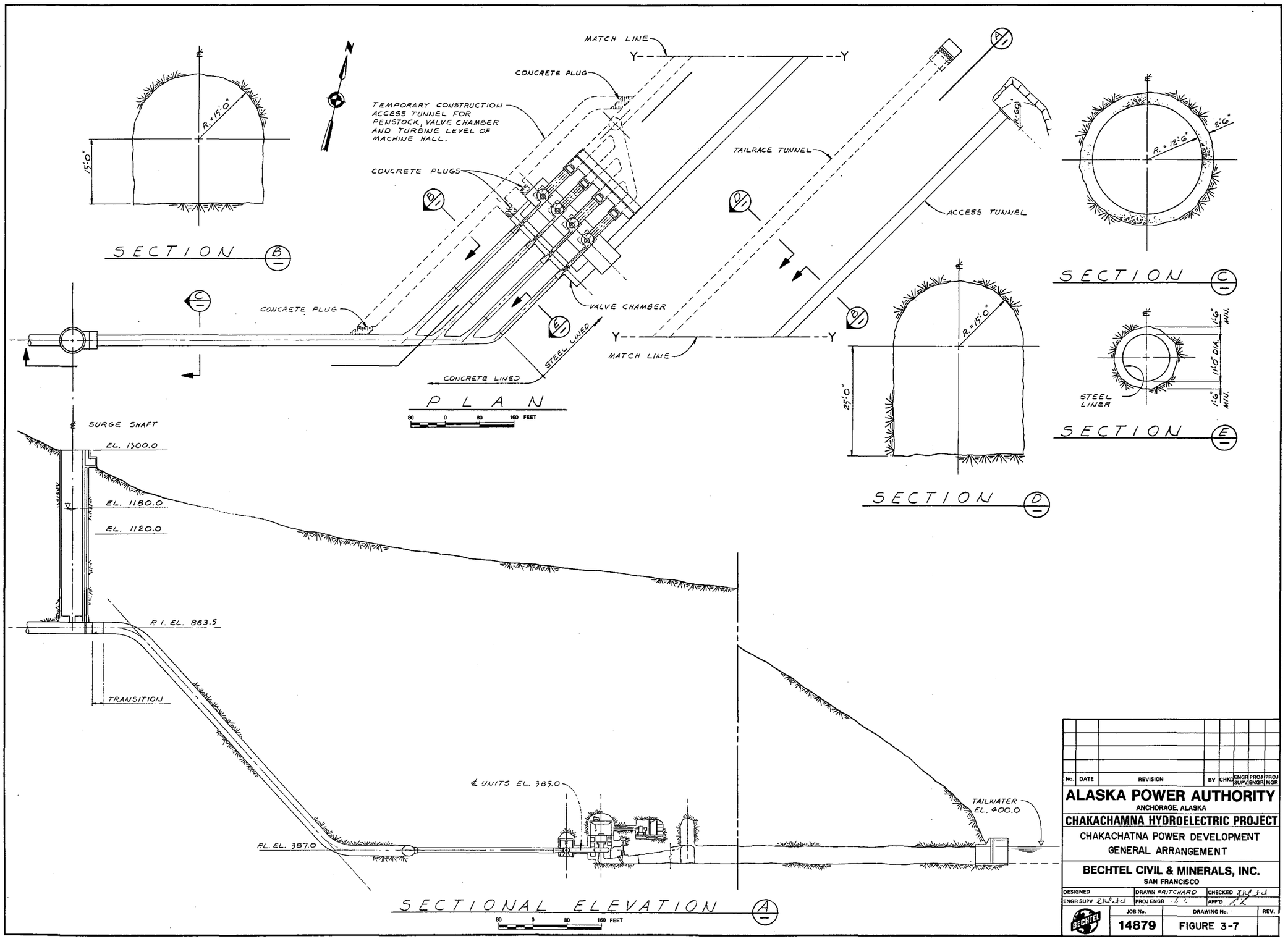
CHAKACHAMNA HYDROELECTRIC PROJECT

CHAKACHATNA TUNNEL
ALTERNATIVES C & D

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED	
ENGR SUPV	PROJ ENGR	APP'D	

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-3	



No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

CHAKACHATNA POWER DEVELOPMENT
GENERAL ARRANGEMENT

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-7	

For purposes of estimating the present costs of construction, the powerhouse is taken as being located underground. If this Alternative were to be pursued, future studies would be made to determine if economy can be attained by locating it outside on the ground surface. Comments made in Section 3.3.1 regarding the layout sketches for the McArthur powerhouse in Alternative A apply equally to the powerhouse and associated structures for the Chakachatna Powerhouse considered in Alternative C.

3.4.2 Alternative D

Studies of this alternative take account of the effect on electrical generation of reserving water to meet instream flow requirements in the Chakachatna River. The tentative water release schedule is less than that condidered for development by power diversions to the McArthur River as discussed in Section 7.1.5 of this report. The reason for this is that in the lower reaches of the river, downstream from the proposed powerhouse location, the river flow will include those waters that were diverted for electrical generation. These lower reaches of the river are probably more important to the fishery than the reach of the river between the lake outlet and the proposed powerhouse location. This probability is suggested, though not fully confirmed, by observations made of fish runs during the 1981 and 1982 field studies. These have indicated that the Chakachatna River, between the lake outlet and the proposed location of the powerhouse, serves primarily as a travel corridor for fish passing through the lake to spawning areas further upstream. The river itself, in this reach does not appear to offer much in the way of suitable spawning and juvenile rearing habitat. On the other hand,

significant numbers of fish and spawning areas were observed in the lower reaches of the river downstream from the proposed powerhouse locations. Consequently, the tentative instream flow releases are small when compared with those considered for development via power diversions to the McArthur River, as discussed in Section 7.1.5 of this report. The tunnel diameter for development of the power potential via the Chakachatna Tunnel with provision for instream flow releases, is 25 feet, the same as that mentioned in Section 3.4.1 without such releases. The installed capacity in the powerhouse also remains the same at 300 MW. The layout sketches shown in Figures 3-3 and 3-7 for Alternative C are equally applicable to Alternative D as are the comments set forth in Sections 3.3.1 and 3.3.2 regarding the layout sketches for de- velopment via the McArthur River.

3.5 McArthur Development - Recommended Alternative E

3.5.1 General

This alternative is basically similar to Alternative B, but modified to include water release facilities into Chakachatna River, fish passage facilities at the lake outlet and modification of lake operating levels to accommodate these facilities. The power tunnel would have a 24-foot internal diameter circular section and the diameters of other hydraulic conduits, the powerhouse arrangement, sizing and location will be the same as described for Alternative B except as shown in Figures 3-2 and 3-6. It is to be noted that the emergency closure gate located at the head of the penstock in Alternative B cannot be retained in

the layout for Alternative E. This results in a loss of a certain amount of operating flexibility to the extent that the penstock, upstream of the valve chamber, cannot be dewatered for inspection without dewatering the power tunnel. Likewise, in the event of a failure in the valves or the conduits upstream of the valves, the whole station would have to be shut down and the tunnel dewatered, before the rupture could be repaired.

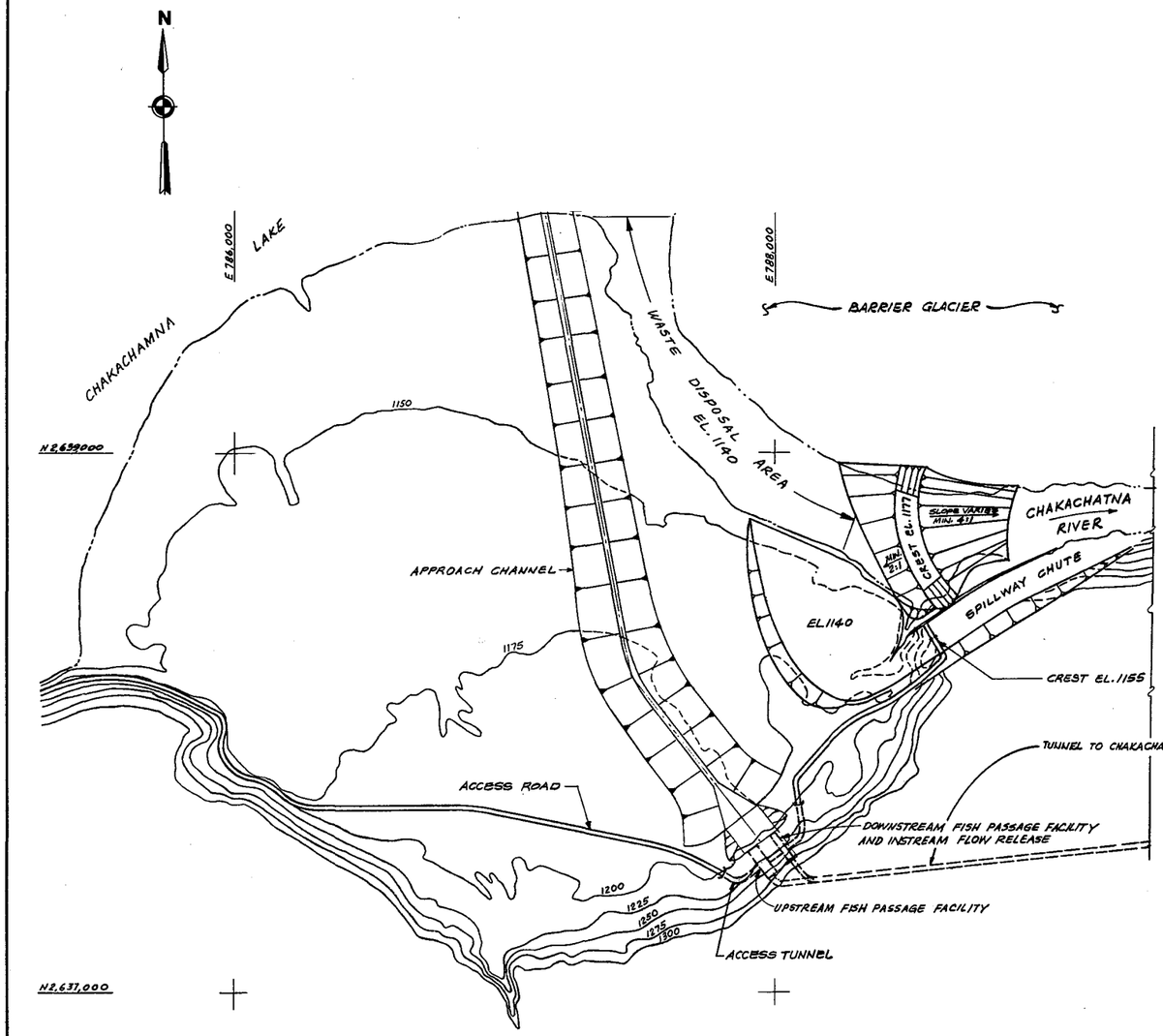
The operating range of the lake will be modified. The maximum level will be taken as the historical maximum evidenced by a white mark on the rock slopes of the lake shoreline at approximately El. 1155. A wide rockfill dike will be constructed at the lake outlet from the spoil material available from the spillway excavation described below to raise the lake outlet by approximately 27 feet. The reservoir level control will be established by an unlined spillway channel at El. 1155 excavated into the rock on the right side of the outlet. The layout is shown in Figure 3.8. The lake level operating range will be 72 feet down to El. 1083 rather than the 113 feet that was previously available in the studies for Alternatives A through D. The power tunnel intake level is maintained at the level previously used to provide even greater submergence to reduce potential problems of attracting downstream migrant fish into the power tunnel. Most flood waters will be released via the unlined spillway channel cut through the granite in the right abutment. This unlined channel has a capacity of 55,000 cfs, and will therefore handle all flood releases up to 55,000 cfs. Flows greater than this up to the presently estimated probable maximum flood of

100,000 cfs will pass both through the spillway and over the rockfill dike. It should be noted that the maximum peak discharge in the period of record of 1959-1971 was 23,400 cfs if the "dam-break" type of flood which occurred in August 1971 is disregarded. Future studies of the required spillway size may indicate that a reduction in size below the 55,000 cfs capacity may be possible.

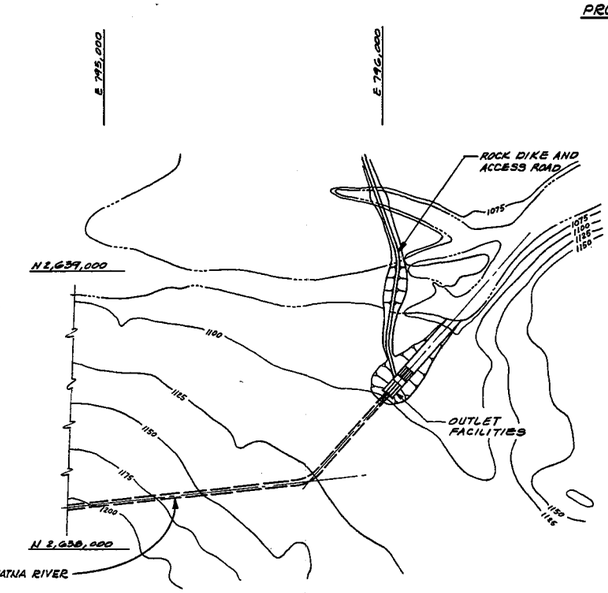
It is considered that since overtopping of the rock dike will be a very infrequent occurrence, repair of the dike after such an event would be an acceptable maintenance procedure. Such repair can be scheduled in the spring before the lake rises to the level of the dike in July or August. Periodic maintenance will also probably be required to repair damage to the dike caused by movement of the ice in the toe of the glacier.

3.5.2 Water Releases and Fish Passage Facilities

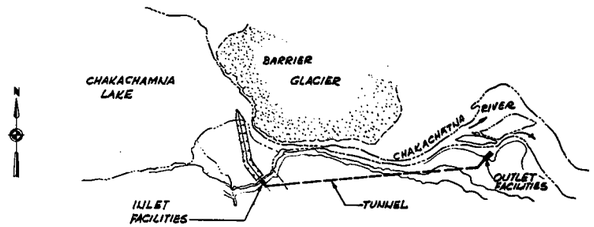
To provide instream releases into the Chakachatna River and arrange for both upstream and downstream migration of fish between the river and the Chakachamna Lake, a concept for a conveyance system was developed which consisted basically of fish ladders at the upstream and downstream ends of two interconnecting channels located in a tunnel. The system is a gravity flow system and does not rely on any pumping for its operation. The layout is shown in Fig. 3-8. The facilities will be located in the right bank granitic rock abutment to provide a secure structure protected against avalanches and rockfalls and to minimize the length of the tunnel. A deep



INLET SITE PLAN
1" = 200'



OUTLET SITE PLAN
1" = 200'



PROJECT KEY PLAN
1" = 2000'

2000 0 2000 4000
GRAPHIC SCALE FEET
1" = 2000'

200 0 200 400
GRAPHIC SCALE FEET
1" = 200'

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ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

CHAKACHAMNA LAKE OUTLET
GENERAL ARRANGEMENT

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-8	

approach channel will be excavated in the alluvial deposits on the right side of the lake outlet to convey water from the lake to the fish release facilities located in an excavated cavern in the right abutment near the lake outlet.

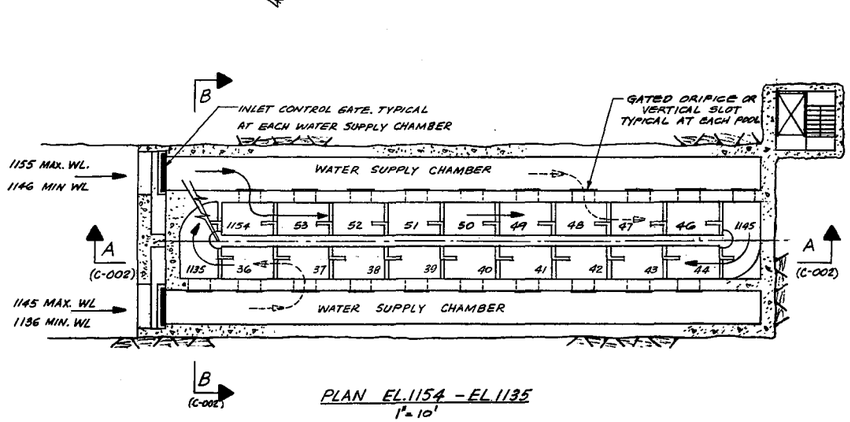
3.5.3 Upstream Migrants Facility

The facility for upstream passage of adult migrant fish would consist of a conventional fish ladder with overflow weirs having 1 foot difference in elevation between each pool. Alongside each tier of ladder pools is a water supply chamber that serves a 10 foot interval in the range of lake level. Each pool in a given tier would have a gated connection to the water supply chamber, so that for a given lake level, the gate leading to the pool whose water level is 1 foot lower than the reservoir would be open, thus letting water run from the supply chamber into the ladder. All other gates between the supply chambers and pools would be closed. As the lake level changes, the gates would be manipulated accordingly. At this stage it is assumed that these gates would be operated manually although it would be possible to automate their operation, with the selection of "open" gate tied to lake level. A control gate is also shown between each water supply chamber and the lake. Fish ascending the ladder would rise through the pools until they reached the one receiving water from its supply chamber. The fish would then pass into the supply chamber and exit into the lake through the control gate opening. This upstream migrant structure would be constructed in an underground chamber excavated in the rock mountainside

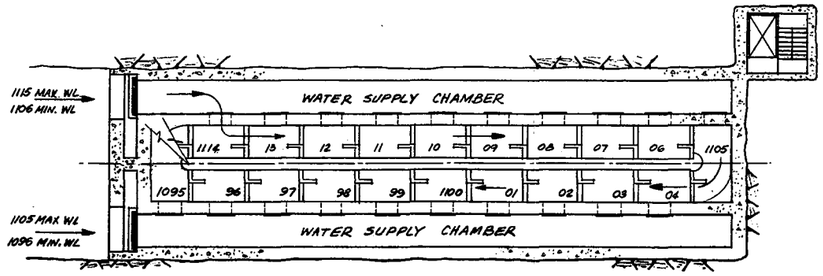
adjacent to the existing natural lake outlet. The concept is shown in Figures 3-9 and 3-10.

3.5.4 Downstream Migrants Facility

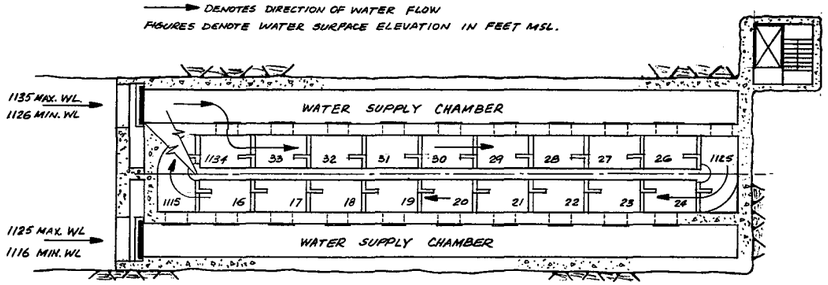
The facility for downstream passage of out-migrants and for provision of minimum downstream flow releases is shown in Figure 3-11. The concept consists of three, 15 feet wide fixed wheel type gates stacked one above the other. The proposed mode of operation is that when the water level is between El. 1155 and El. 1127, the top gate would be lowered the amount necessary to discharge the desired amount of water that would plunge into a stilling basin and return to the river through the discharge tunnel. The middle and bottom gates would be closed. When the lake level falls to El. 1127, the top gate would be raised above the water surface and the middle gate would be lowered to discharge the desired amount of water. As the water level descends below El. 1001, the middle gate would be raised and the lowest gate would take over the control of discharge. This gate will be progressively lowered below the invert of the outlet channel as the lake level falls. Manipulation of the gates would be in the reverse sequence during the condition with a rising lake water level. The depth of flow in the stilling basin immediately downstream from the gates is relatively shallow in order to prevent entrainment of air at depths and pressures which could result in nitrogen saturation harmful to the fish.



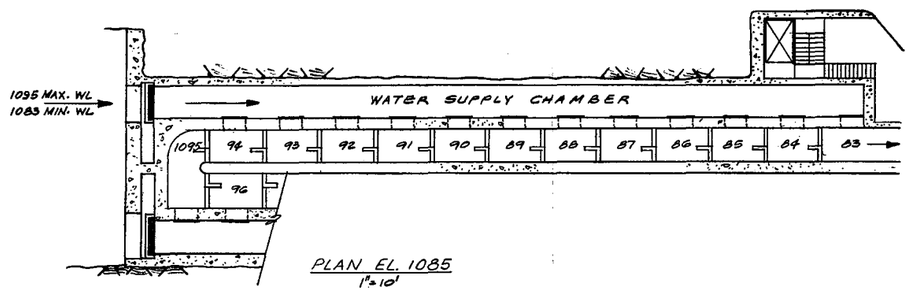
PLAN EL.1154 - EL.1135
1" = 10'



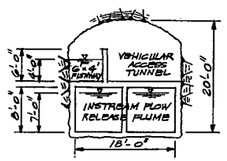
PLAN EL. 1114 - EL. 1095
1" = 10'



PLAN EL.1134 - EL.1115
1" = 10'



PLAN EL. 1085
1" = 10'



ACCESS TUNNEL SECTION
(TYPICAL DOWNSTREAM FROM INTERSECTION WITH INSTREAM FLOW RELEASE PLUME)
1" = 10'

10 0 10 20
GRAPHIC SCALE FEET
1" = 10'

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ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

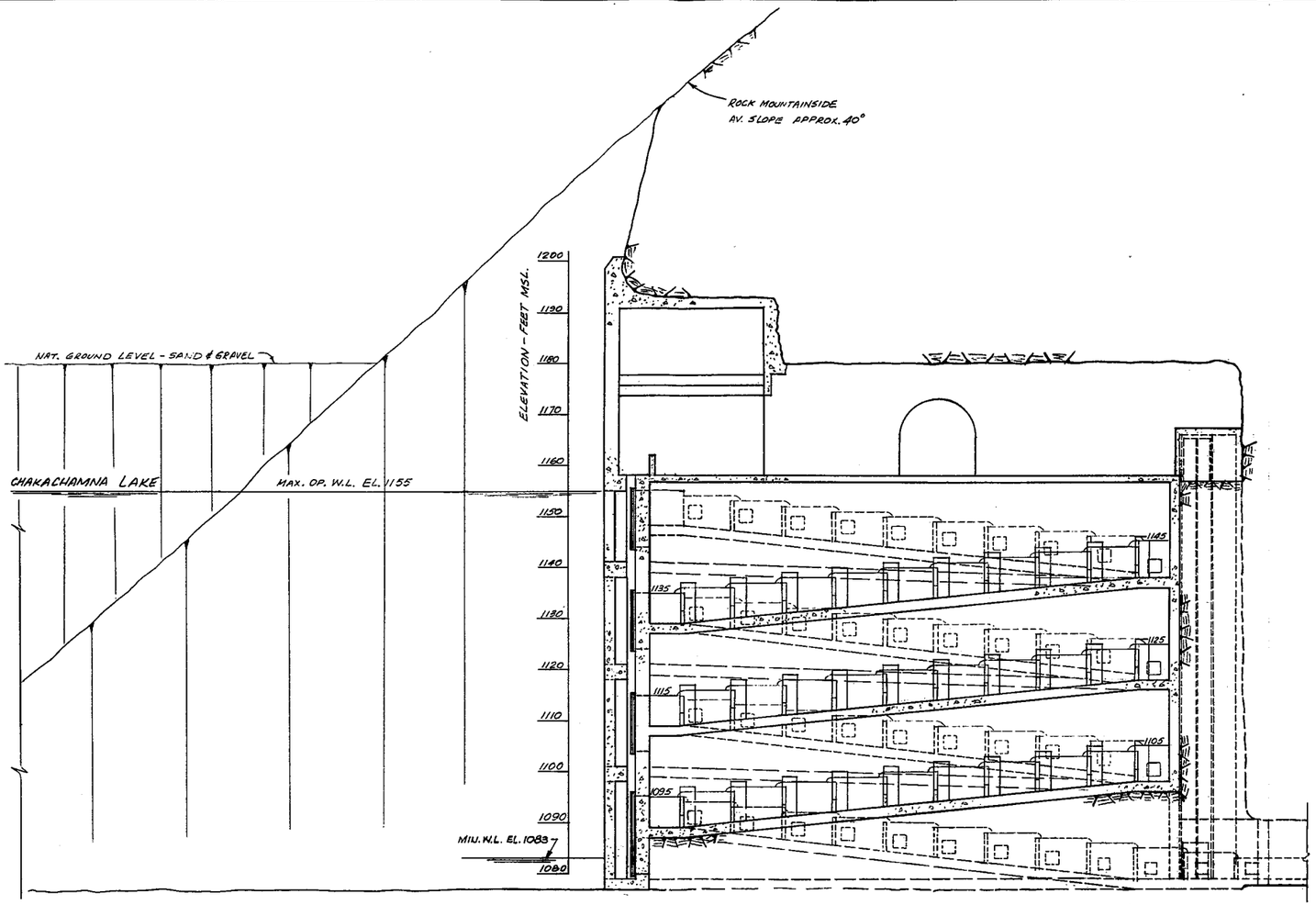
CHAKACHAMNA HYDROELECTRIC PROJECT

UPSTREAM FISH PASSAGE FACILITIES
PLANS AND SECTION

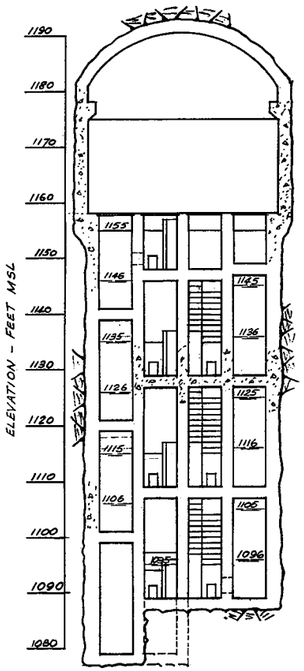
BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-9	



SECTION A
1" = 10'



SECTION B
1" = 10'

10 0 10 20
GRAPHIC SCALE FEET
1" = 10'

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ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

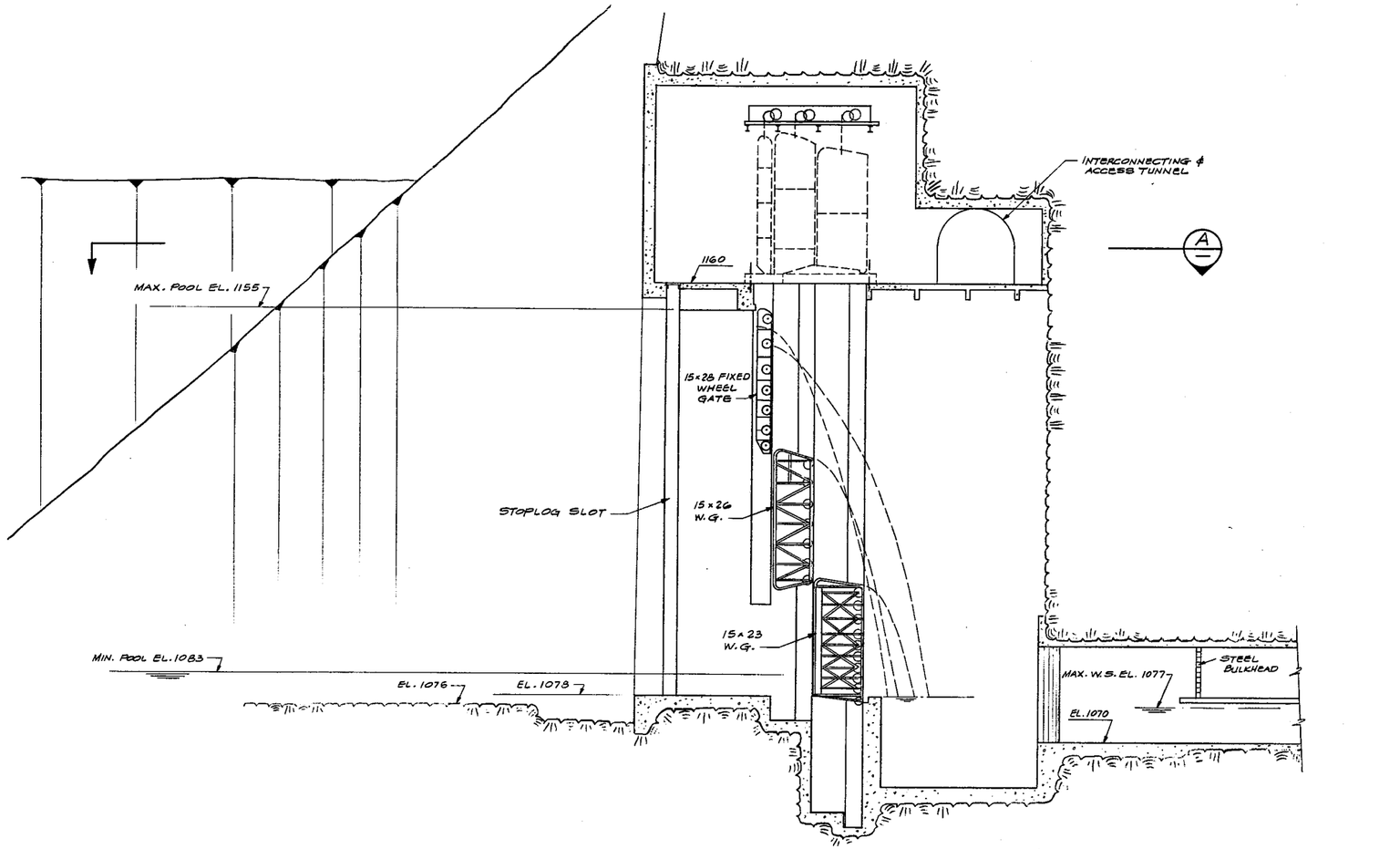
CHAKACHAMNA HYDROELECTRIC PROJECT

UPSTREAM FISH PASSAGE FACILITIES
SECTIONS

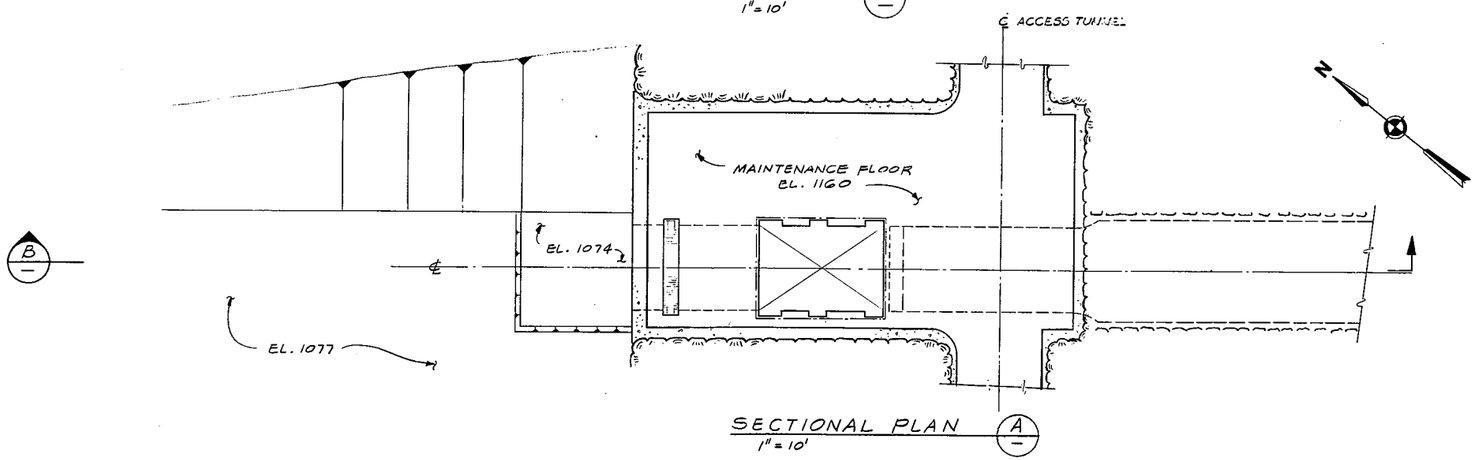
BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-10	



SECTION B
1" = 10'



SECTIONAL PLAN A
1" = 10'

10 0 10 20
GRAPHIC SCALE FEET
1" = 10'

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

DOWNSTREAM FISH PASSAGE FACILITIES
INSTREAM RELEASE STRUCTURE

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-11	

3.5.5 Conveyance Channel

Both upstream and downstream migrants will travel in separate channels located in a common tunnel. The upstream migrants would utilize a 6' x 4' channel dimensioned for the fish ladder discharge of 40 cfs. The out-migrants would use the main channel 18' x 7' dimensioned for maximum required monthly release minus the flow in the small channel. (This maximum downstream release as presented in Section 4 has been set tentatively at 1094 cfs.) The small channel would be located at one side of the tunnel above the main channel with a road access provided on the other side. A typical section of the tunnel is shown in Fig. 3-9. Both channels would be free flowing with freeboard provided. Only the main channel which has a maximum velocity of 8 feet/sec., would be fully lined to reduce head loss. In order to keep velocity in the small channel for the upstream migrants at 2 feet/sec., the floor of the channel would have a slightly less gradient than the large channel and 5 drops of 1 foot each will be provided at regular intervals down the tunnel.

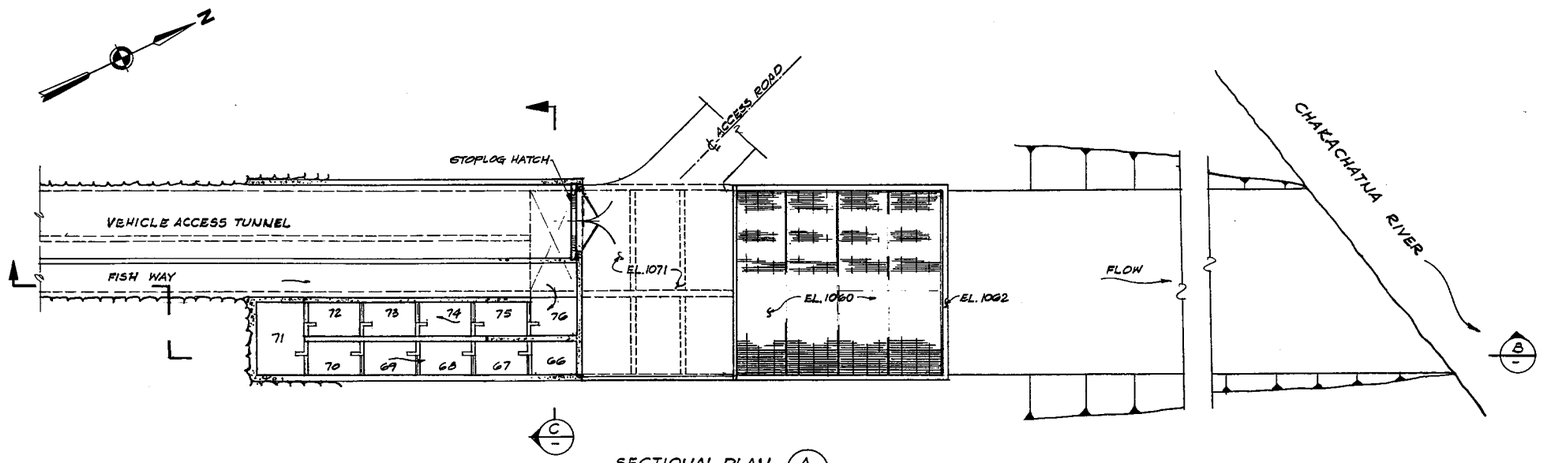
3.5.6 Outlet Structure

A ladder is required at the downstream end of the tunnel to provide a means for the upstream migrants to reach the upper transportation channel inside the tunnel. This ladder will be partially submerged at high releases since the river level rises by an estimated 4 feet when the discharge from the facility is increased from the minimum flow of 343 cfs to the maximum of 1094 cfs. Another 6 ft vertical rise in

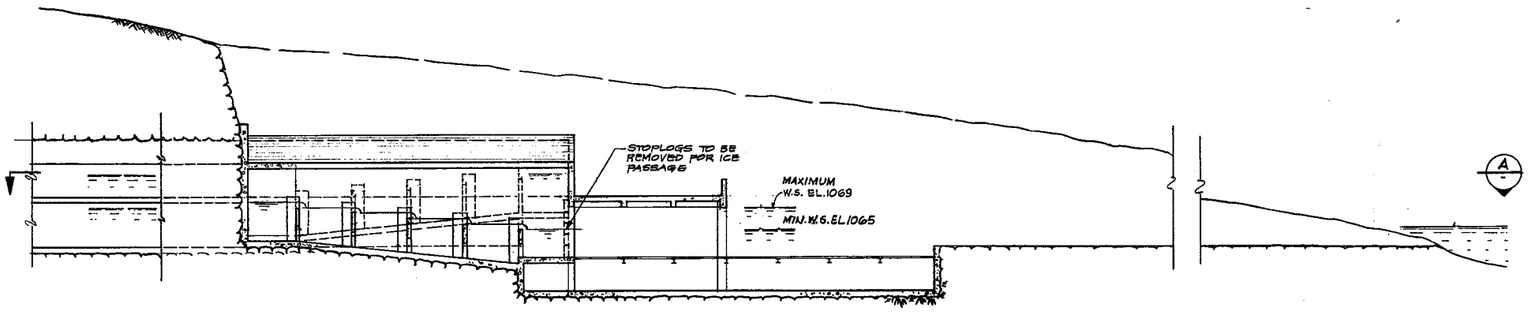
the ladder is provided to accommodate the difference between the water surfaces in the two channels in the tunnel so that a total of 10 ladder pools would be provided. A horizontal submerged screen would allow the out-migrants to reach the main discharge channel while its presence and a velocity of around 1/2 ft/sec through the bars would prevent the large fish from entering the main tunnel discharge channel. The attraction flow coming down the ladder would be 40 cfs. The layout is shown in Figure 3-12.

A floating ice barrier installed in the approach channel just upstream of the fish passage facility will prevent most of the ice from passing into and through the facility during the breakup period. However, as a precaution, since it will be very difficult to ensure the complete elimination of the entrance of ice into the facility, it is planned to remove a stoplog barrier which normally diverts the flow through the horizontal screen, thus allowing the flow and ice to continue straight into the side outlet channel and the Chakachatna River, and thereby by-passing the horizontal screen through which the flow normally passes. This should be an acceptable procedure because the upstream migrants do not travel upstream until after breakup occurs.

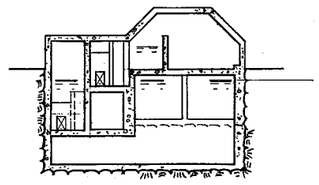
A small rockfill dike will be constructed across the river channel just upstream of the downstream entrance to the outlet facility so that the upstream migrants will be prevented from entering the section of the river between the fish facility and the lake outlet. Any small inflow into the river between the lake



SECTIONAL PLAN (A)
1" = 10'



SECTION (B)
1" = 10'



SECTION (C)
1" = 10'

10 0 10 20
GRAPHIC SCALE FEET
1" = 10'

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

OUTLET FISH PASSAGE FACILITIES
PLAN AND SECTIONS

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-12	

outlet and the fish facilities outlet will filter through the rock dike.

3.6 Transmission Line and Submarine Cable

At the present stage of the project development studies, no specific evaluation has been made of transmission line routing. Whether development should proceed via the proposed McArthur or Chakachatna Powerhouse locations, it is assumed for the purposes of the costs estimates that the transmission lines would run from a switchyard in the vicinity of either powerhouse site to a location in the vicinity of the existing Chugach Electric Association's Beluga Powerplant. The general routing of the proposed lines is shown on Figure 3-13. At Beluga, an interconnection could be made through an appropriate switching facility with the existing Beluga transmission lines if a mutually acceptable arrangement could be negotiated with the owners of those lines. This would enhance reliability of the total system, but for purposes of this report no such interconnection has been assumed. Beyond Beluga, it is assumed for purposes of the estimate, that the new transmission lines for the Chakachatna or McArthur Powerhouses would parallel the existing transmission corridor to a terminal on the westerly side of Knik Arm and cross that waterway by submarine cables to a terminal on the Anchorage side. Beyond that point, no costs are included in the estimates for any further required power transmission installations.

In the project alternatives thus far considered, the cost estimates are based on power transmission via a pair of 230 KV single circuit lines with capacity

matching the peaking capability of the respective power plants. Optimization studies to determine whether transmission should be effected in that manner or by a single line of double circuit towers should be performed in the future.

3.7 References

Giles, Gordon C., April 1967.
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Report on Reconnaissance of Lake Chakachamna, Alaska. USGS.

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United States Bureau of Reclamation, 1962.
Chakachamna Project, Alaska. Status Report.

4 0 4 8 MILES

SCALE : 1" = 4 MILES

NOTES:

1.) TOPOGRAPHY IS FROM USGS QUADRANGLE MAPS

2.) HORIZONTAL GRID IS UNIVERSAL TRANSVERSE MERCATOR PROJECTION, 1927 NORTH AMERICAN DATUM.

3.) VERTICAL DATUM IS MEAN LOWER LOW WATER.

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

TRANSMISSION LINE
ROUTE LOCATION

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED [signature]
ENGR SUPV [signature]	PROJ ENGR [signature]	APP'D [signature]

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-13	

United States Department of the Army, Corps of Engineers, 1950

Survey report on Harbors and Rivers in Alaska. Interim Report No. 2, Cook Inlet and Tributaries.

HYDROLOGICAL AND POWER STUDIES

4.0 HYDROLOGICAL AND POWER STUDIES

4.1 Introduction

River flow records from a gaging station are usually accepted as the best indicator of future runoff from a drainage basin. The longer the period of record is, the more reliable it is assumed to be in forecasting future runoff. For Chakachamna Lake, the records of a gage located near the lake outlet cover only a relatively short period of time, May 1959 to September 1972. During that time some periods occurred during which flow rates were not obtained, reducing the continuous record to a period dating from June 1959 to August 1971.

There are no records of inflow to Chakachamna Lake, and since that information is needed to perform reservoir operation and power studies, inflows were calculated for the continuous period of record by reverse routing of outflows and making appropriate adjustments for changes in water levels. Calculated inflows for the 11 calendar years 1960 through 1970 were used in the power studies conducted during 1981 for Alternates A, B, C and D.

In order to develop a longer series of inflows to Chakachamna Lake, the lake inflows were statistically correlated with hydrometeorological records from other stations. Using the resulting correlation, inflows were calculated to produce a total period of 31 years of recorded and synthesized records. That 31-year sequence was used to determine the energy-generating potential for the recommended project, Alternative E, during the studies conducted during fiscal year 1982.

4.2 Historical Data

Hydrometeorological data from several stations in the Cook Inlet Basin were used for the derivation and extension of estimated lake inflow records. Streamflow records included the following furnished by U. S. Geological Survey:

Station No.	Description
15294500	Chakachatna River near Tyonek (the lake outlet gage)
15284000	Matanuska River near Palmer
15284300	Skwentna River near Skwentna
15292000	Susitna River at Gold Creek

Gaging Station No. 15294500 is located on the right bank of the Chakachatna River close to the outlet of Chakachamna Lake. The gage records include 13 years and 5 months from May 21, 1959 to September 30, 1972. The gage however, was destroyed by a lake outbreak flood on August 12, 1971 and the records between that date and June 20, 1972 are estimated rather than recorded flows. Thus, the period of actual record extends only from May 21, 1959 to August 12, 1971 and from June 20, 1972 to September 30, 1972. Furthermore, during that period, several of the winter-month flows were estimated because of icing conditions and instrument failure. Inaccurate winter records are not a serious engineering concern, because only 11% of the average annual flow normally occurs during the seven months from November through May.

In addition to the streamflow data, records of the water surface elevation at Station No. 15294500 were also obtained from the U. S. Geological Survey in Anchorage.

Available meteorological data consist of daily temperature and precipitation data obtained from the U. S. National Oceanic and Atmospheric Administration, National Climatic Center, Ashville, N.C. for stations at Kenai, Anchorage, and Sparrevohn.

The locations of these three meteorological stations are shown on Figure 4-1. A bar chart showing the periods of record for these stations is plotted on Figure 4-2.

4.3 Derived Lake Inflows

Chakachamna Lake with its surface area of about 26-square miles stores runoff and provides natural regulation of flow to the Chakachatna River. In order to derive a record of inflows to the lake, the regulating effects of the lake were removed from the outflow records using a reverse routing procedure which uses the basic continuity equation

$$I_t - O_t = \Delta s$$

Where

I_t is the inflow volume during month t

O_t is the outflow volume during month t

Δs is the change in lake storage during month t

For all practical considerations, the Chakachatna River near Tyonek gage is, in effect, located at the lake outlet and field observations confirmed that gage

readings closely represent the lake water-surface elevation. Hence, it was assumed for the reverse routing computations that the two were the same. Evaporation, seepage and other losses of water from the lake were assumed to be small and effectively compensated for by direct precipitation onto the lake surface.

The lake stage-storage curve used in the computations is shown on Figure 4-3. This is based on data measured by the USGS and recorded on the USGS maps Chakachatna River and Chakachamna Lake Sheets 1 and 2, dated 1960.

Average monthly inflows were calculated for the period June 1, 1959 through August 31, 1971, and are presented in Table 4-1. The calculated inflows for the 11 calendar years January 1, 1960 through December 31, 1970 were used in the power studies for Alternates A, B, C and D of the project layouts during 1981.

4.4 Synthesis of Long-Term Lake Inflows

In order to develop a long-term estimate of energy-production, methods for extending the inflow record were investigated. Transposition of records from other rivers in the region, correlation with meteorological data from nearby long-term stations, and combinations of both, were studied using regression analysis.

HYDROMETEOROLOGICAL STATION LOCATIONS

FIGURE 4-1

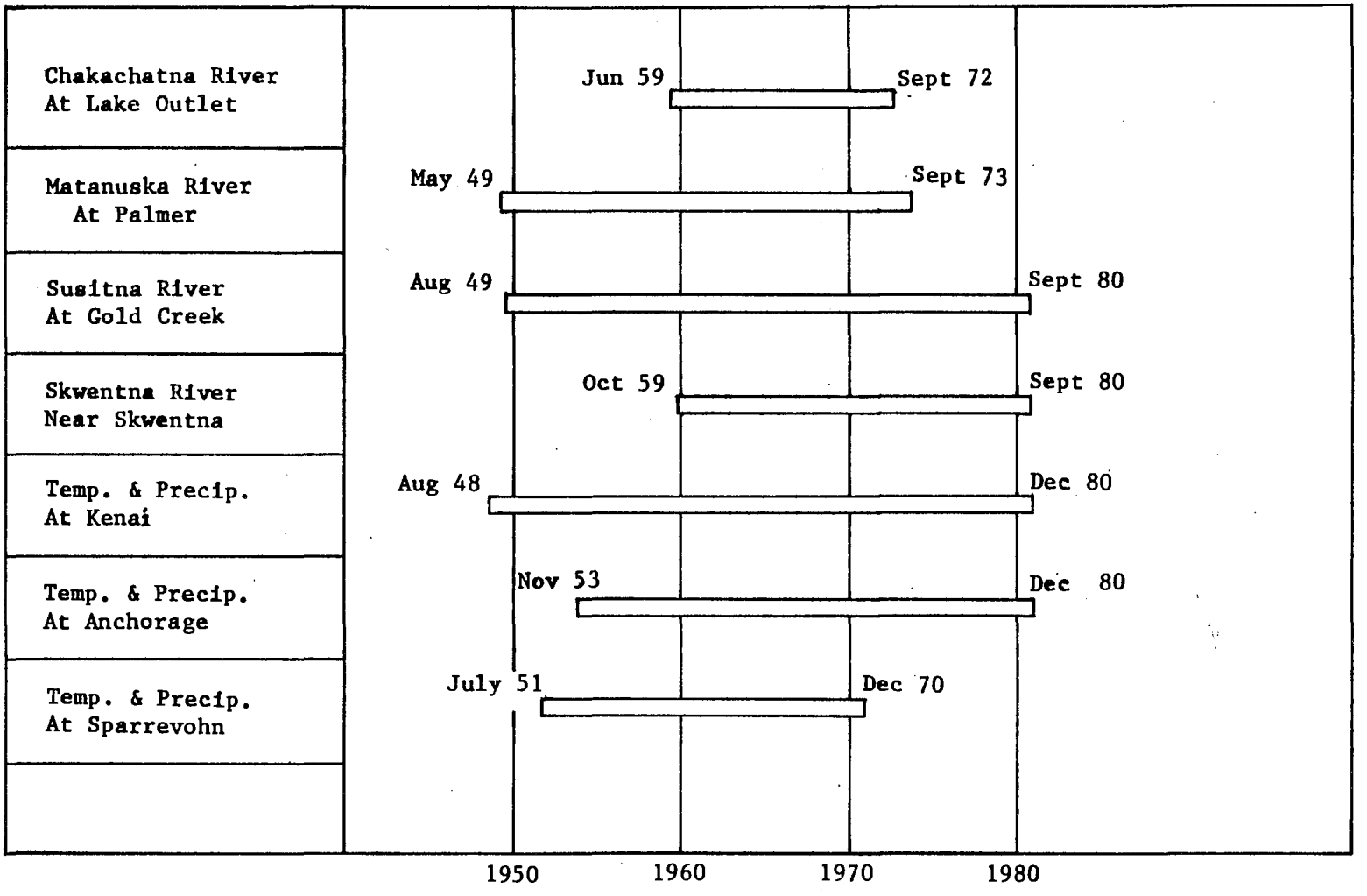


FIGURE 4-2

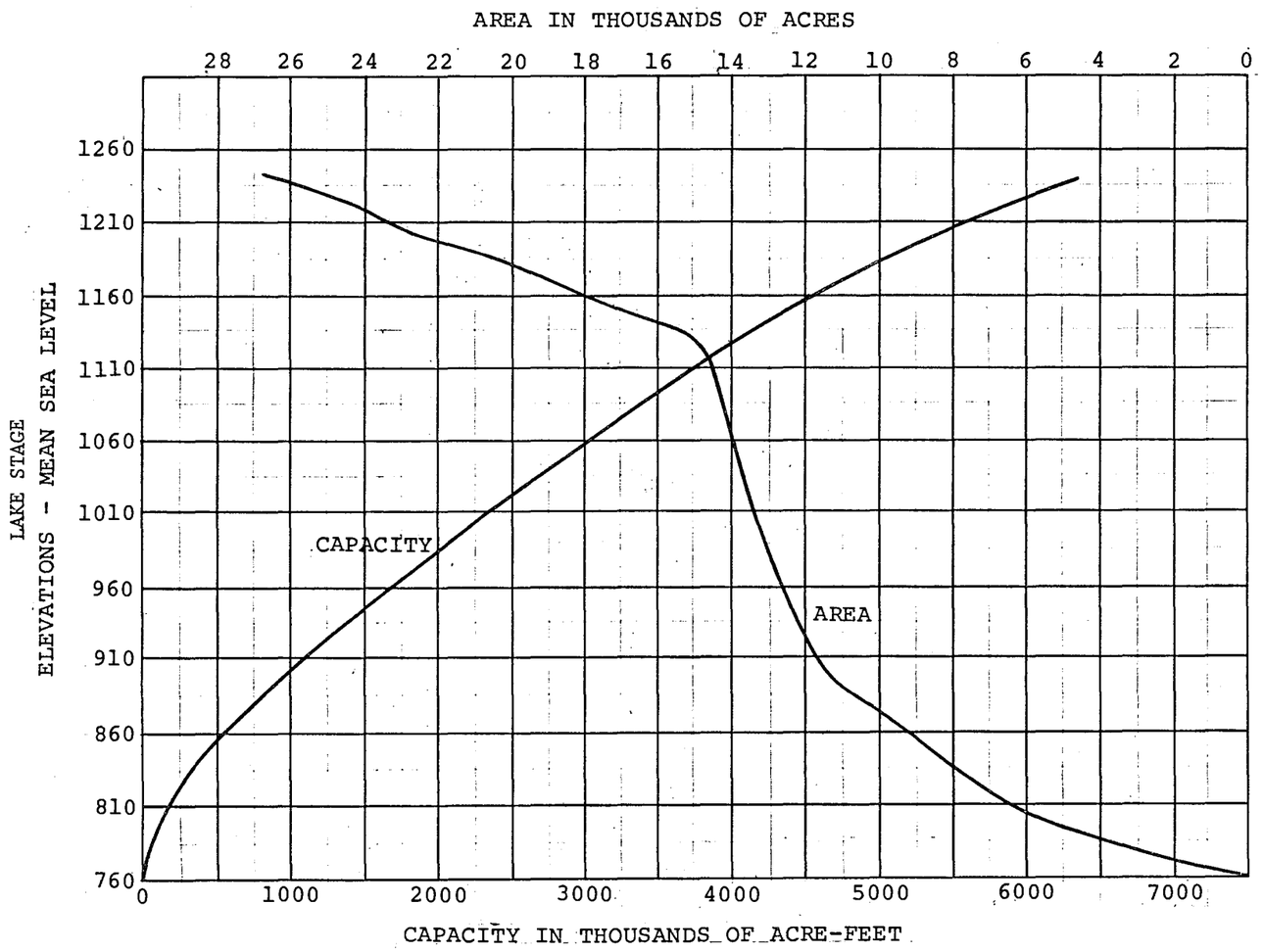
HYDROMETEOROLOGICAL STATIONS
PERIODS OF RECORD

CHAKACHAMNA

LAKE

AREA & CAPACITY DATA

ELEV. M.S.L.	AREA IN ACRES	CAPACITY ACRE FEET
760	0	0
765	810	2,025
770	1,300	7,300
780	2,690	27,200
800	5,670	111,000
20	7,320	241,000
40	8,270	397,000
60	9,280	572,000
80	10,400	769,000
900	11,590	988,000
20	11,960	1,224,000
40	12,320	1,467,000
60	12,650	1,717,000
80	12,980	1,973,000
1000	13,280	2,236,000
20	13,520	2,504,000
40	13,740	2,776,000
60	13,960	3,053,000
80	14,170	3,335,000
1100	14,390	3,620,000
20	14,620	3,910,000
40	16,100	4,218,000
42	16,780	4,250,000
60	18,250	4,572,000
80	19,900	4,953,000
1200	22,956	5,382,000
20	24,104	5,852,000
40	26,038	6,354,000



CHAKACHAMNA LAKE
LAKE STAGE-AREA AND CAPACITY

FIGURE 4-3

TABLE 4-1

LAKE CHAKACHAMNA INFLOWS (cfs)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC	MEAN
1959						9459.	10388.	11731.	3662.	1370.	654.	508.	
1960	400.	307.	267.	393.	3637.	6837.	11209.	9337.	3145.	1439.	799.	870.	3220.
1961	877.	589.	470.	346.	1881.	7983.	12808.	10899.	6225.	1586.	843.	696.	3767.
1962	633.	541.	471.	470.	1265.	7925.	13149.	10411.	5542.	1197.	863.	613.	3590.
1963	498.	357.	315.	337.	1801.	4735.	13249.	12208.	5847.	2056.	930.	710.	3587.
1964	364.	435.	332.	477.	1830.	8093.	10700.	11798.	4246.	1245.	909.	662.	3424.
1965	419.	219.	337.	398.	1286.	3490.	13046.	10516.	10802.	2114.	597.	466.	3641.
1966	388.	336.	350.	410.	1893.	8072.	10303.	9974.	6608.	1953.	910.	313.	3459.
1967	531.	449.	384.	880.	2030.	8761.	14931.	15695.	6191.	2040.	1215.	571.	4473.
1968	534.	510.	467.	630.	2996.	7808.	13117.	11257.	2793.	976.	689.	612.	3532.
1969	485.	486.	500.	652.	1948.	9271.	12510.	7297.	2793.	3057.	1215.	541.	3396.
1970	497.	504.	550.	899.	2265.	6789.	10360.	7986.	2734.	1359.	742.	460.	2929.
1971	394.	441.	513.	1275.	4063.	12672.	13695.	16680.					
MEAN	502.	431.	413.	597.	2241.	7838.	12261.	11215.	5049.	1699.	864.	585.	3606.

Examination of the inflows to Chakachamna Lake in Table 4-1, indicated that, for this watershed, the hydrological year (water year) should be defined as the period from May to April to minimize the overall basin-storage effects. The majority of the lake inflow, 93% of the annual runoff volume, occurs during May through October, while flow recession starts in November. Flows recorded at the lake outlet from November to May were, in general, estimated by USGS personnel using personal judgment because ice cover prevented proper functioning of the stage recorder during that period. The accuracy of the recorded winter streamflow is, therefore, questionable, but estimated total outflow volume during the low-flow winter months is thought to be reasonable. Because of their different hydrologic characteristics, it was decided that regression analyses should be performed separately for the periods, May to October, and November to April. In so doing, the less-accurate monthly-flow estimates for the winter period would not unduly influence calculations for flows during the remainder of each year.

The initial selection of independent variables to be used in the regression analyses was based on the lengths of the available hydrometeorologic records in the region, as well as the potential physical relationship with the inflow regime of Lake Chakachamna. Since Chakachamna Lake is glacially-fed, a heat-input index, such as monthly degree-days above $32^{o}F$ recorded at Kenai and Anchorage, could be an important independent variable. Monthly streamflow records from nearby watersheds which are considered to have hydrologic characteristics similar to that of the

Chakachamna basin were also incorporated in the study. These include the streamflows of Matanuska River at Palmer, Susitna River at Gold Creek and Skwentna River near Skwentna. In addition, monthly precipitation at Kenai and Anchorage were also considered. The final selection of the independent variables used for the lake-inflow synthesis was based on the results of the preliminary analyses.

The final regression analyses were performed systematically using different combinations of the pre-selected independent variables in a step-wise regression-analysis program (Bechtel TM 750). The regression equations obtained were evaluated on the basis of probable physical relationships to topographic, meteorological and hydrologic conditions as well as the computed level of statistical significance of the correlation. It was found that for both the high and low-flow periods, May to October and November to April respectively, the monthly streamflow records for the Matanuska River at Palmer correlate well with the historical monthly Chakachamna lake inflows. The regression equations obtained were:

May - October: $Q_{Lake} = 595.0 + 0.8967\ Q_{Palmer}$

November - April: $Q_{Lake} = 265.3 + 0.4597\ Q_{Palmer}$

Correlation coefficients for these two regression equations were found to be 0.89 and 0.40 respectively and are well within the 95 percent significance level. However, the Matanuska gage was discontinued in September of 1973. Another set of regression equations was therefore required for the flow synthesis for the period after September 1973. New

correlation studies were performed. It was found that recorded streamflows for Skwentna River near Skwentna were a good substitute for those at the Matanuska gage. The regression equations obtained were:

May - October: $Q_{Lake} = 674.67 + 0.5233\ Q_{SK}$

November - April: $Q_{Lake} = 283.27 + 0.2690\ Q_{SK}$

The correlation coefficients for these two regression equations were found to be 0.73 and 0.45 respectively and are well within the 95 percent significance level.

The correlation coefficients for the regression equations for the low-flow season are relatively low. This was to be expected, because, as discussed earlier, streamflow values for this period were known to be inaccurate since they had to be estimated by personnel from the U.S. Geological Survey on the basis of regional streamflow data and/or personal judgment because of frequent malfunctioning of gages during winter. However, the streamflow volume in this period represents only about 7 percent of the total annual runoff volume. Because the operation study used monthly flow volumes, inaccuracies inherent in the flow synthesis for the winter months do not significantly affect the overall accuracy of the study and the respective regression equations are therefore regarded as acceptable for use in the derivation of the long-term streamflow record. Table 4-2 presents the lake inflows synthesized by using these equations and the reverse-routing procedure. The 31 year sequence of inflows includes the June 1959 through August 1971 inflows calculated by reverse-routing of outflows plus the May 1949 through May 1959 and the

TABLE 4-2

CHAKACHAMNA PROJECT OPERATION STUDY
H/H,H&CF,BECHTEL CIVIL&MINERALS INC.,SF.
ALASKA POWER AUTHORITY

PROJECT 14879001 DATE 11783 PAGE 3

ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

INFLOWS TO THE LAKE IN CFS

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	AVEYR	CALYR
1	4513.	10728.	15220.	11615.	6305.	2689.	802.	636.	542.	488.	493.	541.	4548.	1950
2	2055.	8572.	13194.	10548.	4521.	1761.	569.	532.	495.	472.	450.	631.	3650.	1951
3	3801.	10719.	13095.	8831.	8635.	3216.	842.	699.	630.	495.	467.	510.	4328.	1952
4	2027.	8204.	12575.	9431.	3562.	2712.	865.	642.	523.	477.	477.	641.	3511.	1953
5	3992.	13247.	13355.	10808.	4505.	2002.	629.	550.	527.	472.	458.	541.	4257.	1954
6	3434.	9002.	12091.	12046.	6075.	2787.	755.	619.	578.	507.	466.	487.	4071.	1955
7	2193.	6826.	12996.	9983.	5068.	1988.	595.	532.	504.	475.	449.	496.	3509.	1956
8	2936.	7475.	14601.	10235.	5940.	2053.	583.	565.	569.	536.	505.	598.	3883.	1957
9	4393.	14817.	13149.	10405.	6910.	2707.	793.	562.	569.	510.	489.	675.	4665.	1958
10	2496.	9930.	10163.	8691.	3452.	1896.	526.	483.	426.	468.	449.	526.	3292.	1959
11	3120.	9459.	10388.	11731.	3662.	1370.	654.	508.	400.	307.	267.	393.	3522.	1960
12	3637.	6837.	11209.	9337.	3145.	1439.	799.	870.	877.	589.	470.	346.	3296.	1961
13	1881.	7983.	12808.	10899.	6225.	1586.	843.	696.	633.	541.	471.	470.	3753.	1962
14	1265.	7925.	13149.	10411.	5542.	1197.	863.	613.	498.	357.	315.	337.	3539.	1963
15	1801.	4735.	13249.	12208.	5847.	2086.	930.	710.	364.	435.	332.	477.	3598.	1964
16	1830.	8093.	10700.	11798.	4246.	1245.	909.	662.	419.	219.	337.	398.	3405.	1965
17	1286.	3490.	11633.	11929.	10802.	2114.	597.	466.	388.	336.	350.	410.	3650.	1966
18	1893.	8072.	10303.	9974.	6608.	1953.	910.	313.	531.	449.	384.	880.	3523.	1967
19	2030.	8761.	14931.	15695.	6191.	2040.	1215.	571.	534.	510.	467.	630.	4465.	1968
20	2996.	7808.	13117.	11257.	2793.	976.	689.	612.	485.	486.	500.	652.	3531.	1969
21	1948.	9271.	12478.	7297.	2793.	3057.	1215.	601.	497.	504.	550.	899.	3426.	1970
22	2265.	6789.	10360.	7986.	2734.	1359.	742.	460.	394.	441.	513.	1275.	2943.	1971
23	4063.	12672.	13695.	16680.	5075.	3181.	1090.	736.	581.	531.	492.	479.	4940.	1972
24	3468.	8228.	13490.	9263.	5012.	2396.	679.	514.	495.	492.	480.	586.	3759.	1973
25	2131.	7457.	8850.	7809.	2794.	2527.	740.	623.	558.	526.	501.	554.	2923.	1974
26	4215.	6248.	6781.	6159.	6850.	3059.	909.	530.	498.	485.	485.	489.	3059.	1975
27	4784.	10649.	10889.	6802.	5107.	3136.	814.	622.	544.	524.	498.	625.	3750.	1976
28	5283.	8587.	8304.	6494.	4947.	3917.	1058.	1055.	1044.	773.	606.	606.	3556.	1977
29	5335.	19864.	13898.	11224.	6059.	3709.	922.	700.	609.	537.	509.	558.	5327.	1978
30	5387.	7917.	10146.	7865.	4513.	3258.	708.	701.	597.	562.	547.	713.	3576.	1979
31	6776.	8514.	8958.	9157.	4572.	4471.	1412.	882.	762.	718.	647.	810.	3973.	1980
MEAN	3201.	8996.	11928.	10147.	5177.	2383.	828.	621.	551.	491.	465.	588.	3781.	
MAX	6776.	19864.	15220.	16680.	10802.	4471.	1412.	1055.	1044.	773.	647.	1275.	5327.	
MIN	1265.	3490.	6781.	6159.	2734.	976.	526.	313.	364.	219.	267.	337.	2923.	

September 1971 through April 1979 inflows calculated from the regression equations.

4.5 Power Studies

During the 1981 project studies four basic alternative project layouts were developed and designated Alternatives A, B, C and D as described in Section 3.3 of this report. Power studies also performed during 1981 for these four alternates were based on the 11 complete calendar years (January 1, 1960 through December 31, 1970) of Chakachamna Lake inflow set forth in Table 4-1. During the 1982 studies, the recommended Alternative E, also described in Section 3.3, was developed, as was the 31 year sequence of inflow to Chakachamna Lake which was used during the 1982 power studies for each of the alternatives A through E. The power operation studies were performed to determine generated firm and secondary energy, flow releases, and the fluctuations in the water surface elevation of Chakachamna Lake for a range of installed capacities for each of the five project alternatives. The studies were made using a computer program that performs sequential routing of the derived monthly inflows while satisfying power demands, projected in-stream flow requirements, and physical system constraints. Power demands were in accordance with a plant load factor of 0.5, and the monthly variations in peak demand listed in Table 4-3. As advised by APA, these demands are those being used in the evaluation of sources of power alternative to that of the Chakachamna Hydroelectric Project.

The in-stream flow requirements, listed in Table 4-4, represent provisional minimum monthly flows to be

TABLE 4-3

MONTHLY PEAK POWER DEMANDS USED IN POWER STUDIES

MONTH	MONTHLY PEAK DEMAND (Percent of Annual Peak Demand)
January	92
February	87
March	78
April	70
May	64
June	62
July	61
August	64
September	70
October	80
November	92
December	100

Source: Susitna Hydroelectric Project Development Selection Report Appendix D, Table D.1 (Second Draft, July 1981)

TABLE 4-4

PROVISIONAL MINIMUM RELEASES FOR INSTREAM FLOW IN CHAKACHATNA RIVER DOWNSTEEAM FROM CHAKACHAMNA LAKE OUTLET FOR USE IN POWER STUDIES

MONTH	MC ARTHUR TUNNEL DEVELOPMENT ALTERNATIVE B (CFS)*	CHAKACHATNA TUNNEL DEVELOPMENT ALTERNATIVE D (CFS)	MCARTHUR TUNNEL DEVELOPMENT ALTERNATIVE E (CFS)*
January	365	30	365
February	343	30	357
March	345	30	358
April	536	30	582
May	1,094	30	1,094
June	1,094	30	1,094
July	1,094	30	1,094
August	1,094	30	1,094
September	1,094	30	1,094
October	365	30	365
November	365	30	365
December	360	30	363

* Criteria used to determine fish instream flow release:
April through September - 1094 cfs or inflow to lake whichever is less
October through March - 365 cfs or inflow to lake whichever is less

released into the Chakachatna River near the lake outlet as further discussed in Sections 7.3.2 and 7.3.3 of this report.

The physical system constraints, set forth in Table 4-5, are the overall plant efficiency, tailwater elevation, and head loss for the hydraulic conduits.

In the power studies water was drafted from lake storage whenever the monthly inflows were insufficient to meet the power demand. It was assumed that spill, or discharge of water from the lake into the Chakachatna River in excess of the tentative instream requirements would occur whenever the lake water level exceeded elevation 1,128 feet, for alternatives A through D, and 1155 for alternative E. The secondary energy is that which can be generated by plant capacity in excess of that needed to meet the load carrying capability, using water which otherwise would have spilled.

For each of the alternatives considered for development of the project, a range of installed powerplant capacities was tested in order to establish the installed capacity that would make the most use of all water available for power generation without drawing the lake level below a given minimum elevation. This minimum was taken as elevation 1,014 feet for alternatives A through D and elevation 1,085 for alternative E respectively. The lake was assumed to be full at the beginning of each run.

4.6 Results

The results of the power studies listed in Table 4-6 show that, on the basis of the 11 calendar years of

TABLE 4-5

POWERPLANT SYSTEM CONSTRAINTS FOR
ALTERNATIVE PROJECT DEVELOPMENTS

ALTERNATIVE	PLANT EFFICIENCY (%)	PLANT FACTOR	AVERAGE TAILWATER ELEVATION (FT.)	HEAD LOSS IN HYDRAULIC CONDUITS (FT.)
A	85	0.50	210	$0.0000024 \times Q^2$
B	85	0.50	210	$0.0000024 \times Q^2$
C	85	0.50	400	$0.0000028 \times Q^2$
D	85	0.50	400	$0.0000028 \times Q^2$
E	85	0.45	210	$0.0000024 \times Q^2$

Note: Q = Flow in cubic feet per second.

TABLE 4-6

POWER STUDIES SUMMARY

Development Alternative	Installed Capacity (MW)	Average Annual Energy		Average Annual Flow	
		Firm (GWh)	Secondary (GWh)	Power Diversion (CFS)	Provisional Instream (CFS)
A	400	1752	153	3322	0
B	330	1446	124	2701	679
C	300	1314	139	3230	0
D	300	1314	130	3239	30
E	330	1301	290	2274	685

Note: Period of record January 1, 1960 to December 31, 1970
Average annual inflow to Chakachamna Lake 3547 cfs (2.6 million AF)
Alternatives A, B - Development via McArthur tunnel
Alternatives C & D - Development via Chakachatna tunnel

Period of record May 1, 1949 to April 30, 1979
Average annual inflow to Chakachamna Lake 3781 cfs (2.7 million AF)
Alternative E - Development via McArthur Tunnel

Power diversion flows are the flows needed to meet firm energy requirements.

inflow, and with the parameters used in the studies, the optimum development via the McArthur Tunnel could support a powerplant of 400 MW installed capacity when all controlled water is used for power generation as in Alternative A. At 50% plant factor, this provides an average annual 1,752 GWh of firm energy. The provisional instream flow requirements of Alternative B discussed in Section 7.3.2 of this report represent about 19% of the average annual flow in the Chakachatna River during the period of record. If that amount of water is reserved for instream flow, the installed capacity of powerplant that could be justified at the McArthur River would be reduced to 330 MW and the firm average annual energy would be 1446 GWh.

For development via the Chakachatna tunnel, the optimum power development using all controlled water for power generation, Alternative C, would have an installed capacity of 300 MW and firm annual average energy would be 1314 GWh for a 50% plant factor. The provisional minimum instream flow reservations in Alternative D, discussed in Section 7.3.3 of this report, represent less than 1% of the average annual flow during the period of record. Thus, the installed capacity and firm energy in Alternative D for practical purposes would remain the same. There would however be about 15% reduction in the amount of secondary energy that could be generated.

Alternatives A through D cannot firmly support the capacities determined from the 11 years of inflow during the 1981 studies and the recommended Alternative E cannot firmly support 330 MW at 50% plant factor due to two consecutive dry years (1973-74) that occur during the 31 years of

correlated lake inflow. These two years do not occur in the 11 calendar years (1960-1970) of inflow used in the 1981 power studies for Alternates A through D and some additional analyses should be made in future studies of the project. Using the 31 years of inflow, and 330 MW installed capacity, Alternate E could produce 1301 GWh at 45% load factor.

4.7 Variations in Lake Water Level

The variations in lake water-surface elevation calculated at the end of the month during the course of the power studies for each of the five alternatives and cases listed in Table 4-6 are shown in the computer output included in the Appendix to Section 4.0, and are also plotted in Figures 4-4 and 4-5.

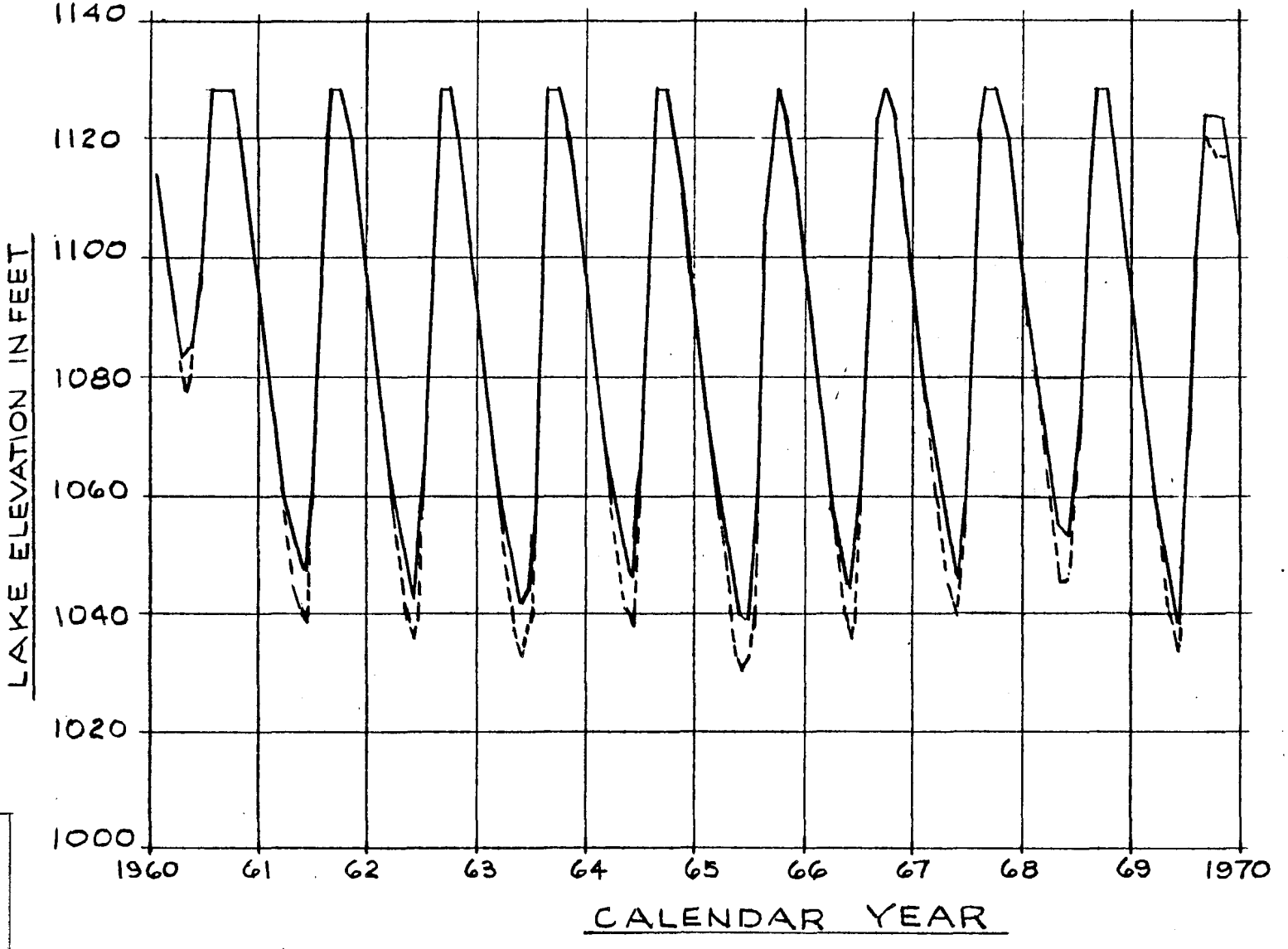


FIGURE 4-4

ALTERNATIVES A & B
LAKE LEVEL VARIATIONS

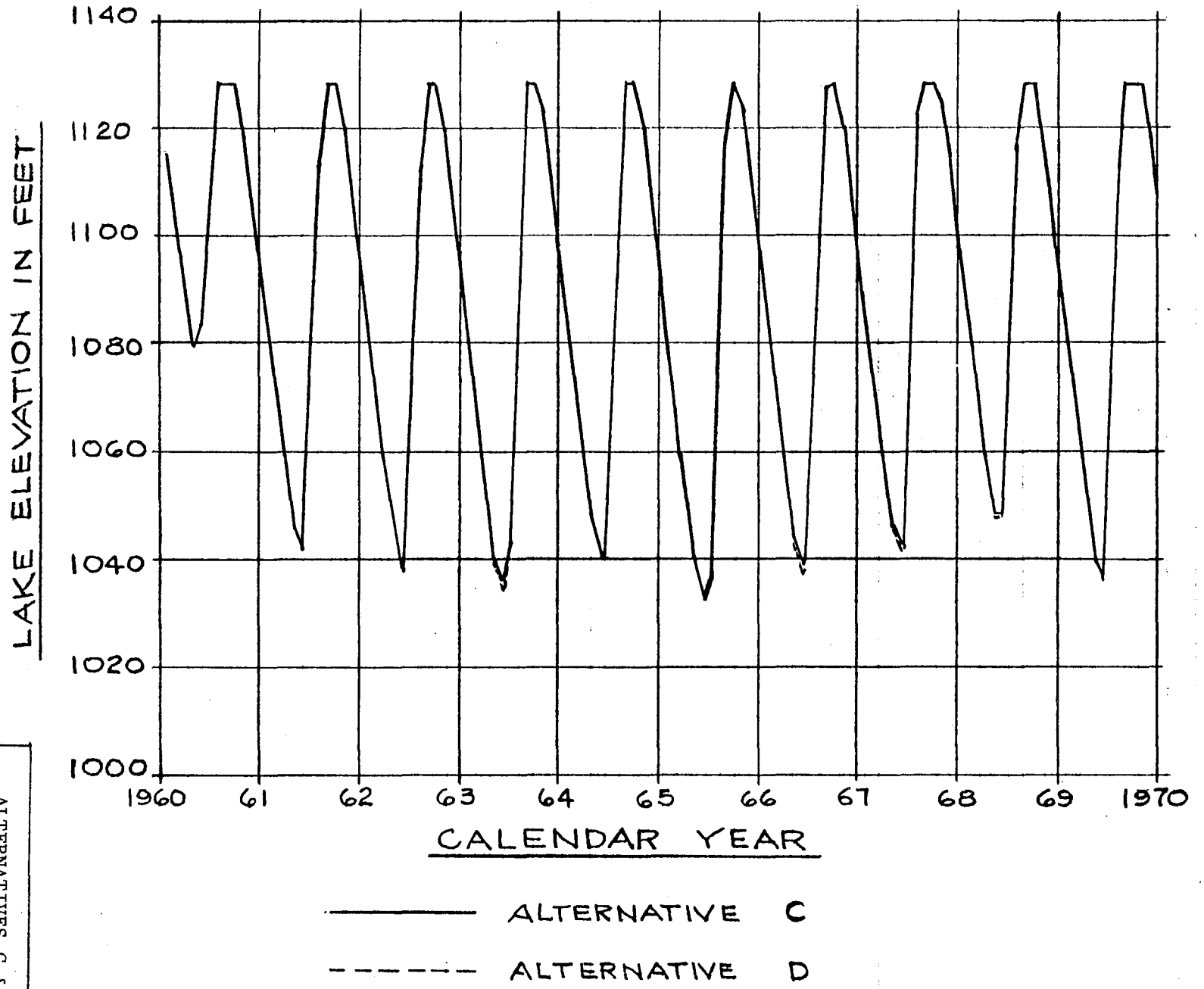


FIGURE 4-5

ALTERNATIVES C & D
LAKE LEVEL VARIATIONS

GEOLOGIC INVESTIGATIONS

5.0 GEOLOGIC INVESTIGATIONS

5.1 Scope of Geologic Investigations

5.1.1 Technical Tasks

The scope of the geologic investigations planned for the Chakachamna Hydroelectric Project Feasibility Study includes five technical tasks:

(1) Quaternary geology,

(2) Seismic geology,

(3) Tunnel alignment and powerplant site geology,

(4) Construction materials geology, and

(5) Road and transmission line geology.

These tasks were identified and scopes defined so that, upon completion of the investigations, the information needed to assess the potential impact of a range of geologic factors on the feasibility of the proposed project will be available. If the Chakachamna Project is judged to be feasible, additional geologic investigations will be required subsequent to the feasibility study in order to provide the detailed information appropriate for actual design.

At the feasibility level, it is appropriate to gather information regarding the general character of the geologic environment in and around the project area, with particular attention to geologic hazards and the geology

of specific facilities siting locations. The Chakachamna Project, as presently conceived, does not include facilities such as large dams that would increase the risks associated with geologic hazards that are naturally present in the project area. The geologic tasks were planned in recognition of the above and were designed to focus on geologic factors that may influence the technical feasibility, the operating reliability, and/or the cost of the proposed project.

The work on the geology tasks began in August 1981 but the majority of the work will take place in future feasibility level investigations. This report includes a summary of the work planned for the geologic investigations (Section 5.1.1) and the schedule for each geology task (Section 5.1.2), summaries of the work completed for the Quaternary geology (Section 5.2) and seismic geology (Section 5.3) tasks, and some preliminary commentary on geologic conditions in the project area in Section 7.0. The commentary and any tentative conclusions presented here are subject to revision as the project work continues in the future.

5.1.1.1 Quaternary Geology

The Quaternary geology task was designed to include an assessment of the glaciers and glacial history of the Chakachamna Lake area, an investigation of the Mt. Spurr and associated volcanic centers, and a study of the slope conditions near sites proposed for project facilities.

A study of the glaciers was judged to be appropriate because:

(1) movement of the terminus of Barrier Glacier influences the water level in Chakachamna Lake and any structures to be built near the lake outlet;

(2) the possibility that changes in the terminal position of Blockade Glacier could alter the drainage at the mouth of the McArthur River Canyon; and

(3) questions regarding the influence of other glaciers in the study area on the size and hydrologic balance of Chakachamna Lake.

In addition, knowledge of the ages of geomorphic surfaces is important to the assessment of possible seismic hazards and such knowledge depends on an understanding of the glacial geology.

The simple presence of Mt. Spurr, an active volcano, at the eastern end of Chakachamna Lake provides a clear rationale for investigating the volcanic history and potential volcanic hazards of the project area. Of particular interest is the possibility that lava flows or volcanic mudflows (a possibility increased by the glacier ice on Mt. Spurr) could enter the lake and produce large waves, an increase in lake level, and/or a change in conditions at the lake outlet or on the upper reaches of the river. In addition, the possible impact of a dark, heat-absorbing layer of volcanic ejecta on the glaciers' mass balance, and thus the lake's hydrologic balance is of interest.

Chakachamna Lake, Chakachatna River Canyon, and McArthur River Canyon are all bordered by steep slopes that may be subject to a variety of types of slope failure. A large landslide into the lake could change the usable volume of water stored in the lake and could alter conditions at the proposed lake tap and at the natural outlet from the lake. Potential outlet portal and surface powerhouse sites in the river canyons are all on or immediately adjacent to steep slopes. Both the integrity of and access to these facilities could be impaired in the event of landslide and rockfall activity.

Because of the concerns indicated above, the Quaternary geology task was designed to investigate the timing and size of past glacial fluctuations, the frequency and type of volcanic activity, and the slope conditions in order to provide an estimate of possible future events that could influence the costs and operating performance of the proposed hydroelectric project. In addition, this task should provide information regarding the possibility of the project destabilizing the lake outlet by producing or allowing changes in Barrier Glacier.

5.1.1.2 Seismic Geology

The seismic geology of the Chakachamna Lake area is of interest because southern Alaska is one of the most seismically active areas in the world. Potential seismic hazards of direct concern to the proposed hydroelectric project include surface faulting, ground shaking, seismically-induced slope failure, lake seiche, and liquefaction. Specifically, the seismic geology task was designed to investigate the possibility of active faults in the immediate vicinity of the proposed facilities, to

assess the location and activity of regional faults (e.g., Castle Mountain, Bruin Bay), and to estimate the type and intensity of seismic hazards that may be associated with these faults and with the subduction zone.

The seismic geology investigations were planned to maximize the use of existing information by following a sequence of subtasks that become increasingly site specific as the work proceeds. The primary elements in the sequence are:

- literature review
- remote sensing imagery analysis
- field reconnaissance
- low-sun-angle air photo acquisition and analysis
- detailed field studies

The data produced by the above sequence is required to assess directly the surface faulting hazard and for input to the probabilistic assessment of ground motion parameters.

In order to develop approximate ground motion spectra for the various elements of the project, existing ground motion information developed for other projects in southern Alaska will be reviewed and modified, as appropriate. A simplified evaluation of the liquefaction potential of the transmission line alignment should also be carried out.

5.1.1.3 Tunnel Alignment and Powerplant Site Geology

The scope of work for this task should be based on the need to assess the feasibility of constructing a lake tap in Chakachamna Lake, a long tunnel, and a powerhouse as the primary components of the proposed hydroelectric development. Because of the steep mountainous terrain above the tunnel alignment, the tunnel feasibility study should be planned around the mapping of bedrock exposures in the mountains and production of a strip map; drilling would be limited to the powerhouse site during the feasibility investigations. The strip map should focus on those bedrock characteristics that determine the technical and economic feasibility of tunnelling. Geophysical techniques should be used to assess the lake bottom bedrock and sediment characteristics at and near the proposed lake tap and subsurface conditions at the proposed powerhouse site.

All reasonably possible surface powerplant and outlet portal sites are on or adjacent to high, steep slopes. Hazards such as landslides, rockfalls, and avalanches, which are a particular concern in seismically active areas, should be assessed during the feasibility study.

5.1.1.4 Construction Materials Geology

The proposed Chakachamna Hydroelectric Project will, if constructed, require aggregate for concrete, road construction, and construction of the transmission line. In addition, rockfill will be required for the low dike at the lake outlet and boulder rip-rap may be required at the outlet portal and outfall from the powerhouse. This task should be planned to yield information about potential

aggregate sources at the powerhouse-outlet portal site, along the road, and along the transmission line alignment.

5.1.1.5 Road and Transmission Line Geology

Geologic considerations will be important in the assessment of the road and transmission line routes. This task will use aerial photograph analysis and reconnaissance-level field studies in order to provide information on the general character of the alignments. The task plans should give particular attention to river crossings, which may be subject to large floods, and to wetland areas where special construction techniques may be required.

5.1.2 Schedule

The 1981 geologic field program did not commence until late August that year and was therefore relatively limited in scope, covering only the Quaternary geology and part of the seismic geology tasks. Future investigations should concentrate on the remaining geologic tasks as discussed below.

5.1.2.1 Quaternary Geology

All of the Quaternary geology field studies were either of a regional nature or directed at targets that would not vary as a function of final configuration of the project facilities. Therefore, it was possible to complete the field work planned for this task. Some additional review of unpublished data, such as that held by the U.S. Geological Survey in Fairbanks, and discussions with geologists who have worked in the

Chakachamna area remain to be completed. Although several important implications with respect to the proposed hydroelectric project have been identified and some tentative conclusions may be drawn, additional analyses and discussions are needed before the conclusions can be finalized.

5.1.2.2 Seismic Geology

As discussed in Section 5.1.1.2, the seismic geology task is designed around a sequence of investigations, each of which builds on the preceding ones. Because of this characteristic, the seismic geology task demands a certain amount of elapsed time and cannot be speeded up by adding additional staff.

During 1981 it was possible to complete the literature review, analysis of existing remote sensing imagery, field reconnaissance, and the acquisition and initial analysis of the low-sun-angle aerial photography. The detailed field studies and ground motion assessment will be conducted during future feasibility study work.

5.1.2.3 Tunnel Alignment and Powerplant Site Geology

No field investigations were conducted for this task in 1981 because the various tunnel alignment locations and configurations to be studied were not identified prior to completion of the 1981 field season. All of the geologic and geophysical investigations planned for this task should be completed during future feasibility study work.

5.1.2.4 Construction Materials Geology

The work for this task will be conducted during future feasibility study work.

5.1.2.5 Road and Transmission Line Geology

The work for this task will be conducted during future feasibility study work.

5.2 Quaternary Geology

The Quaternary, approximately the last 2 million years of geologic time, is commonly subdivided into the Pleistocene and the Holocene (most recent 10,000 years). Although the Pleistocene is generally equated to the glacial age and the Holocene with post-glacial time, such a distinction is less clear in southern Alaska where the mountains still contain extensive glaciers.

The Quaternary was a time of extreme and varied geologic activity in southern Alaska. In addition to the extensive glacial activity and associated phenomena, the Quaternary was also a time of mountain building and volcanic activity. The products of these and other geologic processes that were active during the Quaternary, and are still active today, are broadly present in the Chakachamna Lake area. Although the geologic investigations for this feasibility study consider a broad range of topics that fall under the general heading of Quaternary geology, this task was planned to address three specific topics:

(1) glaciers and glacial geology;

(2) Mt. Spurr volcano; and

(3) slope conditions.

In addition, the seismic geology task (Section 5.3) is designed to focus on Quaternary and historic fault activity and seismicity and is highly dependent on an understanding of the glacial history of the area for temporal data.

For the Quaternary geology task of the Chakachamna study, field work consisted of a twelve-day reconnaissance during which all three primary topics of interest (above) were studied. When combined with information available in the open literature and that gained through interpretation of aerial photography, the field reconnaissance provides a basis for assessing the potential impact of the glaciers, volcano, and slope conditions on the proposed hydroelectric project.

5.2.1 Glaciers and Glacial Geology

5.2.1.1 Regional Glacial Geologic History

At one time or another during the Quaternary, glaciers covered approximately half of Alaska (Pewe, 1975). Previous investigations have demonstrated that the Cook Inlet region has had a complex history of multiple glaciation (Miller and Dobrovolny, 1959; Williams and Ferrians, 1961; Karlstrom, 1964; Karlstrom and others, 1964; Trainer and Waller, 1965; Pewe and others, 1965;

Schmoll and others, 1972). The current understanding of the region's glacial history is based on interpretation of the morphostratigraphic record in association with relative and absolute age dating and other Quaternary studies. The complex history is recorded in glacial, fluvial, lacustrine, marine, and eolian sediments that have been studied primarily in their surface exposures where they can be associated with specific landforms. Although more recent work has led to modification and refinement of Karlstrom's (1964) history of glaciation in the Cook Inlet region, that work still provides a good general overview and, except where noted, serves as the basis for the following summary.

On at least five separate occasions during the Quaternary, the glaciers in the mountains that surround Cook Inlet have expanded onto the Cook Inlet lowlands where they coalesced to cover much or all of the lowland with ice. Evidence for the two oldest recognized glaciations (Mt. Susitna, Caribou Hills) consists dominantly of erratic boulders and scattered remanants of till at high elevation sites around the margins of the lowland. Evidence for the next glaciation, the Eklutna, includes moraines and till sheets that demonstrate the coalescence of ice from various source areas to form a Cook Inlet piedmont glacier. The available evidence suggests several thousand feet of ice covered virtually all of the Cook Inlet lowland during these early glaciations.

The next two glaciations, the Knik and the Naptowne, correspond to the Early Wisconsin and Late Wisconsin glaciations of the midwestern United States, respectively. Thus, the Naptowne glaciation of the Cook

Inlet region correlates, in general, with the Donnely (Pewe, 1975) and McKinley Park (TenBrink and Ritter, 1980; TenBrink and Waythomas, in preparation) glaciations reported from two areas on the north side of the Alaska Range. During the Knik and Naptowne glaciations ice again advanced onto the Cook Inlet lowland, but the ice did not completely cover the lowland as it apparently did during the earlier glaciations. Even at the glacial maxima, portions of the lowland were ice free; such areas were commonly the sites of large ice-dammed lakes that have been studied in some detail (Miller and Dobrovolny, 1959; Karlstrom, 1964).

The maximum ice advance during the Naptowne glaciation is recorded by distinct end moraine complexes located near the mouths of the major valleys that drain the Alaska Range and by moraines on the Kenai lowland. The moraines on the Kenai lowland are of particular interest because they were, at least in part, formed by the Trading Bay ice lobe, which originated in the Chakachatna-McArthur rivers area and advanced across Cook Inlet at the time of the Naptowne maximum. Karlstrom (1964) reported on these features on the Kenai lowland in some detail.

Karlstrom (1964) used a combination of radiocarbon dates and relative-age dating techniques to develop a chronology for the Cook Inlet glaciations. According to Karlstrom, the Naptowne glaciation continued, although with decreasing intensity, past the Pleistocene-Holocene boundary (generally taken as being near 10,000 years before present [ybp]), through the Climatic Optimum, to the beginning of Neoglaciation (see Porter and Denton, 1967). Recent work on the north side of the Alaska Range has produced a well-dated chronology for the McKinley

Park glaciation (TenBrink and Ritter, 1980; TenBrink and Waythomas, in preparation). That chronology shows major stadial events at:

(1) 25,000-17,000 ybp (maximum advance at about 20,000 ybp);

(2) 15,000-13,500 ybp;

(3) 12,800-11,800 ybp; and

(4) 10,500-9,500 ybp.

Recognizing the differences in ice extent and other factors between the Cook Inlet region and the north side of the Alaska Range, the TenBrink chronology is probably reflective of the timing of the primary Naptowne stadial events. Dates from the Cook Inlet region proper have yet to yield such a clear picture, probably because of the greater complexity of the conditions and thus the record there.

Following the Naptowne glaciation (about 9,500 ybp by TenBrink's chronology, as late as 3,500 ybp according to Karlstrom, 9164), glacial advances in the Cook Inlet region have been limited to rather small-scale fluctuations that have extended only up to a few miles beyond present glacier termini. Karlstrom (1964) referred to these Neoglacial advances as the Alaskan glaciation, which he divided into two distinct periods of advance (Tustumena and Tunnel) and further subdivided into three and two short-term episodes, respectively. According to Karlstrom (1964) these Neoglacial events range in age from approximately 3,500 ybp to historic fluctuations of the last several decades.

Two points of particular interest regarding Neoglaciation in Alaska emerged from the literature review:

(1) the idea that "... the youngest major advance typically was the most extensive of the Neoglaciation" (Porter and Denton, 1967, p. 187), and

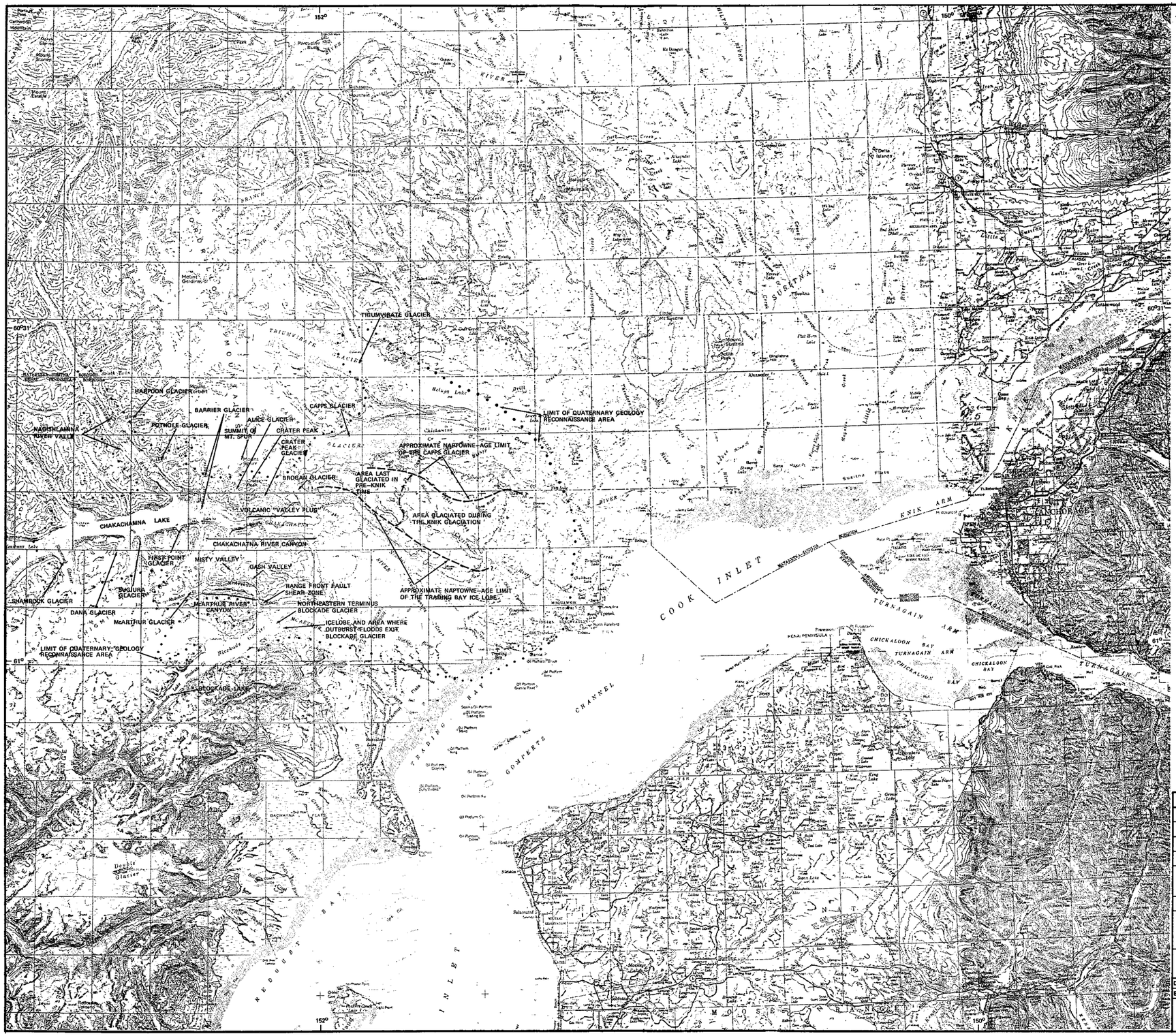
(2) Karlstrom's (1964) suggestion that, at least in the mountains around the margins of the Cook Inlet region, there was no distinct hiatus between the last small Naptowne readvance and the first Neoglacial advance.

These points will be addressed in the following section.

5.2.1.2 Project Area Glacial Geologic History

The reconnaissance-level investigations conducted for the Chakachamna study confirm the general picture for the project area presented by Karlstrom (1964). The area examined during the field reconnaissance is indicated on Figure 5-1. Although a rather broad area was included in the study area, most of the field work took place in the Chakachamna Lake basin, along the Chakachatna River, and on the southern slopes of Mt. Spurr.

Most of the study area was covered by glacier ice during the maximum stand of the Naptowne-age glaciers. Based on Karlstrom's (1964) work, it would appear that only high, steep slopes and local elevated areas were not covered by Naptowne ice. Within the area examined in the field, the upper limit of Naptowne ice is generally clearly defined, particularly in the area between Capps Glacier and



EXPLANATION

PLACE NAMES AND LOCATIONS WITHIN THE QUATERNARY GEOLOGY RECONNAISSANCE AREA INVESTIGATED BY WOODWARD–CLYDE CONSULTANTS DURING THE 1981 FIELD SEASON.

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

QUATERNARY GEOLOGY
SITE LOCATIONS

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	Figure 5-1	

Blockade Glacier, at and east of the range front (Figure 5-1). In this area lateral moraines produced during the maximum stand of Naptowne ice (25,000-17,000 ybp) are distinct and traceable for long distances; younger Naptowne lateral and terminal moraines are also present. The largest area that was not buried by Naptowne ice and which was observed during field reconnaissance is located high on the gentle slopes east of Mt. Spurr, between Capps Glacier and Straight Creek. The two older surfaces (Knik and [?] Eklutna) observed in this area (Figure 5-1) correspond well to the ideas presented by Karlstrom (1964).

Not only are moraines marking the Naptowne maximum present, but a large number of moraines produced during subsequent stadial advances or recessional stillstands are also present. These features demonstrate that even at the Naptowne maximum, ice from Capps Glacier and other glaciers to the north did not coalesce with ice coming from the Chakachatna canyon, except possibly near the coast. The Chakachatna ice and that issuing from the McArthur River Canyon and Blockade Glacier did join, however, to produce Karlstrom's (1964) Trading Bay ice lobe. That ice lobe covered the alluvial flat that, at the coast, extends from Granite Point to West Foreland. From the present coast, the Trading Bay lobe (according to Karlstrom, 1964) extended across Cook Inlet to the Kenai lowland.

The complex of moraines located between Blockade Glacier and the Chakachatna River area allow one to trace the slow retreat of Naptowne ice. As the Trading Bay lobe retreated westward across the inlet and then across the Trading Bay alluvial flats to the mountain front,

separate ice streams became distinct. As the Naptowne ice continued to retreat up the Chakachatna Canyon more and more individual glaciers became distinct from one another. For example, Brogan Glacier (informal name, Figure 5-1), separated from the Chakachatna River by a low volcanic ridge, produced a recessional sequence that is independent of that formed by ice in the Chakachatna canyon. Such a sequence of features is less distinct or absent for the other glaciers between Brogan Glacier and Barrier Glacier.

Within the Chakachamna Lake basin, the evidence of Naptowne and older glaciations is largely in the form of erosional features and scattered boulders. Naptowne-age till apparently occurs only in isolated pockets within the lake basin and its major tributary valleys. The Naptowne-age surfaces in the basin are mantled with a sequence of volcanic ashes that averages two to three feet in thickness. The solids are typically developed on these volcanics rather than on the underlying glacially-scoured granitic bedrock or till.

In contrast to the erosional topography that characterizes the Naptowne and older surfaces within the Chakachamna Lake basin, Neoglacial activity produced prominent moraines and outwash fans. Neoglacial features were examined at or near the termini of the following glaciers;

(1) all glaciers along the south shore of the lake from Shamrock Glacier to the lake outlet;

(2) Barrier Glacier;

(3) Pothole and Harpoon Glaciers, where they enter the Nagishlamina River Valley;

(4) all of the glaciers that flow to the south, southeast, and east from the Mt. Spurr highland (Alice Glacier to Triumviarte Glacier, Figure 5-1); and

(5) Blockade Glacier.

The Neoglacial history of several of these glaciers is discussed in more detail in Sections 5.2.1.3 through 5.2.1.5. The Neoglacial record is of particular importance to an assessment of possible glacier fluctuations over the next several decades.

Returning to the two points raised at the end of Section 5.2.1.1:

(1) In most cases observed in the study area, it appears that the latest Neoglacial advance was an extensive or more extensive than earlier Neoglacial advances. This is in agreement with the Porter and Denton (1967) general conclusion for southern Alaska.

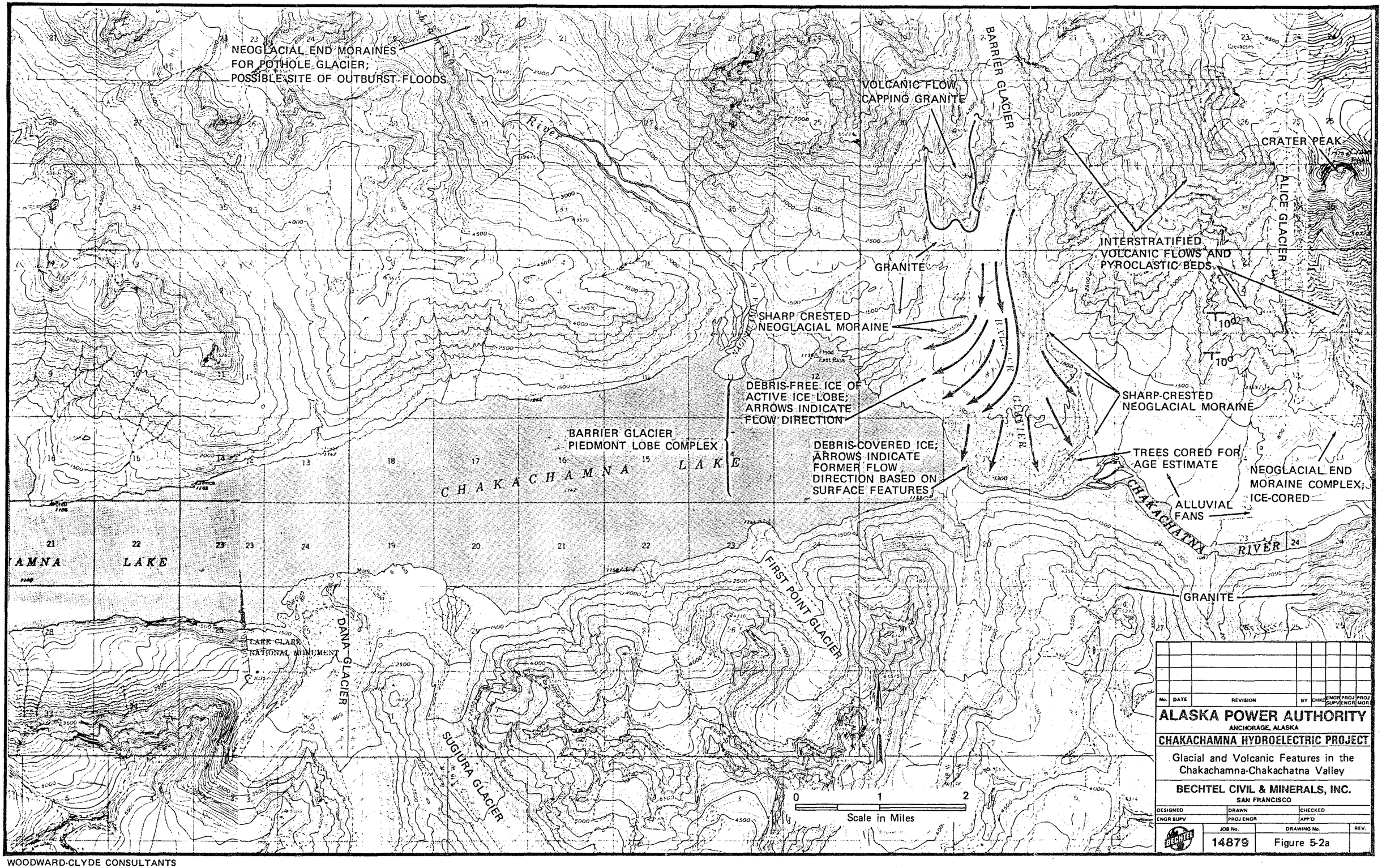
(2) Karlstrom's (1964) chronology suggested a continuous sequence of decreasing glacial advances leading from Naptowne to Neoglacial time. In most parts of the study area it was not possible to assess this suggestion. However, the morainal sequence produced by Brogan Glacier (Figure 5-1) and the difference in the topographic characteristics of those moraines suggest that there was little, if any, hiatus between the youngest Naptowne moraine and the oldest Neoglacial moraine.

5.2.1.3 Barrier Glacier

Barrier Glacier originates in the snow and ice field high on the slopes of Mt. Spurr. From there it flows down a steep, ice-carved canyon to the shore of Chakachamna Lake where its piedmont lobe forms the eastern end of the lake (Figures 5-2a, 5-2b). Barrier Glacier is of particular interest to this study because the glacier forms the eastern end of the lake and influences the size and character of the outlet from the lake.

Barrier Glacier was described by Capps (1935) in his report on the southern Alaska Range and was considered in several reports on the hydroelectric potential of Chakachamna Lake (Johnson, 1950; Jackson, 1961; Bureau of Reclamation, 1962). Giles (1967) conducted a detailed investigation of the terminal zone of Barrier Glacier. Most recently, the U.S.G.S. investigated Barrier Glacier as a part of a volcanic hazards assessment program at Mt. Spurr (Miller, personal communication, 1981).

Giles' (1967) investigation of Barrier Glacier was the most comprehensive to date and was specifically designed to assess the possible impact of the glacier on hydroelectric development of Chakachamna Lake, and vice versa. That work, which took place between 1961 and 1966, included mapping of the lake outlet area and measurements of horizontal and vertical movement and of ablation on various portions of the glacier. Those measurements indicated that:



No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

Glacial and Volcanic Features in the Chakachamna-Chakachatna Valley

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
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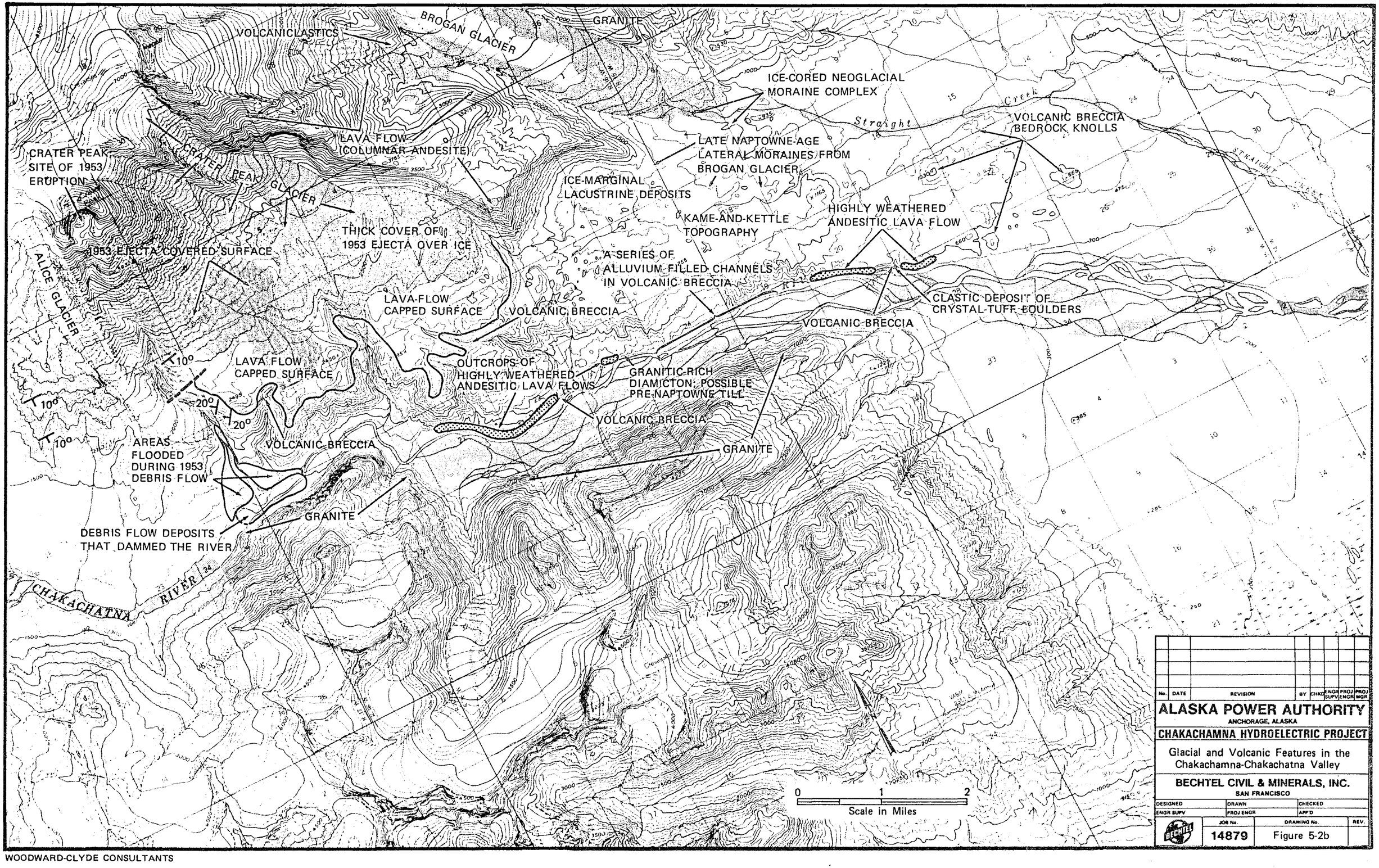


No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

Glacial and Volcanic Features in the Chakachamna-Chakachatna Valley

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	Figure 5-2b	

(1) horizontal movement is in the range of 316 to 125 ft/yr on the debris-free ice and 28 to 1 ft/yr on the debris-covered lobe of ice that forms the southernmost component of the glacier's piedmont lobe complex; and

(2) surface elevation changes were generally small (+0.8 to -2.9 ft/yr), but ablation on the relatively debris-free ice averaged about 35 ft/yr in the terminal zone.

Giles (1967) identified five ice lobes, two on the debris-covered ice and three on the exposed ice, in the terminal zone of Barrier Glacier. Examination of color infrared aerial photographs for the current study suggests that he defined topographic, but not necessarily glaciologically-functional lobes or ice streams. For example, on the debris-covered portion of the piedmont zone, Giles identified two lobes on the basis of a deep drainage that cuts across that zone. On the air photos it is clear that the drainage in question parallels and then trends oblique to the curvilinear flow features preserved in the debris mantle. The drainage does not appear to mark the boundary between two ice streams.

Giles (1967) concluded that the level of Chakachamna Lake is controlled by Barrier Glacier, specifically by one 900-ft wide portion of debris-covered ice along the river; that zone reportedly advances southward, into the river channel, at a rate of about 25 ft/yr. Although the rate of ice movement was apparently relatively constant throughout the year, the low stream discharge in the winter allows the glacier to encroach on the channel but the ice is eroded back during the summer. Thus, Giles

suggested that there is metastable equilibrium in the annual cycle. The annual cycle appears to be superimposed on a longer-term change such as that suggested by Giles' measurements.

Observations made during analysis of the color infrared (CIR) aerial photographs and during the 1981 field reconnaissance lead to general agreement with the conclusions produced by previous investigations. Nonetheless, the CIR air photos and extensive aerial and ground-based observations have allowed for the development of several apparently new concepts regarding Barrier Glacier; those new ideas may be summarized as follows:

(1) All of the moraines associated with Barrier Glacier are the products of late Neoglacial advances of the glacier and subsequent retreat. The large, sharp-crested moraines that bound the glacier complex on the eastern and a portion of the western margin (Figure 5-2a) mark the location of the ice limit as recently as a few hundred years ago (maximum estimate) and perhaps as recently as the early to middle part of this century. Cottonwood trees, which are the largest and among the oldest of the trees on the distal side of the moraine are approximately 300 to 350 years old based on tree ring counts on cores collected during the 1981 field work (location of trees on Figure 5-2a). Those dates provide an upper limit age estimate. The vegetation-free character of the proximal side of the moraine and the extremely sharp crest suggest an even more youthful ice stand.

(2) When Barrier Glacier stood at the outermost moraine (no. 1 above), the terminal piedmont lobe was larger than that now present and probably included a portion that floated on the lake; the present river channel south of the glacier could not have existed in anything near its present form at that time. The extent of the piedmont lobe, as suggested here, is based on interpretation of the flow features preserved on the debris-mantled portion of the terminal lobe and the projected continuation of the outermost moraine (no. 1 above).

(3) The most recent advance of Barrier Glacier did not reach the outermost moraine. It appears that the flow of ice was deflected westward by pre-existing ice and ice-covered moraine at the point where the glacier begins to form a piedmont lobe. This pulse was responsible for the vegetation-free zone of till that mantles the ice adjacent to the debris-free ice and for the large moraines that stand above the delta at the northeast corner of the lake.

(4) The presently active portion of Barrier Glacier has the same basic flow pattern as that described in no. 3, above, but the terminus appears to be retreating. The flow of ice is deflected westward as it exits the canyon through which the glacier descends the slopes of Mt. Spurr. The flow pattern is clearly visible on and in the debris-free ice and is further demonstrated by the distribution of the distinct belt of volcanic debris present along the eastern margin of the glacier.

(5) All of the above may be combined to suggest that the large debris-mantled (ice-cored) lobe that forms the most distal portion of the glacier complex, and which borders the river, is now, at least in large part, decoupled from the active portion of the glacier. This interpretation in turn suggests that the movements measured by Giles (1967) are due to adjustments within the largely independent debris-mantled lobe and to secondary effects transmitted to and through this lobe by the active ice upslope.

(6) In spite of the fact that disintegration of the debris-mantled lobe is extremely active locally, the lobe appears to be generally stable because remnant flow features are still preserved on its surface. The debris cover shifts through time, thickening and thinning at any given location as topographic inversion takes place due to melting of the ice and slumping and water reworking of the sediment. It appears that the rate of melting varies as a function of the thickness of the debris cover, with a thick cover insulating the ice and a thin cover producing accelerated melting. Removal of the covering sediment along the edge of the river leads to slumping and exposure of ice to melt-producing conditions. Thus the distal portion of the debris-mantled lobe that borders the river is one site of accelerated melting. Other areas of accelerated melting are concentrated along drainages that have developed within the chaotic ice-disintegration topography.

(7) There is no ice now exposed along the lake shore or around the lake outlet, at the head of the Chakachatna River, as was the case as recently as a few decades ago (Giles, 1969). These areas are rather uniformly vegetated and the debris mantle over the ice appears to be relatively thick compared to areas where accelerated melting is taking place. These areas appear to be reasonable models of what to expect when melting of the ice and the associated sorting and readjustment of the overlying debris have produced a debris cover thick enough to insulate the ice.

(8) If the debris-mantled ice lobe is functionally decoupled from the active ice, as suggested above, the move of ice toward the river is likely to gradually slow in the near future. The Giles' (1967) data suggest that this slowing may be underway; the 1971 flood on the Chakachatna suggests that the ice movement is still occasionally rapid enough to constrict the river channel, however. Nonetheless, it appears likely that, barring a dramatic or catastrophic event, the degrading portion of the ice lobe along the river will slowly stabilize to a condition similar to that along the lake shore. This will probably lead to a channel configuration somewhat wider than at present but the channel floor elevation is unlikely to change significantly. This scenario assumes that the discharge will remain relatively similar to that today. If discharge increases, then a channel deepening, as suggested by Giles (1967), may occur. If discharge decreases, the available data suggest that the outlet channel is likely to become more

narrow and perhaps more shallow as the debris-covered ice continues to stabilize (see Section 7.0).

(9) Over the long term the possible changes along the uppermost reaches of the Chakachatna River, where the lake level is controlled, are potentially more varied and more difficult to predict. One reason for this is that the longer time frame (i.e., centuries vs. decades) provides an increased probability for both dramatic (e.g., marked warming or cooling of the climate) and catastrophic (e.g., large volcanic eruption) events. In this regard, it should be noted that Barrier Glacier and the lake outlet appear to be within the zone of greatest potential impact from eruptions of Mt. Spurr volcano (see Section 5.2.2).

Post and Mayo (1971) listed Chakachamna Lake as one of Alaska's glacier-dammed lakes that can produce outburst floods. They rated the flood hazard from the lake as "very low" unless the glacier advances strongly. The 1971 flood on the Chakachatna (Lamke, 1972) was attributed to lateral erosion of the glacier terminus at the lake outlet. This flood may have, in fact, been triggered by waters from an outburst flood at Pothole Glacier, a surging glacier (Post, 1969) in the Nagishlamina River Valley (Section 5.2.1.5).

5.2.1.4 Blockade Glacier

Blockade Glacier (Figure 5-1) originates in a very large snow and ice field (essentially a mountain ice cap), high

in the Chigmit Mountains south of Chakachamna Lake. This same ice cap area is also the source of several of the glaciers that flow to the south shore of Chakachamna Lake (e.g., Shamrock, Dana, and Sugiura Glaciers; Figure 5-1). Blockade Glacier flows southward out of the high mountains into a long linear valley, which trends NE&SW and which is apparently fault controlled (Section 5.3). Once in the linear valley, Blockade Glacier flows both to the northeast and to the southwest. The southwestern branch terminates in Blockade Lake, which is one of Alaska's glacier-dammed lakes that is a source of outburst floods (Post and Mayo, 1971). The northeastern branch of the glacier terminates near the mouth of the McArthur River Canyon and melt water from the glacier drains to the McArthur River.

Blockade Glacier is of specific interest to the Chakachamna feasibility study because one of its branches does terminate so near the mouth of the McArthur River Canyon, and a likely site for the powerhouse for the hydroelectric project is in the lower portions of the canyon (Section 3.0). Changing conditions at the northeastern terminus of Blockade Glacier could conceivably change the drainage of the McArthur River to a degree that may influence conditions in the canyon, i.e., at the proposed powerhouse sites in the canyon.

Blockade Glacier has not been the subject of previous detailed studies such as those for Barrier Glacier (Section 5.2.1.3). Observations made during the 1981 field reconnaissance covered the lower-elevation portions of the source area and both terminal zones, but were concentrated around the northeastern terminus, near the McArthur River.

At its northeastern terminus Blockade Glacier is over two miles wide. Over about half of that width (the northern half) the glacier terminates in a complex of melt water lakes and ponds that are dammed between the ice and Neoglacial moraines. The melt water from the lake system drains to the McArthur River via one large and one small river that join and then flow into the McArthur about 2.5 miles downstream from the mouth of the McArthur River Canyon. A complex of recently abandoned melt water channels formerly carried flow to the McArthur at the canyon mouth. A small advance of the ice front would reinstitute drainage in these now dry channels.

Melt water issuing from the southern half of the ice front flows to the McArthur River in braided streams that cross a broad outwash plain. Whereas the northern portion of the terminus is very linear, the southern portion includes a distinct lobe of ice that is more than a half mile wide and protrudes beyond the general ice front by more than three-quarters of a mile. Another notable characteristic of this zone is that the Neoglacial moraines, which are so prominent to the north, have been completely eroded away by melt water along the southern margin of the glacier.

On the basis of the above observations and the report that Blockade Lake produces outburst floods (Post and Mayo, 1971), it appears that the distinct features in the southern portion of the northeast terminal zone are present because this is the area where the outburst floods exit the glacier front. The broad outwash plain and the removal of the Neoglacial moraines are probably both due to the floods; the vegetation-free (i.e., active) outwash plain is much larger than the size of the

melt water streams would suggest. The distinct lobe of ice that protrudes beyond the general front of the glacier probably marks the location of the sub-ice channel through which the outburst floods escape.

The outermost Neoglacial moraines present near the northeastern terminus lie about three-quarters of a mile beyond the ice front. With the exception of the distinct ice lobe, the general form of the ice front is mirrored in the shape of the Neoglacial terminal moraines. The outermost end moraine, which stands in the range of 20 to 40 ft above the surrounding outwash plain (distal) and ground moraine (proximal), is in the form of a continuous low ridge with a gently rounded crest. Three or four less distinct and less continuous recessional moraines are present between the ice and the Neoglacial maximum moraines. Distinct glacial fluting is present in the till in this area.

The Neoglacial end moraine can be traced to a distinct, sharp-crested Neoglacial lateral moraine that is essentially continuously present along the glacier margins well up into the source area for Blockade Glacier. The proximal side of the lateral moraine is steep and vegetation-free, suggesting ice recession in the very recent past. The crest of the lateral moraine stands about 40 or 50 ft (estimate based on observations from the helicopter) above the ice along the lower portions of the glacier.

A readvance of Blockade Glacier's northeastern terminus on the order of one-quarter to one-half a mile would reestablish drainage through the abandoned channels near the mouth of the McArthur River Canyon. Such a change is

unlikely to significantly impact conditions within the canyon but would disrupt facilities (e.g., roads) on the south side of the McArthur River, immediately outside the mouth of the canyon. The glacier will have to advance about three-quarters of a mile before conditions in the canyon are likely to be seriously affected. An advance of a mile and a half would essentially dam the mouth of the canyon and would flood a major portion of the lower reaches of the canyon, including the sites under consideration for the powerhouse. Such a glacier-dammed lake would likely produce outburst floods.

There is no evidence that any of the Neoglacial advances of Blockade Glacier were extensive enough to dam the McArthur River Canyon. The outmost of the Neoglacial moraines lies at least one-quarter of a mile short of the point where ice-damming of the canyon would begin, however. Outwash fans on the distal side of the moraine may have produced minor ponding in the lowermost reaches observed in the field and on the color infrared air photos suggest that the last time that Blockade Glacier may have dammed the McArthur Canyon was in late Naptowne time, approximately 10,000 years or more ago.

The only reasonable mechanism that could produce an advance of Blockade Glacier that would be rapid enough to impact on the proposed hydroelectric project is a glacier surge; a surging glacier could easily advance a mile or more within a period of a few decades. Evidence for surges in the recent past might include an advancing glacier front in an area where glaciers are generally in recession and/or distorted medial moraines or longitudinal dirt bands on the glacier surface (Post, 1969; Post and Mayo, 1971). It is clear that Blockade

Glacier's recent history has been one of recession, as is the case for all other glaciers examined during the 1981 field reconnaissance. There are many distinct longitudinal dirt bands and small medial moraines visible on the surface of Blockade Glacier. If one or more of the individual ice streams that comprise Blockade Glacier had recently surged, such activity should be reflected in contortions in the dirt bands and medial moraines. Visible deformation of the surface features on the glacier is very subtle and not suggestive of recent surging of even individual ice streams in the glacier. Thus, there is no evidence of a general surge of Blockade Glacier in the recent past.

In summary, it appears that Blockade Glacier began to withdraw from its Neoglacial maximum within the last few hundred years. At that maximum stand, melt water drainage joined the McArthur River at the canyon mouth and outwash may have produced some ponding and sediment aggradation in the lower reaches of he canyon, but the glacier was not extensive enough to have dammed the canyon. Surging is the most reasonable mechanism that could produce a future advance large enough and rapid enough to impact on the proposed powerhouse sites in the McArthur Canyon. No evidence suggestive of surging of Blockade Glacier was identified during this study.

Currently, melt water is carried away from the canyon mouth. Even markedly accelerated melt water production from Blockade Glacier is unlikely to change this condition or to have a negative impact on the proposed hydroelectric project.

5.2.1.5 Other Glaciers

In order to get a reasonably broad-based sense of the glacial record and history of recent glacier behavior in the Cakachamna Lake region, the field reconnaissance included aerial and ground-based observations of a number of the glaciers in the region in addition to Barrier and Blockade Glaciers. Those glaciers included:

(1) Shamrock Glacier, Dana Glacier, Sugiura Glacier, and First Point Glacier along the south shore of Chakachamna Lake (see figure 5-1 for locations);

(2) Harpoon Glacier and Pothole Glacier in the Nagishlamina River Valley;

(3) Alice Glacier, Crater Peak Glacier, and Brogan Glacier on the slopes of Mt. Spurr, above the Chakachatna River;

(4) Capps Glacier and Triumvirate Glacier on the eastern slopes of Mt. Spurr; and

(5) McArthur Glacier in the McArthur River valley.

Post (1969) surveyed glaciers throughout western North America in an effort to identify surging glaciers. Four of his total of 204 surging glaciers for all of western North America are in the Chakachamna study area (Figure 5-1). Three, including Pothole Glacier and Harpoon Glacier, are located in the Nagishlamina River Valley, tributary to Chakachamna Lake, and one, Capps Glacier, is on the eastern slope of Mt. Spurr. Surface features

indicative of surging are clearly visible on the color infrared aerial photographs used in this study and were observed during field reconnaissance.

Specific observations pertinent to an understanding of the glacial history of the area include:

(1) All of the glaciers listed above appear to have only recently withdrawn from prominent Neoglacial moraines, which in most (if not all) cases mark the Neoglacial maximum advance positions of the glaciers. These moraines and younger recessional deposits are generally ice-cored for those glaciers in groups 1 through 3 (above), but have little or no ice core in groups 4 and 5, which terminate at slightly lower elevations.

(2) Ponding and sudden draining of the impoundment upstream of the Pothole Glacier (a surging glacier) end moraine complex in the Nagishlamina River valley may be an episodic phenomena that can produce flooding in the lower portions of that valley and thus a pronounced influx of water into Chakachamna Lake. Published topographic maps (compiled in 1962) show a small lake upstream of the end moraine, which with the exception of a narrow channel along the western valley wall, completely blocks the Nagishlamina River Valley. That lake is no longer present but there is clear evidence for its presence and the presence of an even larger lake in the recent past. Features on the floor of the lower Nagishlamina River Valley suggest recent passage of a large flood. Such a sudden influx of water into

Chakachamna Lake could produce significant changes at the outlet from the lake. It may be that the 1971 flood on the Chakachatna River (U.S.G.S., 1972) was triggered by such an event, the stage having been set by the slow increase in the level of Chakachamna Lake in the years prior to the flood (Giles, 1967).

(3) Only glaciers south and east, and in the immediate vicinity at Crater Peak on Mt. Spurr retain any evidence of a significant cover of volcanic ejecta from the 1953 eruption of Crater Peak. On both Crater Peak Glacier and Brogan Glacier (see Figure 5-1) the ice in the terminal zone is buried by a thick cover of coarse ejecta. The volcanic mantle, where present, appears to be generally thick enough to insulate the underlying ice. The ejecta cover on Alice Glacier is surprisingly limited. Areas where the volcanic cover formerly existed, but was thin enough so that its presence accelerated melting, have probably largely been swept clean by the melt-water. In any case, the only areas where there is now evidence that the dark volcanic mantle has or is producing more rapid melting is on the margins of the thickly covered zones on the two cited glaciers.

(4) Highly contorted medial moraines on Capps Glacier, Pothole Glacier, and Harpoon Glacier suggest that several of the individual ice streams that comprise those glaciers have surged in the recent past. No comparable features were observed on any of the other glaciers in the Chakachamna study area.

5.2.1.6 Implications with Respect to the Proposed Hydroelectric Project

Implications derived from the assessment of the glaciers in the Chakachamna Lake area, with respect to specific project development alternatives, are included in Section 7.2 while project risk evaluation is disucssed in Section 7.4. General implications, not directly tied to any specific design alternative, may be summarized as follows:

(1) In the absence of the proposed hydroelectric project, the terminus of Barrier Glacier is likely to continue to exist in a state of dynamic equilibrium with the Chakachatna River and to produce small-scale changes in lake level through time; the terminal fluctuations are likely to slow and decrease in size in the future, leading to a more stable condition at the lake outlet.

(2) If development of the hydroelectric project or natural phenomena dam the Chakachatna River Valley and flood the terminus of Barrier Glacier, the rate of disintegration is likely to increase. If the level of the lake is raised, the rate of calving on Shamrock Glacier is likely to increase.

(3) If hydroelectric development lowers the lake level, the debris-covered ice of Barrier Glacier is likely to encroach on and decrease the size of the river channel; a subsequent rise in lake level could yield conditions conducive to an outburst flood from the lake. A lowering of the level of Chakachamna Lake will also cause the stream channels that carry water from Kenibuna Lake and Shamrock Lake into

Chakachamna Lake to incise their channels, thereby lowering the levels of those upstream lakes over time.

(4) There is no evidence to suggest that Blockade Glacier will have an adverse impact on the proposed hydroelectric project or that the project will have any effect on Blockade Glacier.

(5) Glacier damming of the Nagishlamina River Valley may result in outburst floods that influence conditions at the outlet from Chakachamna Lake.

(6) With the exception of Shamrock Glacier, the terminus of which may be affected by the lake level, there is no evidence to suggest that the proposed project will influence the glaciers (other than Barrier Glacier) in the Chakachatna-Chakachamna Valley. Changes in the mass balance of the Glaciers will influence the hydrologic balance of the lake-river system, however.

5.2.2 Mt. Spurr Volcano

5.2.2.1 Alaska Peninsula-Aleutian Island Volcanic Arc

Mt. Spurr is an active volcano that rises to an elevation above 11,000 ft at the eastern end of Chakachamna Lake. Mt. Spurr is generally reported to be the northernmost of a chain of at least 80 volcanoes that extends for a distance of about 1,500 miles through the Aleutian Islands and along the Alaska Peninsula; recent work has identified another volcano about 20 miles north of Mt. Spurr (Miller, personal communication, 1981). Like Mt.

Spurr, about half of the known volcanoes in the Aleutian Islands-Alaska Peninsula group have been historically active.

The volcanoes of this group are aligned in a long arc that follows a zone of structural uplift (Hunt, 1967), and that lies immediately north of the subduction zone at the northern edge of the Pacific Plate. The volcanoes on the Alaska Peninsula developed on a basement complex of Tertiary and pre-Tertiary igneous, sedimentary, and metasedimentary rocks. The pre-volcanic rocks are poorly exposed in the Aleutian Islands. At the northern end of the chain, such as at Mt. Spurr, the volcanoes developed on top of a pre-existing topographic high. Mt. Spurr is the highest of the volcanoes in the group and the summit elevations generally decrease to the south and west.

The Alaska Peninsula-Aleutian Islands volcanic chain is, in many ways, similar to the group of volcanoes in the Cascade mountains of northern California, Oregon, Washington, and southern British Columbia. In general, both groups of volcanoes developed in already mountainous areas, both consist of volcanoes that developed during the Quaternary and include historically active volcanoes. In both areas the volcanic rocks encompass a range of compositions but are dominantly andesitic, and both groups contain a variety of volcanic forms. The Alaskan volcanoes include low, broad shield volcanoes, steep volcanic cones, calderas, and volcanic domes. Much of the present volcanic morphology developed in late- and post-glacial time.

5.2.2.2 Mt. Spurr

Capps (1935, p. 69-70) reported, "The mass of which the highest peak is called Mt. Spurr consists of a great outer crater, now breached by the valleys of several glaciers that flow radially from it, and a central core within the older crater, the highest peak of the mountain, from vents near the top of which steam sometimes still issues. One small subsidiary crater, now occupied by a small glacier, was recognized on the south rim of the old, outer crater."

Subsequent work has shown that Capps' observations were, in part, in error. The error is specifically related to the suggestion that the peaks and ridges that surround the summit of Mt. Spurr mark the rim of a large, old volcanic crater. Why Capps had this impression is clear because as one approaches the mountain from the east or southeast, the view strongly suggests a very large crater; such a view has suggested to many geologists that Capps was correct in his observations. It is only when one gets up on the mountain, an opportunity made practical by the helicopter, that it becomes clear that most of the "crater rim" consists of granitic and not volcanic rocks. The most recent and comprehensive report on the distribution of lithologies present on Mt. Spurr is found in Magoon and others (1976). The U.S. Geological Survey plans to issue an open file report on Mt. Spurr in 1982 (Miller, personal communication, 1981).

Field work aimed at assessing the potential impact of volcanic activity from Mt. Spurr on the proposed hydroelectric development at Chakachamna Lake was concentrated in the area bounded by the Nagishlamina River on the

west, the Chakachatna River on the south, a north-south line east of the mountain front on the east, and the Harpoon Glacier-Capps Glacier alignment on the north (Figure 5-1). Most of the observations at the higher elevations were from the helicopter; landing locations high on Mt. Spurr are few and far between and many of the steep slopes are inaccessible to other than airborne observations. It was possible to make numerous surface observations in the Nagishlamina River and Chakachatna River valleys and on the slopes below 3,000 ft elevation to the south and southeast of the summit of Mt. Spurr.

Observations made during the 1981 reconnaissance indicate that the Quaternary volcanics of Mt. Spurr, with the exception of airfall deposits, are largely confined to a broad wedge-shaped area bounded generally by Barrier Glacier, Brogan Glacier, and the Chakachatna River (Figures 5-1, 5-2a and 5-2b); the distribution of Quaternary volcanics north of the summit, in areas that do not drain to the Chakachamna-Chakachatna basin, was not investigated.

The bedrock along the western margin of Barrier Glacier is dominantly granite. The only exception observed during the field reconnaissance, which focused at elevations below about 5,000 ft, was an area where the granite is capped by lava flows (Figure 5-2a). East of Barrier Glacier the slopes above about 2,000 ft consist of interstratified lava flows and pyroclastics, which are exposed in cross section. The slopes of Mt. Spurr in this area are not the product of triginal volcanic deposition but are erosional features. Thus, it is clear that the volcanics once extended farther to the south and southwest into what is now the Chakachamna Lake basin and

Chakachatna River Valley. The lower slopes immediately east of Barrier Glacier and south of Mt. Spurr consist of a broad alluvial fan complex.

Between Alice Glacier and the mountain front, the upper slopes of Mt. Spurr, where not buried by glacier ice or Neoglacial deposits, expose interbedded lava flows (often with columnar jointing), pyroclastic units, and volcaniclastic sediments. As is the case near Barrier Glacier, most of the slopes in this area are steep, often near vertical erosional features that expose the volcanic sequence in cross-section. The primary exception to this is found on and adjacent to Crater Peak where some of the slopes are original depositional features.

Crater Peak was the site of the most recent eruption of Mt. Spurr. That eruption, which took place in July, 1953, was described by Juhle and Coulter (1955). The 1953 eruption produced an ash cloud that was observed as far east as Valdez, 100 miles from the volcano; the distribution of ejecta on Mt. Spurr demonstrates that virtually all of the airborne material traveled eastward with the prevailing winds. The thick debris cover on Crater Peak and Brogan Glaciers (Figure 5-2b) is largely the product of this eruption.

Any lava that issued from Crater Peak in 1953 was limited to the slopes of the steep-sided cone. The eruption did produce a debris flow, which began at the south side of the crater where volcanic debris mixed with water from the glacier that reportedly occupied the crater (Capps, 1935) and the outer slopes of the cone began to move downslope toward the Chakachatna River. The debris flow, which was probably more a flood than a debris flow

initially, eroded a deep canyon along the eastern margin of Alice Glacier, through the Neoglacial moraine complex at the terminus of Alice Glacier, and through older volcanics and alluvium adjacent to the Chakachatna River. When it reached the Chakachatna River, the debris flow dammed the river and produced a small lake that extended upstream to the vicinity of Barrier Glacier. The dam was subsequently partially breached, lowering the impoundment in the Chakachatna Valley to its present level. Evidence for the high water level includes tributary fan-deltas graded to a level above the current water level and a "bath tub ring" of sediment and little or no vegetation along the southern valley wall.

East of the 1953 debris flow, the Chakachatna River flows through a narrow canyon within the broader valley bounded by the upper slopes of Mt. Spurr on the north and the granitic Chigmit Mountains on the south. The southern wall of the canyon (and valley, as whole) consists of glacially-scoured granitic bedrock. With the exception of remnant deposits of the 1953 debris flow that are present against the granitic bedrock (Figure 5-2b), the 1981 reconnaissance yielded no evidence of volcanic or volcaniclastic rocks on the southern wall of the Chakachatna Valley. The northern wall of the Chakachatna Canyon exposes a complex of highly weathered (altered ?) andesitic lava flows, pyroclastics, volcaniclastic sediments, outwash, and in one location, what appears to be an old (pre-Naptowne) till.

Although the general late-Quaternary history of the Chakachatna River Valley is reasonably clear, the details of that history are very complex and would require an

extensive field program to unravel. The observations made during the 1981 reconnaissance suggest the following:

(1) Late-Tertiary and/or early-Quaternary volcanic activity at Mt. Spurr built a thick pile of lava flows, pyroclastics, and volcaniclastic sediments on top of a granitic mountain mass of some considerable relief.

(2) Interspersed volcanic and glacial activity occurred during the Pleistocene, with alternating periods of erosion and deposition. The width of the valley at Chakachamna Lake is maintained downstream to the area of Alice Glacier (Figure 5-2a). From that point to the mountain front, where the same broad valley form seems to reappear, the overall valley is plugged by a complex of volcanic (and glacial) deposits. This, along with the volcanic cliffs high on the slopes of Mt. Spurr, suggests that volcanics once largely filled what is now the Chakachatna Valley, that glaciers then eroded a broad, U-shaped valley (such as is still present in the lake basin), and that subsequent volcanic activity produced the bulk of the deposits that form the valley "plug".

(3) The age of the volcanics in the "plug" is not clear. Some of the characteristics of the basal volcanic rocks exposed along the river suggest some antiquity. For example, many lava flows are so deeply weathered (or altered ?) that the rocks disintegrate in one's hand. These volcanics appear to be overlain by outwash and may be interbedded with till, which is also deeply weathered

(altered?). These and other features suggest that at least some of the volcanics in this area were deposited in pre-Naptowne time. Glacial deposits, including moraines, a large area of kame and kettle deposits,and glacier-marginal lake deposits interpreted to be a late-Naptowne age overlie portions of the volcanic valley plug. [See Section 7.2 for discussion of implications with respect to a dam in the Chakachatna Canyon.]

In contrast, it is difficult to understand how the apparently easily eroded volcanics in this area survived the Naptowne-age glaciers that filled the Chakachatna Valley and were large enough to extend across Cook Inlet (Karlstrom, 1964). In addition, there are many landforms, such as volcanic pinnacles, that clearly are post glacial as they could not have survived being overriden by glacier ice. Such landforms demand the removal of several tens of feet of volcanics over large areas.

Although the evidence is conflicting and an unambiguous interpretation difficult, it does appear that much of the volcanic valley plug is of pre-Naptowne age. The basis for this conclusion is most clearly documented by the presence of outwash on top of volcanics, a sequence exposed at several sites in the canyon. The outwash is capped by a three-to-four foot thick cap of volcanic ash (many discrete depositional units) as is typical of Naptowne-age surfaces in the area. Just how these volcanics survived the Naptowne glaciation is not clear.

(4) Following the withdrawal of the Naptowne ice from the Chakachatna River Valley, Holocene volcanic activity, glacial activity, and fluvial and slope processes have produced the present landscape. Most, if not all of the present inner canyon, through which the Chakachatna River flows, appears to be the product of Holocene downcutting by the river.

Given that many of the details of the Quaternary history of Mt. Spurr are not well understood, it is nonetheless clear that Mt. Spurr is an active volcano that may produce lava flows, pyroclastics, and volcaniclastic sediments in the immediate vicinity within the life of the project. Airfall deposits can be expected to influence a larger area. Considering the size and type of volcanic events for which there is evidence at Mt. Spurr and the present topography, the area of interest to the proposed hydroelectric project most likely to be affected is the area between Barrier Glacier and the 1953 debris flow. The topography of the valley plug volcanics appears to afford some, but certainly not total protection to the canyon portion of the river valley; an example of this "protection" is provided by a second debris flow produced in 1953 that was prevented from reaching the river by intervening topography on the valley "plug".

The types of volcanic event judged to be most likely to impact the Chakachatna River Valley in the near future are:

(1) 1953-type debris flows which could inundate a portion of the valley and re-dam the river,

(2) lava flows, which could enter and dam the valley, and

(3) large floods that would be produced by the melting of glacier ice during an eruption.

Post and Mayo (1971) suggested that melting of glacier ice on Mt. Spurr during volcanic activity may present a serious hazard. Significant direct impact on Barrier Glacier would demand a summit eruption that included the flow of hot volcanics at least into the upper reaches of the glacier or the development of a new eruptive center (such as Crater Peak) west of the present summit. Of course the character of the volcanoes in the Aleutian Island-Alaska Peninsula chain make it clear that a very large event (i.e., a Mt. St. Helens--or even a Crater Lake-type event) is possible at Mt. Spurr; such an event has a very low annual probabilty of occurrence at any given site, however.

5.2.2.3 Implications with Respect to the Proposed Hydroelectric Project

The potential impact of Mt. Spurr on the proposed hydroelectric project will, in part, vary as a function of the project design (see Sections 7.2 and 7.4), but some potential will always exist because of the location of Mt. Spurr relative to Chakachamna Lake and the Chakachatna River. The amount of negative impact on the project is clearly a function of the size of volcanic event considered; larger events, which would have the greatest potential for adverse impact, are, in general,

less likely to occur than smaller volcanic events. Some general possibilities that might be associated with low- to medium-intensity events (such as a Crater Peak event or slightly larger) include:

(1) Damming of the Chakachatna River by lava or debris flows, with the most likely site being in the vicinity of the 1953 debris dam. Flooding of the terminus of Barrier Glacier may increase the rate of ice melt and possibly alter the configuration of the current lake outlet. Any project facilities on the valley floor of the upper valley would be buried by the flow and/or flooded.

(2) Flooding of the Chakachatna River Valley as a result of the melting of glacier ice on Mt. Spurr during an eruption. Project facilities near or on the valley floor would be flooded.

(3) Accelerating the retreat of Barrier Glacier due to the flow of hot volcanic debris onto the glacier. In the extreme, Barrier Glacier could be eliminated if enough hot material flowed onto the ice. A less dramatic scenario could include destabilization of the lake outlet due to accelerated melting in the terminal zone of Barrier Glacier. In contrast, a large lava flow at the present site of Barrier Glacier could replace the glacier as the eastern margin of the lake, providing a more stable dam than that provided by Barrier Glacier.

Each of the design alternatives (Section 3.0) includes a lake tap in the zone between the lake outlet and First Point Glacier. Although it is generally true that a site

farther from Mt. Spurr is less likely to be subject to volcanic hazards than a site closer to the volcano, there is no apparent reason to favor one particular site in the proposed zone over any other site in that zone. A large eruptive event, apparently substantially larger than any of the Holocene events on Mt. Spurr, would be required before the proposed lake tap site would be directly threatened by an eruption of Mt. Spurr.

5.2.3 Slope Conditions

The Chigmit Mountains, south of Chakachamna Lake and the Chakachatna River, and the Tordrillo Mountains, to the north, contain many steep slopes and near-vertical cliffs. This landscape is largely the product of multiple glaciation during the Quaternary, including Neoglaciation which continues in the area today. The proposed hydroelectric project is likely to include facilities in the Chakachamna Lake basin and either or both of the McArthur and Chakachatna River valleys. Any above-ground facilities in these areas will be on or immediately adjacent to steep slopes, and thus subject to any slope processes that may be active in the area. Because of this fact, the 1981 field reconnaissance included observations of slope conditions in the areas of interest. Future field work should include detailed assessment of bedrock characteristics, such as joint orientations, that influence slope conditions.

5.2.3.1 Chakachamna Lake Area

Chakachamna Lake sits in a glacially overdeepened basin that is generally bordered by steep slopes of granitic bedrock that was scoured during Naptowne and earlier

glaciations. Locally, such as along the southern valley wall west of Dana Glacier (Figure 5-2a), distinct bedrock benches are present. In other areas, the slopes rise, with only minor variation in slope, from the lake level to the surrounding peaks. All principal valleys along the southern side of the lake presently contain glaciers. The principal valleys tributary to the north side of the lake, the Chilligan and Nagishlamina, are larger than those on the south side of the lake and are currently essentially ice-free, although their present form is clearly the product of glacial erosion.

No evidence of large-scale slope failures of the slopes in the Chakachamna Lake basin was observed during the 1981 field reconnaissance. Most of the slopes are glacially-scoured bedrock and are essentially free of loose rock debris, although talus is locally present. The orientation of joint sets in the granitic bedrock varies somewhat from area to area. In many areas a near horizontal out-of-slope joint set is present, but it tends to be poorly expressed relative to more steeply-dipping joints. Field work indicates that this and cross-cutting joints have formed boulder-size pieces and small slabs that produce rockfall as the only common type of slope failure for which any evidence was found. This condition is apparently most pronounced along the southern valley wall, between Sugiura Glacier and the lake outlet.

5.2.3.2 Chakachatna River Valley

The Chakachatna River, from its origin at Chakachamna Lake to the mountain front, flows through a valley that is rather variable in its form and characteristics along

its length and from side to side. Throughout the valley, the south side consists of steep glaciated granitic bedrock slopes that rise essentially continuously from the river to the adjacent mountain peaks. All major tributary valleys on the southern valley wall, many of which are hanging valleys, now contain glaciers. The comments regarding slope conditions on the slopes above the lake (Section 5.2.3.1) apply to the southern wall of the Chakachatna River Valley.

The north side of the valley differs from the south side in virtually every conceivable way. On this side bedrock is volcanic, and glacial and fluvial sediments are also present. In the westernmost portion of the valley, the river is bordered by the Barrier Glacier moraine and alluvial fans; steep volcanic slopes above the alluvial fans are subject to rockfall activity. Between Alice Glacier (the area of the 1953 debris flow) and the valley mouth, the river flows through a narrow canyon, the north side of which consists of a variety of interbedded volcanics, glacial deposits, and fluvial sediments (Figure 5-2b). The north canyon wall has been the site of several landslides that range in size from small slumps to large rotational slides. Such activity is likely to continue in the future. Its impact will most frequently be limited to the diversion of the main river course away from the north canyon wall; there are several examples of this now present in the canyon. A large landslide, which appears to be unlikely given the height of the slopes, could completely dam the canyon; partial damming with temporary ponding appears to be a more likely possibility.

Volcanic activity on Mt. Spurr could directly influence conditions along the Chakachatna River (Section 5.2.2), or could, by slowly altering conditions along the north wall of the canyon, have a secondary impact on the valley.

5.2.3.3 McArthur River Canyon

The McArthur River Canyon is a narrow, steep-walled glaciated valley. A possible powerhouse site has been identified along the north wall of the canyon (Section 3.0) and the following comments specifically refer to the north wall of the McArthur River Canyon. The valley walls, which consist of granitic bedrock, expose a complex of cross-cutting joint sets and shear zones. The character and dominant orientations of the joints and shears vary along the length of the canyon and the character of the slopes also varies, apparently in direct response.

Except near the canyon mouth, there is no evidence of large-scale slope failure and rockfall is the dominant slope process. Between the terminus of McArthur Glacier and Misty Valley (Figure 5-1) the joint sets are of a character and orientation such that rockfall has been active and the bedrock on the lower slopes on the north valley wall are uniformly buried beneath a thick talus. The vegetation on the talus suggests that the bulk of talus development took place some time soon after de-glaciation and rockfall has been less active recently. The slopes between Misty and Gash Valleys (Figure 5-1) consist of glacially-scoured bedrock that is essentially talus free, suggesting little or no rockfall in this area.

From Gash Valley to the canyon mouth, the granitic bedrock appears to become progressively more intensely jointed and sheared and thus more subject to rockfall and small-scale slumping. Talus mantles the lower slopes in much of this area. A large fault zone (Section 5.3) is present at the canyon mouth. The fault has produced intense shearing over a broad zone that is now subject to intense erosion and is the site of several landslides.

5.2.3.4 Implications with Respect to the Proposed Hydroelectric Project

As in the case for volcanic hazards, there is no apparent reason with respect to slope conditions to favor one site over any other in the zone between the lake outlet and First Point Glacier for the lake tap. Rockfall appears to be the only potential slope hazard in that zone; there was no evidence observed in the field to suggest other types of slope failure.

As indicated on Figure 5-9, the Castle Mountain fault (Section 5.3), which is a major fault, crosses the McArthur River just outside the canyon mouth (Section 7.4) where the granitic bedrock has been badly shattered by fault movement. Surface examination reveals that the rock quality progressively improves with distance upstream from the canyon mouth and the best quality rock lies between Gash Valley and Misty Valley (Figure 5-1), beginning about 1-1/2 miles upstream from the powerhouse location presently shown on the drawings. This location is based on economic considerations alone, without taking account of the higher excavations costs that would be associated with the poorer quality rock. A critical evaluation of the rock conditions in this area should be

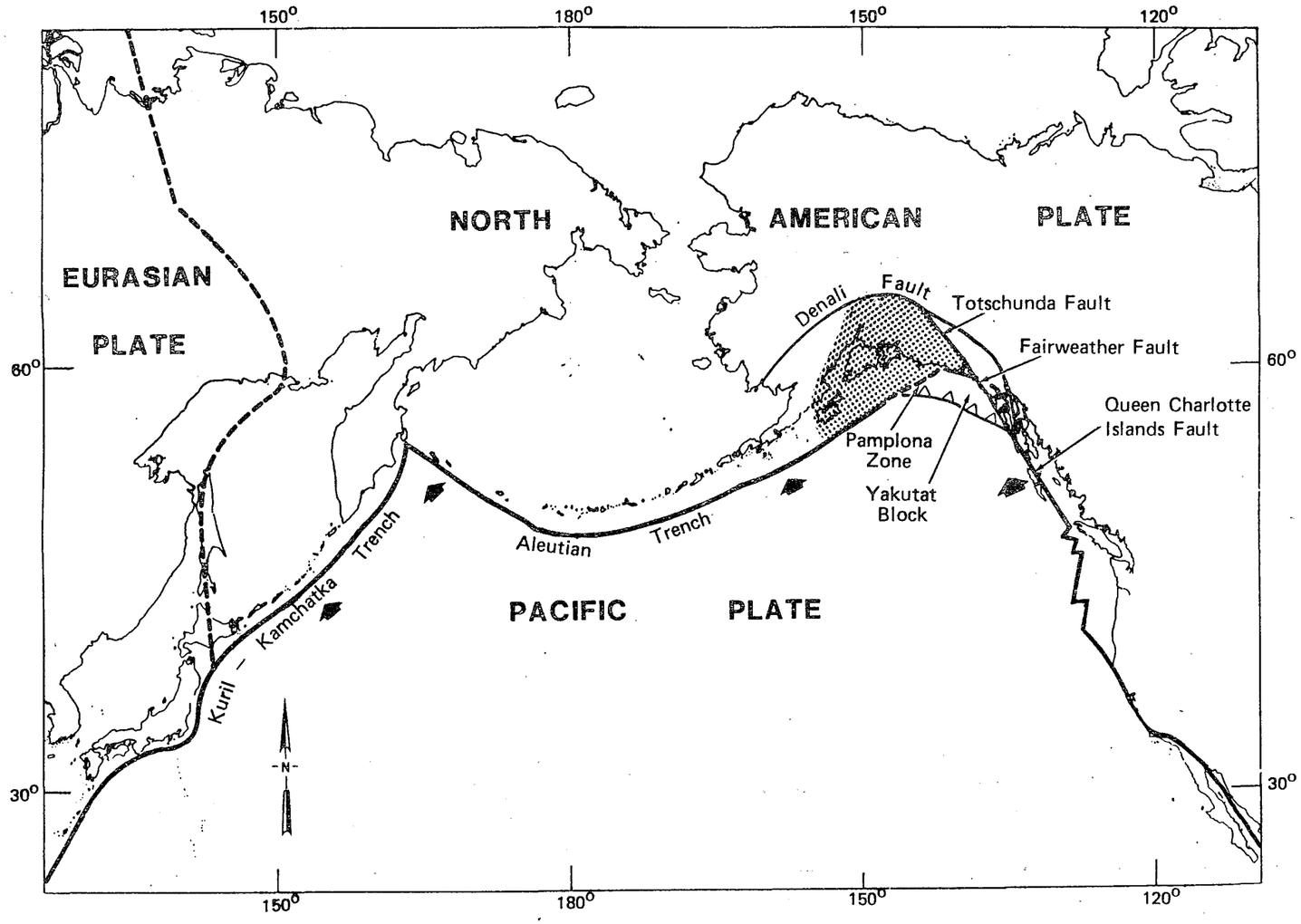
included in future studies and a site should be selected for drilling a deep core hole.

A powerhouse site at or immediately outside the canyon mouth, as has been considered in other studies, is likely to be in the fault zone and subject to fault rupture as well as high ground motions. In addition, facilities outside the canyon will be in Tertiary sedimentary rocks and glacial deposits, not granite.

5.3 Seismic Geology

5.3.1 Tectonic Setting

The active faulting, seismicity, and volcanism of southern Alaska are products of the regional tectonic setting. The primary cause of the faulting and seismic activity is the stress imposed on the region by the relative motion of the Pacific lithospheric plate relative to the North American plate along their common boundary (Figure 5-3). The Pacific plate is moving northward relative to the North American plate at a rate of about 2.4 inches/year (Woodward-Clyde Consultants, 1981 and references therein). The relative motion between the plates is expressed as three styles of deformation. Along the Alaska Panhandle and eastern margins of the Gulf of Alaska, the movement between plates is expressed primarily by high-angle strike-slip faults. Along the northern margins of the Gulf of Alaska, including the Cook Inlet area, and the central and western portions of the Aleutian Islands, the relative motion between the plates is expressed by the underthrusting of the Pacific plate beneath the North American plate. At the eastern end of the Aleutian



LEGEND

- Wrangell Block
- Relative Pacific Plate Motion
- Plate Boundary, dashed where inferred
- Shelf Edge Structure with Oblique Slip
- Intraplate Transform or Strike-Slip Fault

NOTES

1. Base map from Tarr (1974).
2. After Packer and others (1975), Beikman (1978), Cormier (1975), Reed and Lamphere (1974), Plafker, and others (1978).

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CHAKACHAMNA HYDROELECTRIC PROJECT

Plate Tectonic Map

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14879	Figure 5-3	

Islands, the relative plate motion is expressed by a complex transition zone of oblique thrust faulting.

The Chakachamna Lake area is located in the region where the interplate motion is producing underthrusting of the Pacific plate beneath the North American 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 underthrusting occurs is a northwestward-dipping megathrust fault or subduction zone. The Aleutian Trench, which marks the surface expression of this subduction zone, is located on the ocean floor approximately 270 miles south of the Chakachamna Lake area. The orientiation of the subduction zone, which may be subdivided into the megathrust and Benioff zone (Woodward-Clyde Consultants, 1981), is inferred at depth to be along a broad inclined band of seismicity that dips northwest from the Aleutian Trench.

The close relationship between the subduction zone and the structures within the overlying crust introduces important implications regarding the effect of the tectonic setting on the Chakachamna Lake Project. The subduction zone represents a source of major earthquakes near the site. Faults in the overlying crust, which may be subsidiary to the subduction zone at depth, are sources of local earthquakes and they may present a potential hazard for surface fault rupture. This is of special concern because the Castle Mountain, Bruin Bay, and several other smaller faults have been mapped near to the Chakachamna Lake Hydroelectric Project area

(Detterman and others, 1976; Magoon and others, 1978). Future activity on these faults may have a more profound affect on the seismic design of the project structures than the underlying subduction zone because of their closer proximity to proposed project site locations.

5.3.2 Historic Seismicity

5.3.2.1 Regional Seismicity

Southern Alaska is one of the most seismicially active regions in the world. A number of great earthquakes (Richter surface wave magnitude Ms 8 or greater) and large earthquakes (greater than MS 7) have been recorded during historic time. These earthquakes have primarily occurred along the interplate boundary between the Pacific and North American plates, from the Alaskan panhandle to Prince William Sound and along the Kenai and Alaska Peninsulas to the Aleutian Islands. Among the recorded earthquakes are three great earthquakes that occurred in September 1899 near Yakutat Bay, with estimated magnitudes Ms of 8.5, 8.4, and 8.1 (Thatcher and Plafker, 1977). Ground deformation was extensive and vertical offsets ranged up to 47 ft. (Tarr and Martin, 1912); these are among the largest known displacements attributable to earthquakes. Large parts of the plate boundary were ruptured by these three earthquakes and by twelve others that occurred between 1897 and 1907; these included a magnitude Ms 8.1 event on 1 October 1900 southwest of Kodiak Island (Tarr and Martin, 1912; McCann and others, 1980) and a nearby magnitude Ms 8.3 earthquake on 2 June 1903, near 57° north latitude, 156° west longitude (Richter, 1958).

A similar series of major earthquakes occurred along the plate boundary between 1938 and 1964. Among these earthquakes were the 1958 Lituya Bay earthquake (Ms 7.7) and the 1972 Sitka earthquake (Ms 7.6), both of which occurred along the Fairweather fault system in southeast Alaska; and the 1964 Prince William Sound earthquake (Ms 8.5), which ruptured the plate boundary over a wide area from Cordova to southwest of Kodiak Island and which produced up to 39 ft. of displacement (Hastie and Savage, 1970). Figure 5-4 shows the aftershock zones of these and other major earthquakes in southern Alaska and the Aleutian Islands. The main earthquakes and aftershocks are inferred to have ruptured the plate boundary in the encircled areas.

Three zones along the plate boundary which have not ruptured in the last 80 years have been identified as "seismic gaps" (Sykes, 1971). These zones are located near Cape Yakataga, in the vicinity of the Shumagin Island, and near the western tip of the Aleutian Chain as shown in Figure 5-4. The Yakataga seismic gap is of particular interest to the project because of its proximity to the site region. The rupture zone of a major earthquake filling this gap has the potential to extend along the subduction zone to the north and northwest of the coastal portion of the gap near Yakataga Bay.

5.3.2.2 Historic Seismicity of the Project Study Area

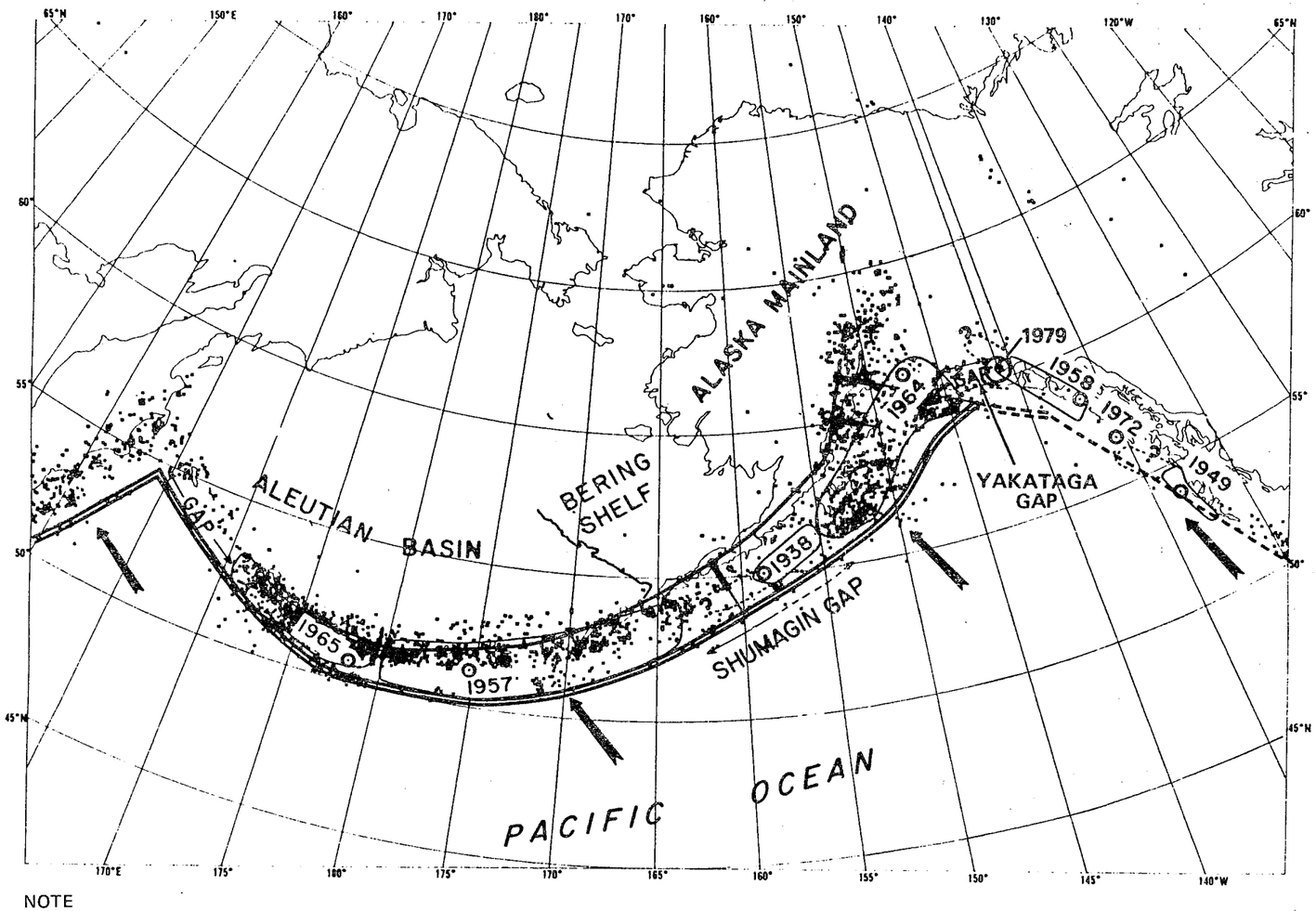
The historic seismicity within 90 miles of the project area, approximately centered on the east end of Chakachamna Lake, is shown in Figures 5-5, 5-6, and 5-7. The earthquake locations are based on the Hypocenter Data

File prepared by NOAA (National Oceanic and Atmospheric Administration, 1981). The Hypocenter Data File includes earthquake data from the U.S. Geological Survey and other sources and represents a fairly uniform data set in terms of quality and completeness since about 1964.

Based on Figures 5-5, 5-6, and 5-7 and data available in the open literature, the seismicity of the project area is primarily associated with four principal sources: the subduction zone, which is divided into two segments--the Megathrust and Benioff zone (Woodward-Clyde Consultants, 1981,; Lahr and Stephen, 1981); the crustal or shallow seismic zone within the North American Plate; and moderate to shallow depth seismicity associated with volcanic activity. The seismic sources are briefly discussed below in terms of their earthquake potential.

The Megathrust zone is a major source of seismic activity that results primarily from the interplate stress accumulation and release along a gently inclined boundary between the Pacific and North American plates. This zone is the source area of many of the large to great earthquakes, include the Ms 8.5 1964 Prince William Sound earthquake, which ruptured along the inclined plate boundary from the eastern Gulf of Alaska to the vicinity of Kodiak Island. The maximum magnitude for an earthquake event along the Megathrust zone is estimated to be Ms 8.5 (Woodward-Clyde Consultants, 1980, 1981).

The Benioff zone portion of the subduction zone is believed to be restricted to the upper part of the descending Pacific plate, which lies beneath the North American plate in southern Alaska. This zone is the source of smaller magnitude and more continuous



LEGEND

⊙ 1964 Location and year of major earthquake; rupture zones including aftershock areas are outlined

Inferred direction of motion of Pacific plate

Trench axis

Approximate transform plate margin

NOTE

1. Modified after Davies and House (1979)

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CHAKACHAMNA HYDROELECTRIC PROJECT

Major Earthquakes and
Seismic Gaps in Southern Alaska

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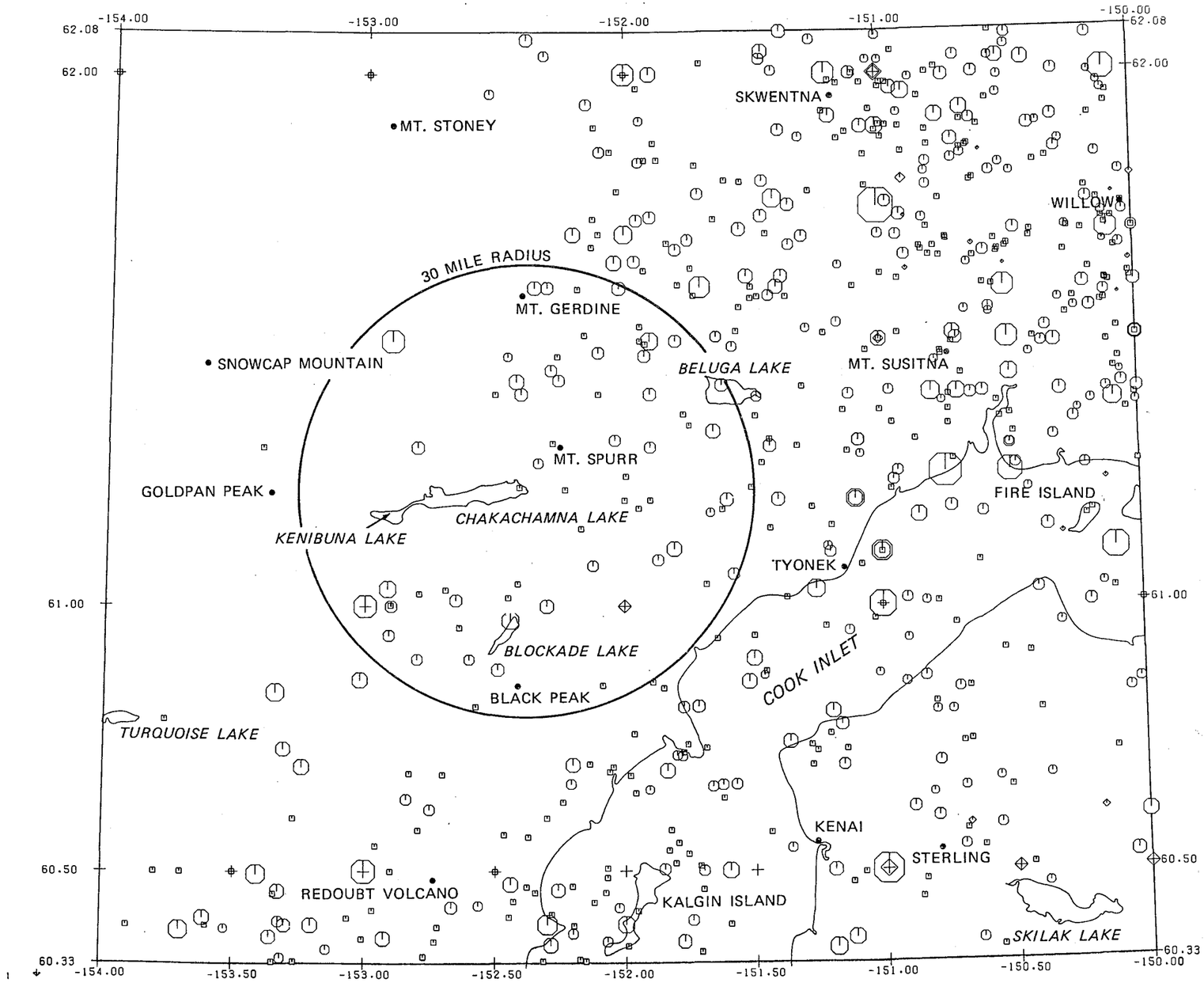

0 5 10 15 20 Miles

0 5 10 15 20 25 Kilometers

LEGEND

REPORTED MAGNITUDE

- 8.0
- 7.0
- 6.0
- 5.0
- 4.0
- 3.0
- 2.0
- 1.0
- No Reported Magnitude

INTENSITY

- XII
- XI
- X
- IX
- VIII
- VII
- VI
- V

NOTE

1. Magnitude symbol sizes are shown on a continuous nonlinear scale

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CHAKACHAMNA HYDROELECTRIC PROJECT

Historic Earthquakes of All Focal Depths in the Site Region from 1929 Through 1980

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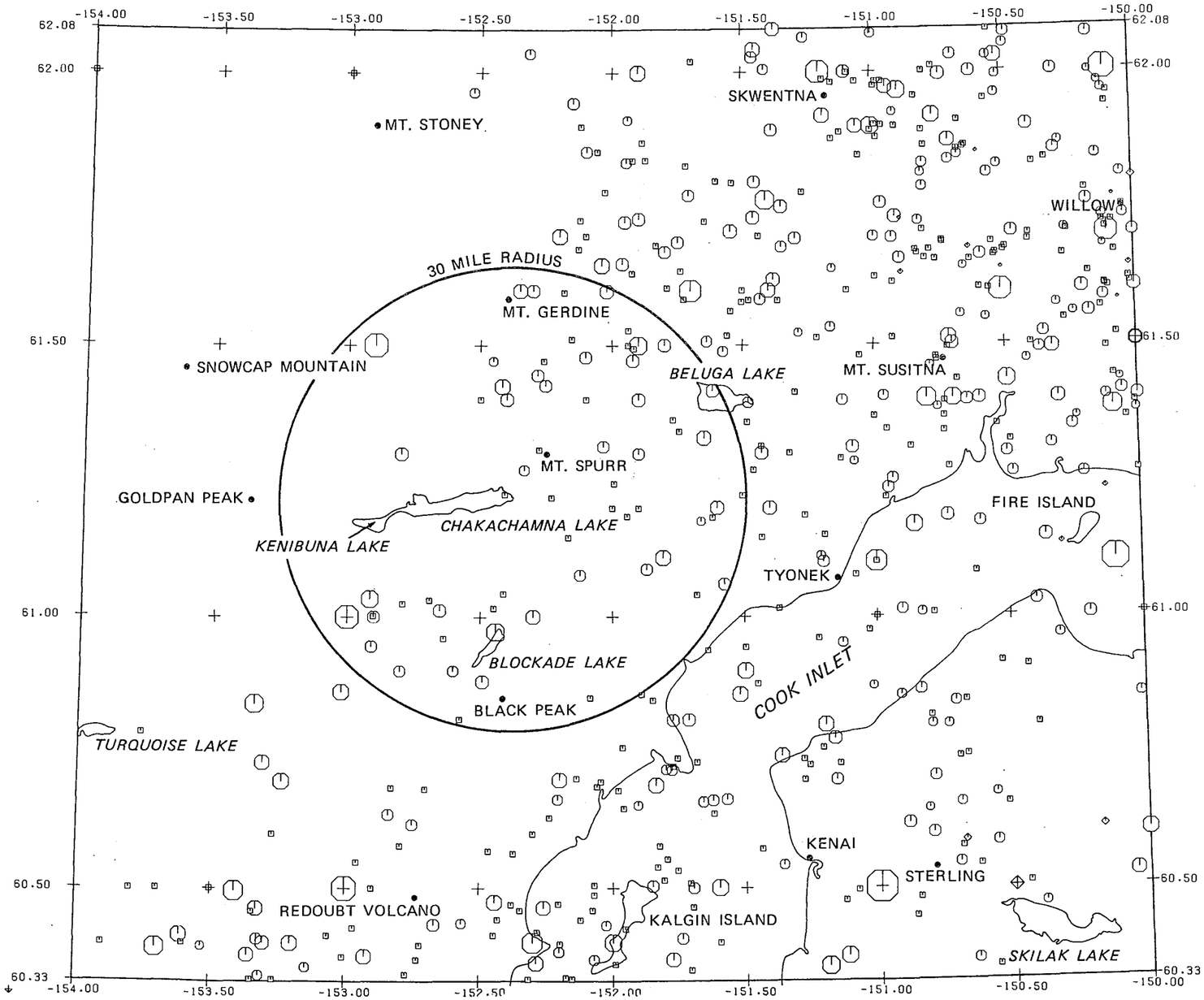

0 5 10 15 20 Miles

0 5 10 15 20 25 Kilometers

LEGEND

REPORTED MAGNITUDE

- 8.0
- 7.0
- 6.0
- 5.0
- 4.0
- 3.0
- 2.0
- 1.0
- No Reported Magnitude

INTENSITY

- XII
- XI
- X
- IX
- VIII
- VII
- VI
- V

NOTE

1. Magnitude symbol sizes are shown on a continuous nonlinear scale

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CHAKACHAMNA HYDROELECTRIC PROJECT

Historic Earthquakes of Focal Depth Greater Than 20 Miles in the Site Region from 1929 Through 1980

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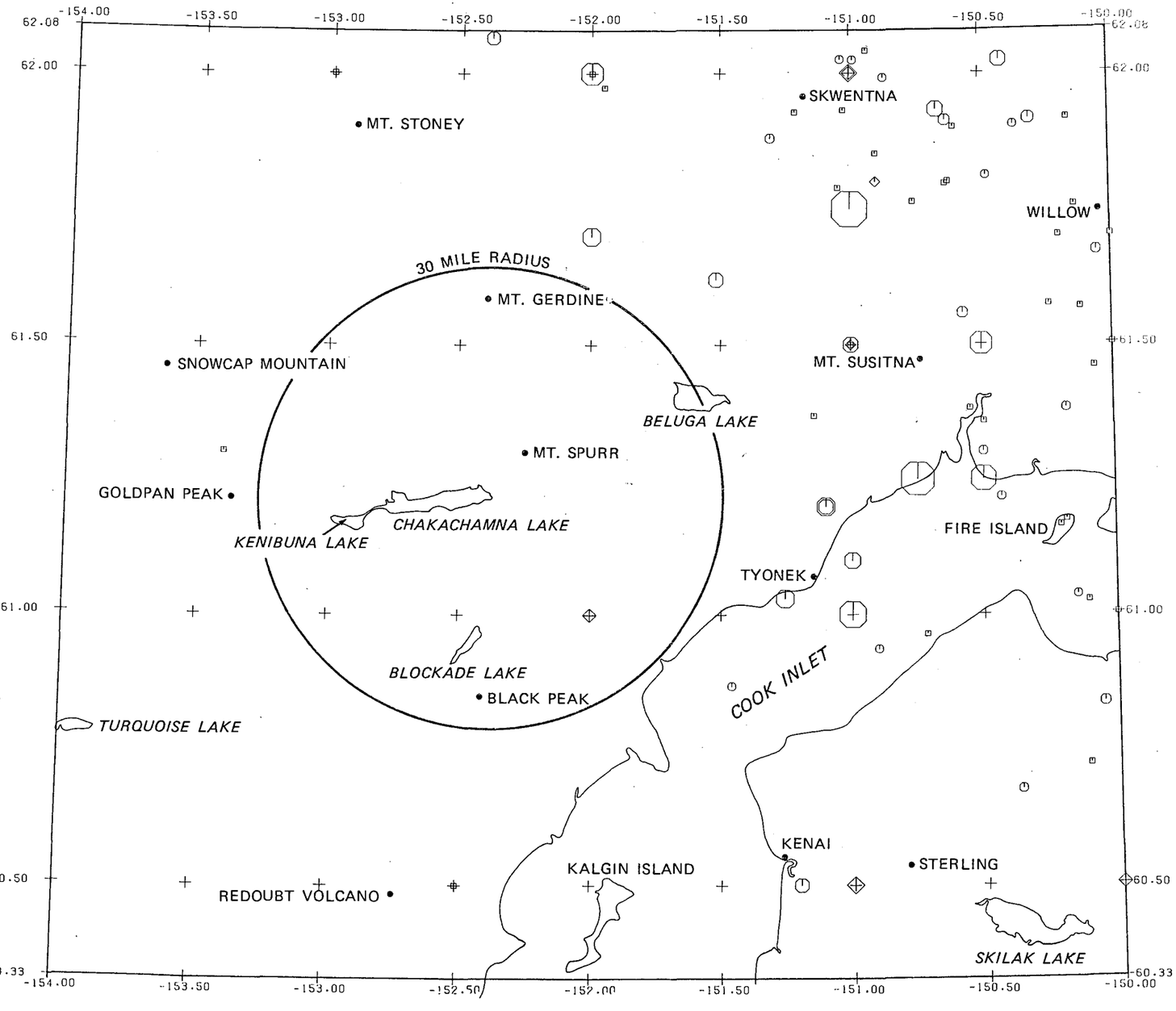

LEGEND

REPORTED MAGNITUDE

- 8.0
- 7.0
- 6.0
- 5.0
- 4.0
- 3.0
- 2.0
- 1.0
- No Reported Magnitude

INTENSITY

- XII
- XI
- X
- IX
- VIII
- VII
- VI
- V

NOTE

1. Magnitude symbol sizes are shown on a continuous nonlinear scale

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CHAKACHAMNA HYDROELECTRIC PROJECT

Historic Earthquakes of Focal Depth Less Than 20 Miles in the Site Region from 1929 Through 1980

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earthquake activity relative to the Megathrust zone. No earthquakes larger than about Ms 7.5 are known to occur along the Benioff zone and therefore, a maximum magnitude earthquake of Ms 7.5 is estimated for this zone (Woodward-Clyde Consultants, 1981).

The primary source of earthquakes in the crustal or shallow seismic zone is movement along faults or other structures due to the adjustment of stresses in the crust. As shown in Figure 5-7, the historic seismicity of the crustal zone within a large part of the project study area is low. The data base used to compile the historic seismicity of the crustal zone for this study has no recorded earthquakes in the vicinity of Chakachamna Lake.

The majority of the recorded earthquakes shown in Figure 5-7 are located along the eastern and southern margins of the project study area. Most of these events have not been correlated or associated with any known crustal structures, with the possible exception of one event that is associated with the Castle Mountain fault. As discussed in Section 5.3.3.3, the Castle Mountain fault is one of the two major faults present in the project study area. It passes within a mile or less of the proposed project facilities in the McArthur River drainage and within 11 miles of the proposed facilities at Chakachamna Lake. Evidence for displacment of Holocene deposits has been reported in the Susitna lowlands, in the vicinity of the Susitna River (Detterman and others, 1976a). Although a number of recorded earthquakes are located along the trend of the Castle Mountain fault (Figure 5-7), only one event, an Ms 7 earthquake in 1933, has been associated with the fault

(Woodward-Clyde Consultants, 1980b). A maximum magnitude earthquake of Ms 7.5 has been estimated for the Castle Mountain fault (Woodward-Clyde Consultants, 1981).

Further studies are needed to assess the possible association of other historic earthquakes shown in Figure 5-7 with candidate significant features identified in the fault investigation phase of the project study.

Because of the proximity of the project site to active volcanoes of the Aleutian Islands-Alaska Peninsula volcanic chain, including Mt. Spurr which is located immediately northeast of the Chakachamna Lake, volcanic-induced earthquakes are considered a potential seismic source. Active volcanism can produce small-to-moderate magnitude earthquakes at moderate-to-shallow depths due to the movement of magma or local adjustments of the earth's crust.

Occasionally, severe volcanic activity such as phreatic explosions or explosive caldera collapses may be accompanied by significant earthquake events. Because such large volcanic events are rare, there is little data from which to estimate earthquake magnitudes that may be associated with them. However, because of the similarities in characteristics of the Mount St. Helens volcano to those of the Aleutian chain (including Mt. Spurr), it is reasonable to assume that earthquakes associated with the recent Mount St. Helens eruption of May 1980 may also occur during future volcanic activity of Mt. Spurr and others in the Aleutian chain. The largest earthquake associated with the Mount St. Helens explosive eruption that occurred on 18 May 1980 had a magnitude of 5.0. Numerous smaller earthquakes with

magnitudes ranging from 3 to 4 were recorded during the period preceding the violent rupture of Mount St. Helens (U.S. Geological Survey, 1980).

As part of a volcanic hazard monitoring program, the U.S. Geological Survey has been operating several seismograph stations in the vicinity of Mt. Spurr to assess its activity. Data acquired by these stations are not presently available but will be released in 1982 as an Open-File Report (Lahr, J. C., personal communication, 1981).

5.3.3 Fault Investigation

5.3.3.1 Approach

The objectives of the Chakachamna Lake Hydroelectric Project seismic geology task are:

(1) to identify and evaluate significant faults within the project study area that may represent a potential surface rupture hazard to project facilities and

(2) to make a preliminary evaluation of the ground motions (ground shaking) to which proposed project facilities may be subjected during earthquakes. In order to meet the specific task objectives and to provide a general assessment of the seismic hazards in the project area, the seismic geology study was designed and conducted in a series of sequential phases (Figure 5-8).

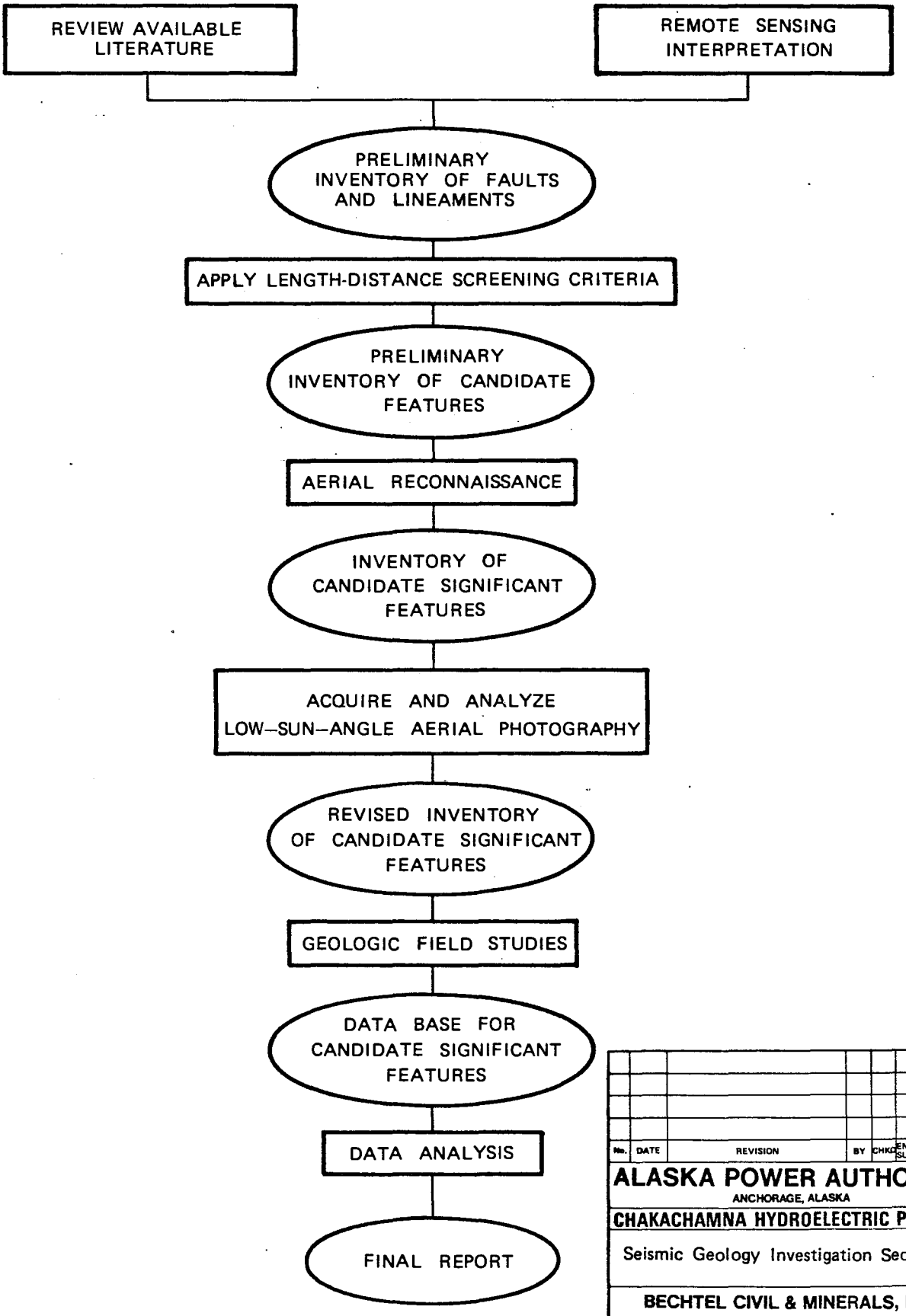
5.3.3.2 Work to Date

The study phases reported here include review of available literature, analysis of remotely sensed data, aerial field reconnaissance, and acquisition of low-sun-angle aerial photographs.

Information of a geologic, geomorphic, and seismologic nature available in the open literature was evaluated to identify previously reported faults and lineaments that may be fault related within the project study area. Geologists presently working in the area or familiar with the study area were also contacted. The locations of all faults and lineaments derived from the literature review and discussions with other geologists were plotted on 1:250,000-scale topographic maps.

Lineaments interpreted to be fault related were also derived from the analysis of high-altitude color-infrared (CIR) aerial photographs (scale 1:60,000) and Landsat imagery (scale 1:250,000) of the study area outlined by the 30-mile diameter circle on Figure 5-9. These lineaments were initially plotted (with brief annotation) on clear mylar overlays attached to the photographs and images on which they were observed. The lineaments were then transferred and plotted on the 1:250,000-scale topographic maps. The faults and lineaments identified from the review of the available literature and interpretation of CIR photographs and landsat imagery comprise a preliminary inventory of faults and lineaments within the study area.

The faults and lineaments in the preliminary inventory were then screened on the basis of a one-third length



No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

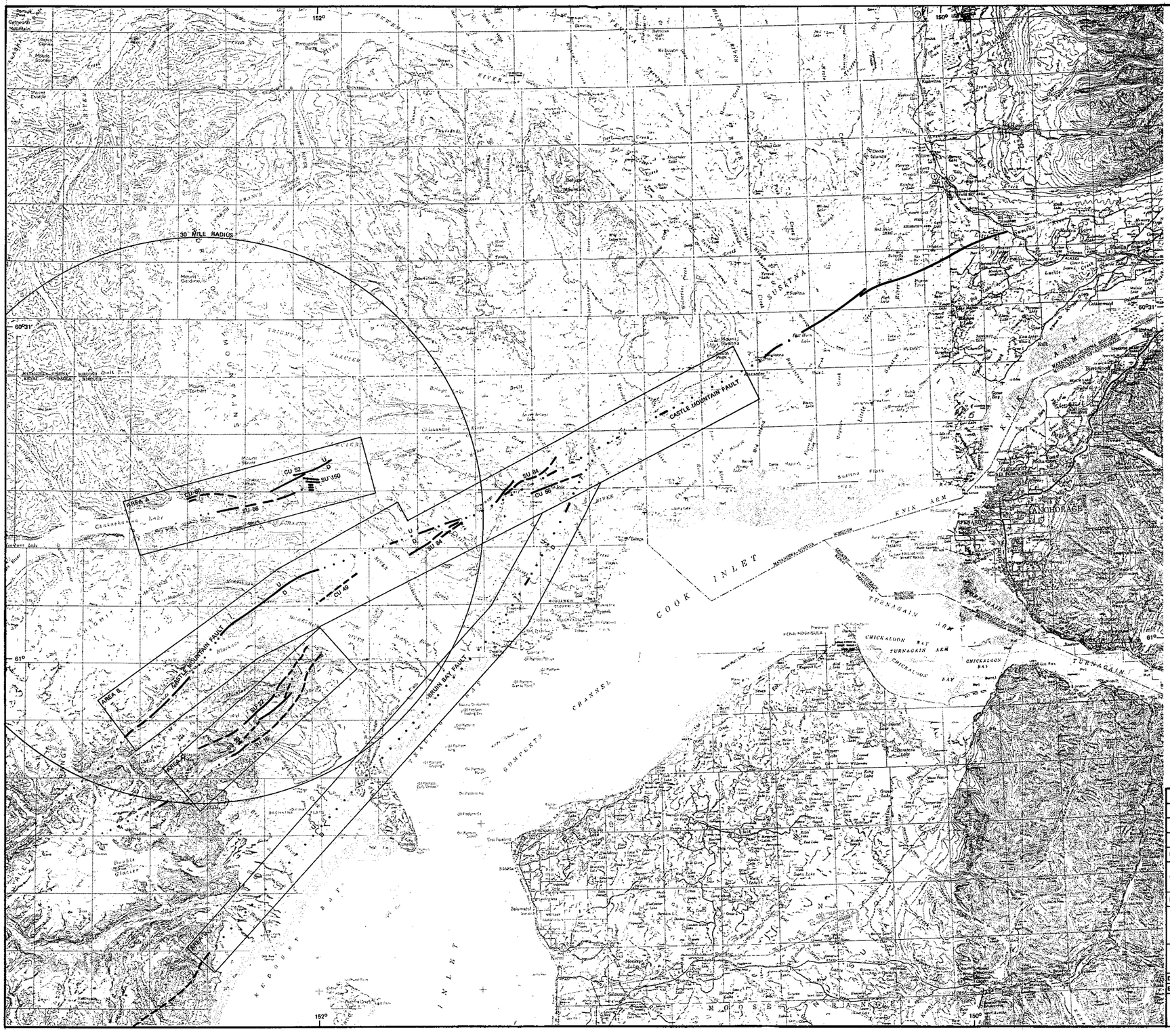
Seismic Geology Investigation Sequence

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	Figure 5-8	

WOODWARD-CLYDE CONSULTANTS



EXPLANATION

Candidate significant fault or lineament, dashed where approximately located, dotted where concealed, queried where location uncertain or inferred

Project Study Area. Reconnaissance assessment of surface fault rupture by Woodward-Clyde Consultants during 1981 field season

AREA A — Areas discussed in Section 5.3.3.3

0 5 10 15
SCALE IN MILES

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

MAP SHOWING LOCATIONS OF CANDIDATE SIGNIFICANT FEATURES IN THE PROJECT STUDY AREA

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED	
ENGR SUPV	PROJ ENGR	APP'D	
	JOB No.	DRAWING No.	REV.
	14879	Figure 5-9	

length-distance criterion to select those faults and lineaments within the study area that potentially could produce surface rupture at sites proposed for facilities. The length-distance criterion specifies a minimum length for a fault or lineament and a minimum distance from the project site for a fault or lineament to be retained for further study. For example, a fault or lineament that trends toward the project site and has an observed length of 10 miles would be selected for further study if it was less than 30 miles from the project site. A fault or lineament with the same trend and same length, but at a distance of greater than 30 miles from the project site would not be selected for further study.

The one-third length-distance criterion used is based on the empirical data that suggest that fault rupture rarely occurs along the full length of a fault (except for very short faults) during an earthquake (Slemmons, 1977, 1980). The length-distance criterion also takes into account

(1) the possibility of surface rupture within or near to the project site occurring on faults that may be identified only in areas remote from the project site, but which in actuality may extend undetected to the project site, and

(2) the fact that at greater distances from the project site, only longer faults would have the potential of producing rupture at the site.

Regional faults in southern Alaska that are known or inferred to be active but are distant from the project

study area were not evaluated for surface rupture potential. These faults, because of their activity, were considered to be potential seismic sources and therefore were evaluated in terms of their potential for causing significant ground motions at the project site.

The faults and lineaments selected for further study on the basis of the length-distance criterion or because they appeared to be potential sources of significant ground shaking were transferred to 1:63,360-scale topographic maps for use during the aerial reconnaissance phase. During the aerial reconnaissance, the faults were examined for evidence (geologic features, and geomorphic expression) that would suggest whether or not youthful activity has occurred. The lineaments were examined to assess:

(1) whether they are or are not faults, and

(2) if they are not faults, what is their origin. For those lineaments that were interpreted to be faults or fault-related, further examination was made to look for evidence that would be suggestive of youthful activity.

After the aerial reconnaissance evaluation of the faults and lineaments, each feature was classified into one of three categories:

(1) a candidate significant feature;

(2) a non-significant feature; or

(3) an indeterminate feature.

Candidate significant features are those that at some point along their length, exhibit geologic morphologic, or vegetational expressions and characteristics that provide a strong suggestion of youthful fault activity. Non-significant features are those, which on the basis of the aerial reconnaissance, apparently do not possess geologic, morphologic, or vegetational characteristics and/or expressions suggestive of youthful fault activity; it was possible to identify non-fault-related origins for many features in this category. Indeterminate features are those lineaments that posses some geologic, morphologic, or vegetational characteristics or expressions that suggest the lineament may be a fault or fault-related feature with the possibility of youthful activity, but for which the evidence is not now compelling.

5.3.3.3 Candidate Significant Features

The candidate significant and indeterminate features identified during the first four phases of this task will require further study in order to evaluate their potential hazard to the proposed project facilities. These features occur in three principal areas, which are designated Areas A, B, and C (Figure 5-9) and are discussed in the following sections. The features presented in each area are discussed in terms of their proximity and orientation with respect to the nearest proposed project facility, previous mapping or published studies in which they have been identified, their expression on CIR photographs, and observations made during the aerial reconnaissance phase of the study.

Area A

Area A is bounded by Mt. Spurr and the Chakachatna River and Chakachamna Lake and Capps Glacier (Figure 5-9). Four candidate significant features, SU 56 and CU 50, CU 52 and SU 150, are located within this area.

Feature CU 50 is a curvilinear fault that trends roughly east-west and extends from the mouth of the Nagishlamina River to Alice Glacier, a distance of about 5 miles. The western end of the feature is approximately 2 miles north of the lake outlet. CU 50 was initially identified on CIR photographs and is characterized by the alignment of:

(1) linear slope breaks and steps on ridges that project southward from Mt. Spurr, east of Barrier Glacier, with

(2) a linear drainage and depression across highly weathered granitic rocks west of Barrier Glacier.

During the aerial reconnaissance, disturbed bedded volcanic flows and tuffs were observed on the sides of canyons where crossed by the feature east of Barrier Glacier. These volcanic rocks are mapped as primarily being of Tertiary age, but locally may be of Quaternary age (Magoon and others, 1976). The possibility of the disturbed volcanic rocks being of Quaternary age suggests that CU 50 may be a youthful fault. The dense vegetation west of Barrier Glacier prohibited close examination of the fault in the granitic terrain.

CU 50 is classified as a candidate significant feature on the basis of its close proximity to proposed project

facility sites and because it appears to displace volcanic rocks that may be Quaternary in age.

Feature CU 52 is a composite feature that consists of a fault mapped by Barnes (1966) and prominent morphological features observed on CIR photographs. The feature tends N63°E and extends along the mountain front from Capps Glacier to Crater Peak Glacier, a distance of about 7.5 miles (Figure 5-9). The southwestern end of this feature is approximately 8 miles from the outlet of Chakachamna Lake. Along the northeastern portion of CU 52, from Capps Glacier to Brogan Glacier, the feature is defined by a fault that separates Tertiary granitic rocks from sedimentary rocks of the Tertiary West Foreland formation (Magoon and others, 1976). The southwestern segment, from Brogan Glacier to the Crater Peak Glacier, which extends the mapped fault a distance of 3 miles, was identified on the basis of aligned linear breaks in slope, drainages, and lithologic contrasts. During the field reconnaissance, a displaced volcanic flow was observed at the southwest end of the feature. Over most of its length, the fault was observed to be primarily exposed in bedrock terrain; youthful lateral moraines crossed by the fault did not appear to be affected.

This fault is considered to be a candidate significant feature because of its prominent expression in the Tertiary sedimentary and volcanic rocks crossed by the fault and because of its close proximity to the proposed project facilities. In addition, the fault may extend farther to the west along the mountain front than was observed on the CIR photographs or during the brief reconnaissance. If such is the case, it may connect with feature CU 50.

Feature SU 56 consists of two segments, a fault and a lineament. The combined feature trends N78°E and can be traced from the toe of Barrier Glacier to the edge of the mesa like area between the Chakachatna River and Capps Glacier, a distance of about 11 miles (Figure 5-9). The western extent of the fault segment is unknown, but if the lineament segment, defined by a linear depression across the toe of Barrier Glacier is associated with the fault, it may extend into and along the south side of Chakachamna Lake, very near the proposed lake tap.

SU 56 was recognized on the CIR photographs on the basis of the alignment of morphologic and vegetation features: a linear depression across the piedmont lobe of Barrier Glacier; a narrow linear vegetation alignment across the alluvial fan east of and adjacent to Barrier Glacier; small subtle scarps between Alice and Crater Peak Glaciers; and a prominent scarp and possibly a displaced volcanic flow between Crater Peak and Brogan Glaciers. During the field reconnaissance, all of the characteristics observed on the CIR photographs could be recognized with the exception of the vegetation alignment east of Barrier Glacier. At two locations along the feature, between Alice and Brogan Glaciers, displaced volcanic flows and tuffs were observed. At both localities the sense of displacement was down on the south side relative to the north side. The amount of displacement could not be measured due to the rugged terrain at the two locations. At the eastern end of the fault, near Brogan Glacier, the fault is on trend and appears to connect with one of seven faults observed in ridges along the eastside of Brogan Glacier where Barnes (1966) mapped two prominent bedrock faults.

Feature SU 56 is classified as a candidate significant feature because:

(1) it displaces volcanic rocks that may be of Quaternary age;

(2) the linear depression across the toe of Barrier Glacier is on trend with the fault; and

(3) the westward projection of the feature would pass very close to the proposed project facilities along the south side of Chakachamna Lake.

Feature SU 150 is composed of a series of parallel west-to-northwest-trending faults mapped by Barnes (1966). These faults are located on the Southwest side of the mesa-like area between Brogan and Capps Glacier, approximately 12 miles east of the outlet of Chakachamna Lake (Figure 5-9). These faults are exposed east of Brogan Glacier along a nearly vertical canyon wall that is deeply eroded into Tertiary sedimentary rocks mapped as the West Foreland formation (Magoon and others, 1976).

During the aerial reconnaissance, five additonal faults were observed along the wall of the canyon, south of the two faults mapped by Barnes (1966). Displacement on these faults, as well as on the two mapped by Barnes (1966), appears to be on the order of a few feet to a few tens of feet, with the south side up relative to the north side. An exception to this is the southernmost fault, on which the displacement appears to be relatively up on the north side. During the aerial reconnaissance, the faults could not be traced for any appreciable distance beyond their approximate length of 2 miles

mapped by Barnes (1966). The southernmost fault, which is on trend with Feature SU 56, is probably an extension of that feature.

The series of faults associated with Feature SU 150 are included in this report as candidate significant features because of the probable connection of the southernmost fault in the series with Feature SU 56, which consists of morphologic features that are suggestive of youthful fault activity.

Area B

Area B includes the Castle Mountain fault and several parallel lineaments (SU 49, SU 84, and CU 56, Figure 5-9). The Castle Mountain fault is one of the major regional faults in southern Alaska. It trends northeast-southwest and extends from the Copper River basin to the Lake Clark area, a distance of approximately 310 miles (Beikman, 1980). The Castle Mountain fault crosses the mouth of the McArthur River Canyon near Blockade Glacier. The Castle Mountain fault is reported to be an oblique right-lateral fault with the north side up relative to the south side (Grantz, 1966; Detterman and others, 1974, 1976a, b).

The Castle Mountain fault is a prominent feature for most of its mapped length. The segment northeast of the Susitna River is defined by a series of linear scarps and prominent vegetation alignments in the Susitna Lowlands and lithologic contrast in the Talkeetna Mountains (Woodward-Clyde Consultants, 1980; Detterman and others, 1974, 1976a). Between the Susitna and Chakachatna Rivers, the fault is less prominent but is marked by a

series of slope breaks, scarps, sag ponds, lithologic contrasts, and locally steeply dipping, sheared sedimentary rocks that are generally flat to gently dipping away from the fault (Schmoll and others, 1981; Barnes, 1966). Southwest of the Chakachatna River, toward the Lake Clark area, the Castle Mountain fault is well defined and expressed by the alignment of slope breaks, saddles, benches, lithologic contrasts between plutonic and sedimentary rocks, shear zones, and a prominent topographic trench through the Alaska-Aleutian Range Batholith (Detterman and others, 1976b).

Displacement on the Castle Mountain fault has been occurring since about the end of Mesozoic time (Grantz, 1966). The maximum amount of vertical displacement is about 1.9 miles or more (Kelley 1963; Grantz, 1966). The maximum amount of right-lateral displacement is estimated by Grantz (1966) to have been several tens of miles along the eastern traces of the fault. Detterman and others (1967 a,b) cited 10 miles as the total amount of right-lateral displacment that has occurred along the eastern portion of the fault and about 3 miles as the maximum amount of right-lateral displacement that has occurred along the western portion, in the Lake Clark area.

Evidence of Holocene displacement has only been observed and documented along a portion of the Castle Mountain fault in the Susitna Lowland (Detterman and others, 1974, 1976a). During their investigation, Detterman and others (1974) found evidence suggesting that 7.5 ft. of dip-slip movement has occurred within the last 225 to 1,700 years. The amount of horizontal displacement related to this event is not known. However, Detterman and others

(1974) cited 23 ft. of apparent right-lateral displacement of a sand ridge crossed by the fault. Bruhn (1979), based on two trench excavations, reported 3.0 to 3.6 ft. of dip-slip displacement, with the north side up relative to the south side, along predominately steeply south-dipping fault traces. He also reported 7.9 ft. of right-lateral displacement of a river terrace near one of the trench locations.

On the CIR photographs, the Castle Mountain fault is readily recognizable on the basis of the alignment of linear morphologic and vegetation features. The most notable features were observed in areas where bedrock is exposed at the surface and include: the prominent slope break that occurs along the southside of Mount Susitna and Lone Ridge; the prominent bench across the end of the Chigmit Mountains, between the McArthur and Chakachatna Rivers; and the alignment of glacial valleys in the Alaska Range, one of which is occupied by Blockade Glacier. In areas covered by glacial deposits, the expression of the Castle Mountain is more subtle and is dominantly an alignment of linear drainages, depressions, elongated mounds, and vegetation contrasts and alignments.

Based on interpretation of the CIR photographs and aerial reconnaissance observations, three lineaments (SU 49 and portions of SU 84 and CU 56) are believed to be traces or splays of the Castle Mountain fault. Lineament SU 49 is approximately 4 miles long, trends northeast, and is on line with the segment of the fault mapped between Lone Ridge and Mount Susitna (Figure 5-9). SU 49 was identified on the basis of the alignment of linear drainages and saddles on a southeast-trending ridge with a vegetation contrast in the Chakachatna River flood

plain and by a possible right-lateral affect or the east facing escarpment along the west side of the Chakachatna River.

Lineament SU 84 partially coincides with the mapped trace of the Castle Mountain fault southwest of Lone Ridge. At the Chuitna River, the mapped trace of the Castle Mountain fault bends slightly to the north (Figure 5-9) whereas lineament SU 84 continues in a more southwesterly direction. Features along SU 84 that make it suspect are the alignment of an elongate mound on trend with steeply dipping sedimentary rocks exposed along the banks of the Chuitna River and the eroded reentrant along the high bluff on the northeast side of the Chakachatna River (Nikolai escarpment).

Lineament CU 56 is located east of Lone Ridge; it trends N70°E, is 7 miles long, and is an echelon to the mapped trend of the Castle Mountain fault. CU 56 was identified on the CIR photographs on the basis of the alignment of linear drainages and depressions and vegetation contrasts and alignments. During the aerial reconnaissance, a broad zone of deformed sedimentary rocks was observed on the location where CU 56 crosses the Beluga River. This locality coincides with a zone of steeply dipping sedimentary rocks mapped by Barnes (1966).

Area C

Area C is located south to southeast of the proposed project facilities sites, along the southeastern side of the Chigmit Mountains between the North Fork Big River and McArthur River (Figure 5-9). Three prominent northeast trending parallel features, SU 16, SU 22, and SU 23,

are located in this area. SU 16 is an inferred fault that transverses both granitic bedrock and glacial deposits. SU 22 and SU 23 are primarily confined to the granitic bedrock terrain.

Feature SU 16 is the longest of the three northeast-southwest trending features located in AREa C. This feature extends from approximately the intersection of the McArthur and Kustatan Rivers southwestward across a broad bench and along the northeast trending segment of the North Fork Big River, a distance of about 25 miles (Figure 5-9). SU 16 may extend even farther to the west if it follows a very linear glacial valley that is aligned with the northeast trending segment of the North Fork Big River. The northern end of SU 16 approaches to within 10 miles of the proposed project facilities in McArthur River area.

SU 16 was identified on the CIR photographs and aerial reconnaissance on the basis of the alignment of elongate low hills, linear depressions, vegetation contrasts, prominent slope breaks, and a lithologic contrast that form the broad bench like area between the North Fork Big River and Kustatan Rivers. The southwestern segment of the feature is defined by the alignment of a linear portion of the North Fork Big River and a linear glacial valley north of Double Peak. During the aerial reconnaissance, no distinctive evidence, such as displaced lithologic units or bedding or scarps, was observed to confirm that SU 16 is actually a fault. Nonetheless, morphologic features that were observed do suggest that SU 16 is a fault and that it may be a youthful fault.

SU 16 is included in this report as a candidate significant fault because the morphologic features observed on the CIR photographs and during the aerial reconnaissance strongly suggest that it is a fault and may be a youthful fault.

Features SU 22 and SU 23 (Figure 5-9) are both northeast trending linear to curvilinear faults that parallel one another at a distance of about one mile. Feature SU 22 can be traced from about the McArthur River southwestward to Black Peak, a distance of about 16 miles. Feature SU 23 is approximately 8 miles in length and extends from Blacksand Creek southwestward to the north Fork Big River area. The northeastern ends of the two features (SU 22 and SU 23) approach to within 8 miles of proposed project facility sites in the McArthur River area. Both features were recognized on CIR photographs and are defined by the alignment of prominent linear troughs that are partially occupied by small lakes and ponds, scarps, slope breaks, benches, and saddles.

During the aerial reconnaissance, the two features could be readily traced across bedrock terrain (mapped as Jurassic to Cretaceous-Tertiary granitic rock; Magoon and others, 1976) on the basis of their morphologic features. Slicken-sided and polished surfaces were observed at several of the scarps and slope break localities examined; sheared zones were also observed during the reconnaissance. The southwestern portions of both features are located in very rugged terrain and are poorly defined due to the highly jointed granitic rocks that are present along this segment.

At the northern end, in the vicinity of Blacksand Creek, SU 23 appears to splay out with one trace trending toward SU 22 and one trace trending toward SU 16 (Figure 5-9). SU 22 also appears to die out in the vicinity of Blacksand Creek, although there was a subtle tonal alignment observed on the CIR photographs on the north side of the creek that suggests it may extend across Blacksand Creek toward the McArthur River.

SU 22 and SU 23 are included as candidate significant features because their prominent expression suggests that they are major structures and that they may be associated with SU 16 which is considered a fault with possible youthful activity.

Area D

Area D (Figure 5-9) includes the Bruin Bay fault, which is one of the major regional faults in southern Alaska. The Bruin Bay fault is a northeast-trending, moderate-to-steeply-northwest-dipping reverse fault that extends along the northwest side of the Cook Inlet from near Mount Susitna to Bechalaf Lake, a distance of about 320 miles (Detterman and others, 1976b). The fault approaches as close as approximately 30 miles south to southwest of the proposed project facilities at Chakachamna Lake and approximately 20 miles of the project facilities in the McArthur River.

The northern segment of the Bruin Bay fault, from about the Drift River area to Mount Susitna, is projected beneath surficial deposits from its last bedrock exposure north of Katchin Creek. The projection is based on a prominent linear depression across Kustatian Ridge,

alignment of linear lakes and depressions in the lowland area west and north of Tyonek, and highly disturbed and faulted Tertiary sedimentary rocks along the Chuitna and Beluga River (Detterman and others, 1976b; Magoon and others, 1976; Schmoll and others, 1981). To the south of Katchin Creek, where the fault is exposed in bedrock areas, the trace of the fault is commonly marked by a zone of crushed rock a few to several hundred meters wide and saddles or notches (Detterman and others, 1976b).

The sense of displacement along the fault is reverse with the north side up relative to the south side (Magoon and others, 1976; Detterman and others, 1976b). Detterman and Hartsock (1966) reported left-lateral displacement of 6 miles or less has occurred along the fault in the Iniskin-Tuxedni region, southwest of the study area. The youngest unit reported displaced by the Bruin Bay fault is the Tertiary sedimentary Beluga formation (Magoon and others, 1976). No displacement of Holocene surficial deposits between Katchin Creek and the probable junction of the fault with Castle Mountain fault near Mt. Susitna has been observed or documented (Detterman and others 1976b; Detterman, personal communication, 1981).

During the analysis of the CIR photographs, several subtle to prominent discontinuous lineaments were identified along the projected trend of the Bruin Bay fault across the McArthur and Chakachatna River flood plains near the Cook Inlet, and along the lowland area west of Tyonek. The lineaments were examined during the aerial reconnaissance and no displacement or disturbed Holocene deposits were observed. Several of the lineaments, however, did coincide with disturbed or faulted sedimentary rocks of the Beluga formation exposed

along the Chuitna and Beluga Rivers. Further work is needed to assess whether the glacial and/or fluvial deposits overlying the sedimentary bedrock have been faulted or disturbed.

Although no evidence has been observed or reported that would indicate youthful fault activity along the Bruin Bay fault, several of the lineaments observed on the CIR photographs are suggestive of youthful fault activity. On the basis of the lineaments along the projected trace of the Bruin Bay fault, and the fact that the fault is suspected to intersect with the Castle Mountain fault, the Bruin Bay fault is considered for this report to be a candidate significant feature.

5.3.3.4 Implications with Respect to the Proposed Hydroelectric Project

Based on the results of the work to date a preliminary assessment can be made regarding the potential surface faulting hazards and seismic sources of ground motion (shaking) with respect to the proposed project site.

(1) Within the study area, faults and lineaments in four areas have been identified for further evaluation in order to assess and better understand their potential effect on project considerations. For example, if feature SU 56 is an active fault, its trend is toward the area proposed for the lake tap and the extent and activity of this feature clearly require evaluation. Several of these features may prove to be capable of producing earthquakes, thus both ground shaking and surface rupture in the project area.

(2) The Castle Mountain fault is located along the southeast side of the Chigmit Mountains at the mouth of McArthur Canyon. Although no displacements of Holocene deposits have been observed or reported for the segment of the Castle Mountain fault between the Susitna River and the Lake Clark area, the fault is considered an active fault on the basis of the reported displacement of Holocene deposits east of the project area in the vicinity of the Susitna River.

(3) Based on a review of the available literature and detailed studies conducted for major projects in southern Alaska there are three potential seismic sources that may have an effect on the project site. These include: the subduction zone, which consists of the Megathrust and Benioff zone; crustal seismic zone; and severe volcanic activity. The Castle Mountain fault (crustal seismic source) and the Megathrust segment of the subduction zone are expected to be the most critical to the project with respect to levels of peak ground acceleration, duration of strong shaking, and development of response spectra. (see Section 7.4).

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ENVIRONMENTAL STUDIES

6.0 ENVIRONMENTAL STUDIES - SUMMARY

Environmental studies were conducted within the Chakachatna and McArthur River drainages during both 1981 and 1982. The 1981 studies included investigations of the hydrology, aquatic and terrestrial biology and human resources of the area. These studies were limited in scope due to the short-time frame which was available for conducting field investigations. Studies conducted in 1982 emphasized aquatic biological investigations (seasonal sampling), but also included supplemental hydrological studies. The following section presents summary information for each of the 1981-1982 studies. The complete detailed reports for the environmental studies are presented in the APPENDIX to Section 6.0 in Volume II of this report.

6.1 Environmental Studies - 1981

In 1981, two environmental reconnaissance level surveys were conducted in the project area. The first was conducted in August to document the presence of sockeye salmon (Oncorhynchus nerka) in the project waters, and to survey the site in preparation for the fall field reconnaissance. The second investigation, conducted in mid-September, involved two weeks of field data collection. Coincident with these studies were ongoing reviews of the literature and discussions with key agency and native corporation personnel.

6.1.1 Environmental Hydrology

Hydrology field studies were conducted for Chakachamna Lake, several of its tributary streams, and the

Chakachatna and McArthur Rivers. The hydrologic field data collected included measurements of discharge taken at eight study locations, a water level survey of Chakachatna Lake, a wetland/river level survey taken in a channel of the Noaukta Slough, and a characterization of channel pattern and configuration including the composition of bed and bank materials.

Office evaluations were also conducted to synthesize hydrologic data at eight study locations. Data that were developed included mean monthly flows, mean annual flows, flood flow frequency, and low flow frequency. In addition, using the Montana Method, preliminary instream flow recommendations for maintaining fisheries habitat were calculated on a monthly basis for the outlet of Chakachamna Lake.

The field data collected from the various streams were typical of glacial rivers, with low flows in late winter, large glacier melt flows in July and August, and annual peaks due to fall rains. The reaches of the McArthur and Chakachatna Rivers vary from mountainous through braided and meandering streams. All except the most infrequent large floods are contained within the unvegetated flood plan. Sedimentation characteristics in the streams appear to be typical of glacial systems with very fine suspended sediments and substantial bed load transport. The water level of Chakachamna Lake (measured in September) was 1,142 feet which was typical for the lake in September based on 12 years of past records.

6.1.2 Aquatic Biology

Two reconnaissance level surveys were conducted in Chakachamna Lake, and in the Chakachatna, Chilligan and McArthur Rivers and tributaries. The first reconnaissance occurred during 17-18 August and consisted of aerial observations of the project area. The second reconnaissance, conducted 15-28 September, involved the collection of data from areas identified during the initial survey. This effort employed both field sampling and visual observations. The major objectives of this reconnaissance were to identify the fish species and life stages during the fall, to identify potential critical fisheries habitats in the system, and to provide information on the species composition of fish and their habitat use occurring at different times of the year.

A total of 14 species of fish were collected from the waters of the project area including all five species of Pacific salmon found in Alaska (Table 6.1). Some of the streams flowing into Chakachamna Lake contained large areas used by sockeye salmon for spawning. Substantial numbers of sockeye were found in the Igitna and Chilligan Rivers, and there was some evidence of potential sockeye spawning in Chakachamna Lake. Juvenile sockeye salmon used Chakachamna and Kenibuna Lakes as nursery habitat. Lake trout (*Salvelinus namaycush*), Dolly Varden (*Salvelinus malma*), round whitefish (*Prosopium cylindraceum*) and slimy sculpin (*Cottus cognatus*) were also found in Chakachamna Lake.

Side channels and tributaries of the Chakachatna and McArthur Rivers contained salmonid spawning sites and

Table 6.1 Species list and drainage of occurrence August-September 1981.

Species		Drainage of Occurrence	
		Chakachatna River[1]	McArthur River
pygmy whitefish	Prosopium coulteri	+	+
round whitefish	Prosopium cylindraceum	+	+
Dolly Varden	Salvelinus malma	+	+
lake trout	Salvelinus namaycush	+	
rainbow trout	Salmo gairdneri	+	+
pink salmon	Oncorhynchus gorbuscha	+	+
chum salmon	Oncorhynchus keta	+	+
coho salmon	Oncorhynchus kisutch	+	+
sockeye salmon	Oncorhynchus nerka	+	+
chinook salmon	Oncorhynchus tshawytscha	+	+
arctic grayling	Thymallus arcticus	+	
slimy sculpin	Cottus cognatus	+	+
threespine stickleback	Gasterosteus aculeatus	+	+
ninespine stickleback	Pungitius pungitius	+	+

[1] Includes Lake Chakachamna and Middle River

numerous fish were observed using them. These habitats were also used as juvenile rearing areas. The Noaukta Slough, a heavily braided reach of the Chakachatna River, was used extensively as a nursery area by juvenile fishes, particularly coho (Oncorhynchus kisutch) and sockeye salmon. Juvenile pygmy whitefish (Prosopium coulteri) and Dolly Varden were also abundant in the slough. The intertidal ranges of both river systems do not contain suitable habitat for salmonid spawning or juvenile rearing.

Lake trout appeared to occur only in Chakachamna Lake, while Dolly Varden were ubiquitous throughout both the Chakachatna River and McArthur drainages. Rainbow trout (Salmo gairdneri) were collected only in the lower portions of the drainages. Round and pygmy whitefish were found in most areas of the drainages, although pygmy whitefish were not found in Chakachamna Lake or drainages above it. Slimy sculpin were found throughout both systems and in tributary streams. Sticklebacks, however, were only found in backwater areas and among vegetation, usually in the lower reaches of the rivers. Only a single grayling (Thymallus arcticus) was observed in a side channel in the upper Nagishlamina River, and none were collected or observed at any other location. It was clear that most of the species found inhabit both drainages.

In general, the fish in this area may be classified into two primary groups, forage fish, and commercial and sport fish. Forage fish in the project area include threespine stickleback (Gasterosteus aculeatus), ninespine stickleback (Pungitius pungitius), slimy sculpin, pygmy whitefish, and round whitefish.

Although the round whitefish is probably not used as a subsistence species in these drainages, it is eaten by lake trout and other species of fish. Sport and commercial fishes include pink (Oncorhynchus gorbuscha), chum (Oncorhynchus keta), sockeye, coho and chinook salmon (Oncorhynchus tshawytscha), and Dolly Varden, lake trout, rainbow trout, and grayling.

6.1.3 Terrestrial Vegetation and Wildlife

The objective of the terrestrial component for the environmental study was to characterize the vegetative and wildlife communities within the project area.

Because this project would affect the lands and waters of both the Chakachatna and McArthur drainage systems, qualitative data were collected throughout the study area and vegetation and wildlife habitat maps were prepared so that areas of a sensitive or critical nature could be identified.

Previous investigations conducted in the general area by the Alaskan Department of Fish and Game (ADF&G) and the U.S. Fish and Wildlife Service (USFWS) have concentrated on documenting waterfowl utilization of the coastal marshes of Cook Inlet. In addition to annual aerial surveys of the Trading Bay State Game Refuge performed by the personnel of ADF&G, personnel of USFWS have conducted aerial swan surveys encompassing the lands in and adjacent to the refuge. Although the main purpose of these surveys has been to census waterfowl, information has also been gathered on bald eagle nest sites, moose calving grounds, and the occurrence of Beluga whales near the McArthur River.

Table 6.2 The species composition and relative abundance of mammals identified within the study area for each of the habitat types. (1=Abundant 3=Common 5=Occasional)

Species		Habitat[a]							
		UAT	HAR	BCR	CMR	BST	RBB	WTR	BSR
grizzly bear	Ursus horribilis	3	1	3	3	5	5	3	3
black bear	Ursus americanus	1	1	3	3	5	3	3	3
gray wolf	Canis lupus	5	3	5	5	5		5	
coyote	Canis latrans	3	3	3	1	3	3	3	3
moose	Alces alces	5	1	1	3	3	3	3	3
barren ground caribou	Rangifer arcticus		5						
wolverine	Gulo luscus	5	5	5				5	5
mink	Mustela vison	5	5	3				5	3
river otter	Lutra canadensis			5				5	5
beaver	Castor canadensis			3				3	3
muskrat	Ondatra zibethica		5	3				3	3
red squirrel	Tamiasciurus hudsonicus	5	5	5	5	5			5
tundra redback vole	Clethrionomys rutilus	1	3	3	3	3	3		
tundra vole	Microtis oeconomus			3					
porcupine	Erethizon dorsatum		3	3	5				
dusky shrew	Sorex obscurus	3	3	3					
harbor seal[b]	Phoca vitulina				5				
beluga whale[b]	Delphinapterus leucas				5				

[a] Upland Alder Thicket (UAT);
High Altitude Riparian (HAR);
Black Cottonwood Riparian (BCR);
Coastal Marsh Riparian (CMR);
Black Spruce Transitional (BST);
Resin Birch Bog (RBB);
Willow Thicket Riparian (STR); and
Black Spruce Riparian (BSR).

[b] sighted offshore near the mouth of the McArthur River.

During the 1981 studies, eight types of vegetation habitats were delineated based on their structural and species composition. These ranged from dense alder thickets in the canyons to vast areas of coastal marsh. The riparian communities were the most prevalent, varying from rivers with emergent vegetation to those with broad floodplains scattered with lichen, willow and alder.

Evaluation of wildlife communities in the project area identified sixteen species of mammals (Table 6.2). Moose, coyote, grizzly bear and black bear occur throughout the area. Birds also were abundant, fifty-six species having been identified, with the coastal marshes along Trading Bay containing the largest diversity.

None of the species of plants, mammals and birds that were found are listed as threatened or endangered, although in May 1981 it was proposed that the tule white-fronted goose, which nests immediately south of the study area, be considered for threatened or endangered status.

6.1.4 Human Resources

These studies were organized into the following six elements:

- Archaeological and historical resources
- Land ownership and use
- Recreational resources
- Socioeconomic characteristics
- Transportation
- Visual resources

Contacts with both state and federal agencies and Native organizations, and a limited reconnaissance of the project area were made during the 1981 studies. No known cultural sites were identified and the field reconnaissance indicated that the proposed sites for the power intake and powerhouses have a low potential for cultural sites.

Land owners in the area comprise federal, state, and borough agencies, Native Corporations and private arties. Land use is related to resource extraction (timber, oil and gas), subsistence, and the rural residential Village of Tyonek. Recreational activity occurs but little data is available to the extent or frequency with which the area is used.

Regional data on population, employment and income characteristics are relatively good. However, employment level and occupational skill data are limitedand need to be developed together with information on local employment preferences.

Transportation facilities in the area are few and small in size. There is an airstrip on the shoreline at Trading Bay and a woodchip loading pier near Tyonek. Several miles of logging roads exist between Tyonek and the mouth of the Chakachatna Valley. The Chakachatna River is bridged near its confluence with Straight Creek. There is no permanent road between the project area and any part of the Alaska road system.

Because of the project area's scenic characteristics and its proximity with BLM lands, the Lake Clark National

Park and the Trading Bay State Game Refuge, visual resource management is a significant concern.

6.2 Environmental Studies - 1982

The 1982 environmental studies included both hydrological and aquatic biological investigations with primary emphasis on the latter. The hydrologic studies were conducted during the fall of 1982 (August and October); aquatic biological studies were conducted seasonally, with the major sampling effort occurring during the summer and fall periods.

6.2.1 Environmental Hydrology

The objective of the 1982 environmental hydrology studies was to collect baseline data to assist in future evaluations of the physical process of the Chakachatna and McArthur River systems, and facilitate the correlation of these processes with fish and wildlife habitats.

During August, two recording gages capable of recording river stage and water temperature were installed, one on the Chakachatna River near the lake outlet, the other on the McArthur River downstream of the powerhouse location. Staff gages were installed at an additional 15 sites and were periodically monitored. In October, discharge measurements and water surface profiles were made at 12 gage stations, and a generalized sediment characterization made for the various stream reaches. Manning's equation was used in the hydraulic analyses to establish preliminary rating curves.

Overall, the discharges at gauge site No. 6 in the lower Chakachatna River, downstream of the fork which discharges into the Noaukta slough but above the split with the Middle River, correlated reasonably well with the discharges at the Chakachatna River recording gage at the lake outlet. The flows averaged about 17 percent of the flow at the lake outlet. The average discharge at the lake outlet during the study period was significantly less than the average for the 13 years of U.S.G.S. records, with August flows well below average. A September rainstorm resulted in a short duration flood flow in the upper McArthur River with a peak flow of about 4500 cfs. This discharge is estimated to have a recurrence interval of about 25 years.

Mean daily water temperatures in the Chakachatna River at the lake outlet ranged from 8°C in August to 6°C in October. Water temperatures in the McArthur River at the rapids exhibited large diurnal variations in August; temperatures varied from 3.0°C to 9.5°C in a six-hour period. Temperatures in the McArthur River from mid-August to mid-September averaged 1.6°C less at the powerhouse than at the recording gage.

The Chakachatna and McArthur River systems are glacial and thus carry fine glacial silts through much of theopen water season. The main channel substrate of these river systems appears to be quite unstable.

6.2.2 Aquatic Biology

The 1982 aquatic biology studies concentrated on the fishery resources of the study area. Two series of programs were conducted, one during the winter and

spring, the other during the summer and fall. The winter-spring studies were designed to extend the data base on seasonal habitat use and distribution of fish, to identify the time spring spawning migration begins, and to examine for the presence of outmigrants. The summer-fall studies were directed at investigating both the adult anadromous fish, and the resident and juvenile anadromous fish in the study areas. A separate program for sampling the fisheries in Chakachamna Lake was also conducted during the summer-fall studies.

A variety of methodologies were utilized to sample and count fish in the study area during the 1982 program. Selected sampling techniques included the use of fyke nets, minnow traps, seines, hook and line, electrofishing, and gill netting. Hydroacoustic sampling was used to examine the relative distribution of fish in Chakachamna Lake.

A total of 18 fish species were identified and/or collected during the 1982 studies, including four species not collected in 1981: Bering cisco (Coregonus laurettae), longfin smelt (Spirinchus thaleichthys), rainbow smelt (Osmerus mordax and eulachon (Thaleichthys pacificus). The species of commercial, subsistence and sport interest utilizing the Chakachatna and McArthur River systems included sockeye, chinook, pink, chum and coho salmon, Dolly Varden and rainbow trout. Summary information for these seven species is presented below. Detailed analyses of the 1982 studies are presented in the APPENDIX to Section 6.0 in Volume 2 of this report.

6.2.2.1 Sockeye Salmon

Sockeye salmon adults probably enter the Chakachatna and the McArthur Rivers in early July. Sockeye first appeared on the spawning streams on July 22, 1982. Spawning continued through the first week of October in various parts of the system and few spawning sockeye were present past early October.

The timing and duration of sockeye-runs varied with location. Runs in the McArthur River tributaries peaked earlier than most of those on the Chakachatna River. Spawning adults were present in the Chilligan River and sloughs at station 17 longer than at other sites.

Sockeye escapements were estimated for all identified spawning areas and are presented in Table 6.3. The largest estimated escapement was for the Chilligan River: 38,576 sockeye. A total of 41,357 sockeye (total of the Igitna and Chilligan River escapements) were estimated to spawn above Lake Chakachamna. Of the other sockeye estimated to spawn in the Chakachatna drainage, 1788 spawned in sloughs or side channel spawning areas receiving slough flow. In the McArthur drainage, of the 34,933 fish, 98.1 percent of the estimated sockeye escapement occurred in tributary streams. Overall, 44.7 percent of the total estimated escapement of sockeye occurred in the McArthur drainage.

Sockeye which are spawned in the Chilligan and Igitna Rivers, rear in Chakachamna and Kenibuna Lakes. The Chakachatna River across from Straight Creek, the Noaukta Slough, and portions of the lower McArthur River also appear to be used as rearing areas. Juvenile

Table 6.3 Summary of estimated salmon escapement by waterbody and drainage for 1982.

Species	Straight Creek Mouth	Chakachatna Bridge Side Channels and Sloughs	Chakachatna Canyon Sloughs	Chakachatna Tributary (C1)	Igitna River	Chilligan River	Straight Creek	Straight Creek Clearwater Tributary	Drainage Total
	CHAKACHATNA RIVER DRAINAGE								
Sockeye Salmon	203	1,193	392	238	2,781	38,576	0	254	43,637
Chinook Salmon	0	0	0	0	0	0	0	1,422	1,422
Pink Salmon	0	59	279	0	0	0	0	7,925	8,263
Chum Salmon	152	1,482	121	165	0	0	0	0	1,920
Coho Salmon	76	1,560	608	183	0	0	0	172	2,599

Species	McArthur Canyon	Stream 13X	Stream 13U	Streams 12.1	12.2	12.3	12.4	12.5	Drainage Total
	MCARTHUR RIVER DRAINAGE								
Sockeye Salmon	666	5,416	1,213	16,711	6,085	2,512	2,328	0	34,933
Chinook Salmon	0	452	1,633	0	22	0	0	0	2,107
Pink Salmon	60	4,225	5,402	8,499	1,566	4	18	3	19,777
Chum Salmon	1	0	23	4	0	0	1	0	29
Coho Salmon	1,182	1,378	32	2,000	46	89	0	0	4,729

Note: Figure 6.30 shows locations in Chakachatna River drainage.
Figures 6.30, 6.47 and 6.48 show locations in McArthur River drainage.

sockeye appear to rear in the system from as short a time as their first summer to as long as their third year (age II+) prior to migrating to the sea.

6.2.2.2 Chinook Salmon

Based upon 1982 observations, chinook salmon adults were entering the river systems prior to late June. Chinook spawning was first observed in the study area on July 17 at Stream 13U in the McArthur system, but spawning could have started as early as the end of June. Spawning adults were observed as late as August 25.

The largest estimated escapement for chinook salmon occurred in Stream 13U in the McArthur drainage (1633 fish) and the second largest in the clearwater tributary to Straight Creek (1422 fish) (Table 6.3). All chinook spawning observed during 1982 occurred in tributary streams. The majority of spawning occurred within the McArthur drainage.

Chinook salmon juveniles rear in fresh water from as short as three months to well into their third year of life. Juvenile chinook salmon collected in the study area ranged in age from 0+ to II+. Chinook salmon juvenile rearing areas consisted of spawning streams (Streams 13U and 19), low velocity side channel and slough areas (stations 17, 15 and 13) and many areas within the Noaukta Slough. Chinook outmigration may start as early as June and appears to continue into the fall.

Fish collected are listed by method and sampling location. Locations of the sampling stations are as follows:

Station Number	Location	Map Coordinate
1	Confluence of Chakachatna River with McArthur River	R. 14 W., T. 10 N.
1D	McArthur River	R. 14 W., T. 10 N.
2	Lower Chakachatna River	R. 14 W., T. 11 N.
3	Lower Chakachatna River	R. 14 W., T. 11 N.
4	Upper Middle River	R. 14 W., T. 11 N.
5	Lower Middle River	R. 13 W., T. 11 N.
6	Chakachatna River above Middle River	R. 14 W., T. 11 N.
6A	Chakachatna River above Middle River	R. 14 W., T. 11 N.
8	Upper Nouakta Slough	R. 14 W., T. 11 N.
9	Lower Nouakta Slough	R. 14 W., T. 11 N.
10	West Nouakta Slough	R. 15 W., T. 11 N.
11	Lower McArthur River	R. 14 W., T. 10 N.
12	McArthur River above Noaukta Slough	R. 15 W., T. 11 N.
13	Upper McArthur River	R. 16 W., T. 11 N.
14	Lower McArthur Canyon	R. 16 W., T. 12 N.
15	McArthur Canyon	R. 17 W., T. 12 N.
16	Upper Noaukta Slough	R. 14 W., T. 12 N.
16A	Upper Noaukta Slough	R. 14 W., T. 11 N.
17	Chakachatna River at DNR Bridge	R. 14 W., T. 12 N.
17D	Chakachatna River Below 17	R. 14 W., T. 12 N.
18	Straight Creek	R. 15 W., T. 12 N.
19	Clearwater tributary to Straight Creek	R. 14 W., T. 12 N.
19A	Clearwater tributary to Straight Creek	R. 14 W., T. 12 N.
20	Chakachatna River across from Straight Creek	R. 15 W., T. 12 N.
21	Chakachatna River across from Straight Creek	R. 15 W., T. 12 N.
22	Chakachatna River at base of canyon	R. 15 W., T. 13 N.
23	Chakachatna River in canyon	R. 15 W., T. 13 N.
24	Chakachatna River in canyon	R. 16 W., T. 13 N.
25	Chakachamna Lake	R. 17 W., T. 13 N.
26	Nagishlamina River delta	R. 18 W., T. 13 N.
27	Chakachamna Lake N. Side	R. 18 W., T. 13 N.
28	Chakachamna Lake S. Side	R. 18 W., T. 13 N.
29	Kenibuna Lake outlet	R. 20 W., T. 13 N.
30	Chilligan River	R. 20 W., T. 13 N.
31	Neacola River	R. 21 W., T. 12 N.
32	Igitna River	R. 21 W., T. 12 N.
33	Another River	R. 21 W., T. 13 N.
Streams	12.1 through 12.4, 13X	R. 15 W., T. 11 N.
Streams	12.1 through 12.4	R. 15 W., T. 12 N.
Stream	12.5	R. 14 W., T. 11 N.
Stream	13U	R. 15 W., T. 11 N.
Stream	13U	R. 16 W., T. 11 N.

FIGURE 6.30

LOCATION AND IDENTIFICATION OF 1982 SAMPLING STATIONS

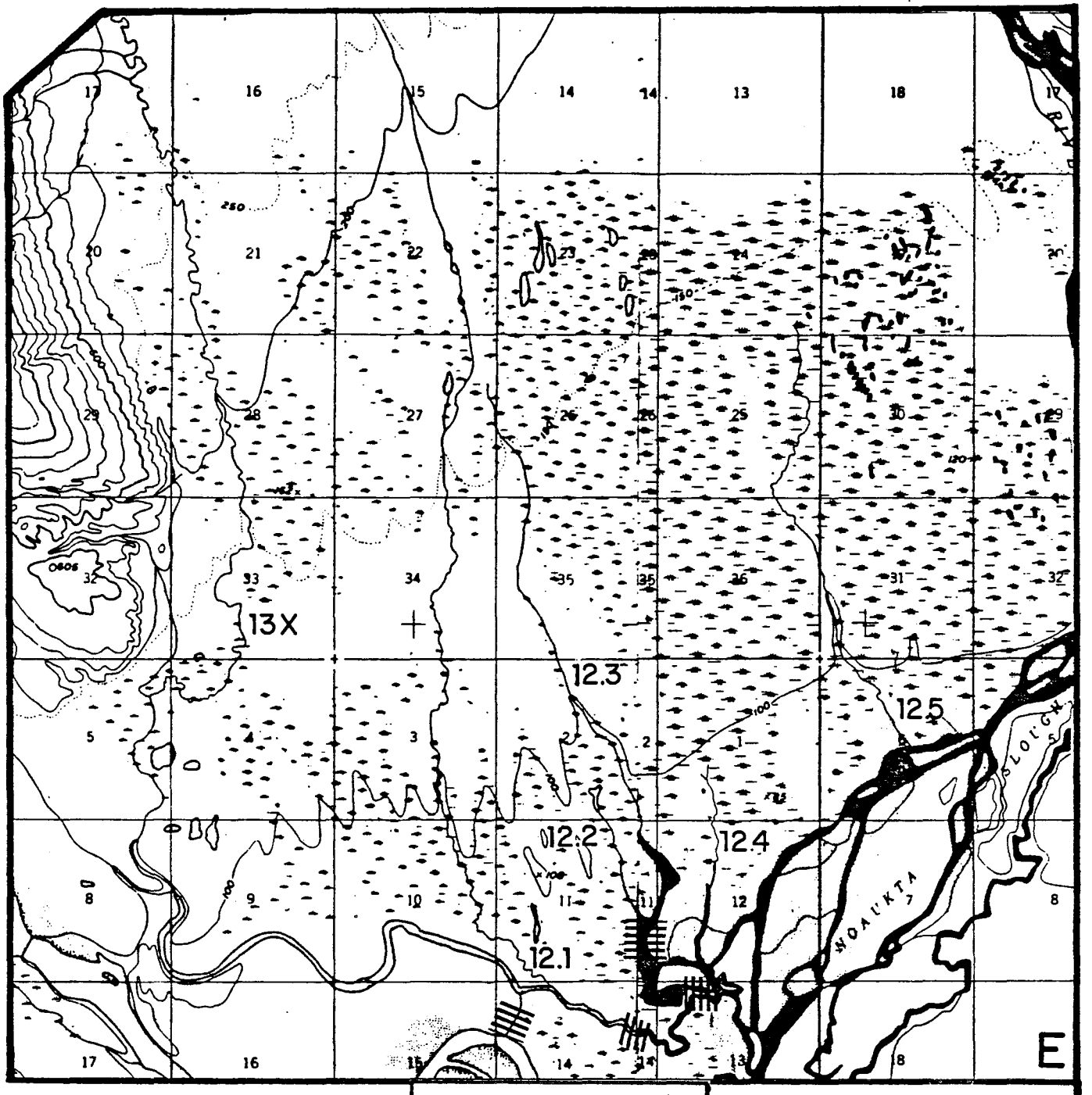


Figure 6.47

Sockeye Milling Areas
Streams 13X, 12.1,
12.2, 12.3
1982

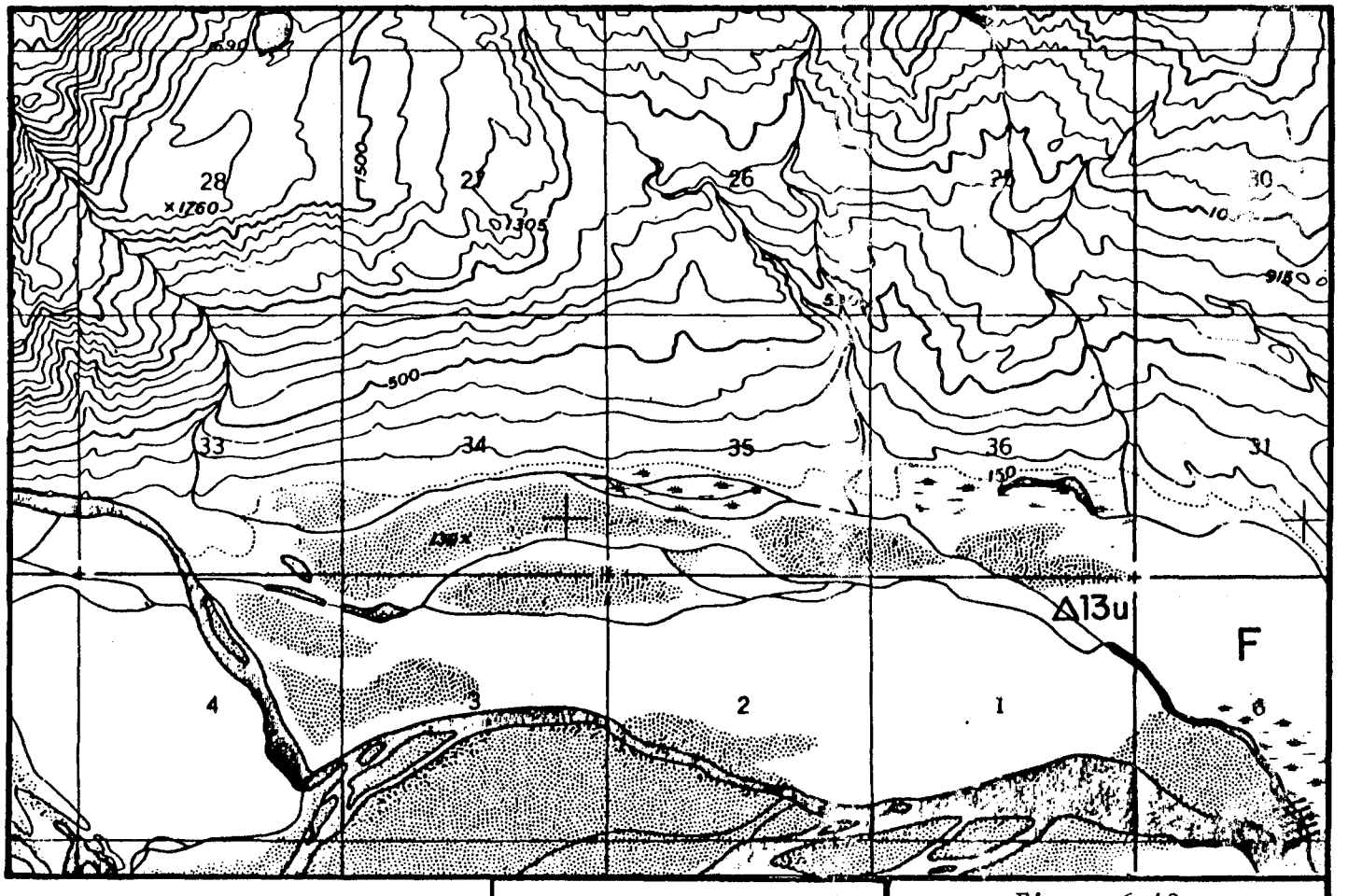


Figure 6.48

Sockeye Milling Area
at Stream 13u
1982

6.2.2.3 Pink Salmon

Pink salmon were first observed milling in fresh water in late July (July 22) and first observed in the spawning streams on July 31. Pinks continued to be observed in the McArthur and Chakachatna River tributaries until mid-September with peak counts made in August.

In Cook Inlet, pink salmon runs in even numbered years are generally larger than runs occurring during odd numbered years. Since 1982 was an even year, larger than average escapements were expected. However, preliminary commercial catch data indicate that 1982 had a lower than average run for an even-numbered year. Estimated escapements for the various water bodies in the system are shown in Table 6.3.

The vast majority of pink spawning occurred in tributary streams. In the Chakachatna drainage, 4.1 percent of the 8,263 estimated pink escapement for that drainage occurred in sloughs and side channels, and in the McArthur drainage less than 0.3 percent of the estimated pink escapement occurred in sloughs or side channels. The majority of the total estimated pink escapement, 70.5 percent or 19,777 fish, occurred in the McArthur drainage. No pinks spawned above the sloughs at the base of the Chakachatna River Canyon.

Emergent pink salmon fry probably move directly down river to the sea. Rearing in fresh water may be for a period as short as one day, and thus, no rearing areas were identified during the 1981 and 1982 studies.

6.2.2.4 Chum Salmon

Chum salmon were in the spawning streams on August 25 and were found at most spawning areas by September 1.

The total estimated spawnings escapement for both the Chakachatna and McArthur River drainages was 1949 fish, which was less than any of the other four salmon species (Table 6.3). The majority of these fish (77 percent - 1481 fish) spawned in the sloughs at station 17 on the Chakachatna River. Over 90 percent of the estimated escapement occurred in sloughs or areas receiving upwelling flow

In early June, chum salmon fry had moved into lower portions of the river systems and smolts were found at collecting stations near the mouth of the McArthur River. By the end of June, only a few smolts were collected near the mouth of the McArthur River, suggesting that the peak downstream migration had occurred. Because of the relatively short rearing period of chum salmon in freshwater, no specific rearing areas were identified during the 1981-1982 studies.

6.2.2.5 Coho Salmon

Coho salmon were first observed in fresh water in mid-August. At that time fairly large numbers of coho were observed milling at the mouths of streams on the McArthur River. Coho were observed on spawning streams on September 1 and peak numbers were observed in mid to late September in most water bodies. Spawning was still in progress when the study was concluded in late October and may have continued under the ice in the Chakachatna Canyon sloughs.

The majority (64.5 percent) of the estimated total coho escapement for the study area occurred in the McArthur River. In the McArthur system, 75 percent (3547 fish) of the estimated escapement of 4729 coho occurred in tributaries (Table 6.3) The other 25.0 percent took place in side channel and slough areas. Spawning occurred in both tributaries and sloughs. The majority (86.3 percent) of the estimated escapement of 2599 coho in the Chakachatna drainage were observed in sloughs and side channels receiving upwelling or slough flow. No coho were observed spawning above the Chakachatna Canyon sloughs.

Yolk-sac fry and emergent fry were found in spawning areas in the study area in late March. Coho juveniles may remain in fresh water for up to four years. Coho of up to age II+ were common in the Chakachatna and McArthur River systems. Juvenile coho salmon were among the more widely distributed fish present in the study area below the lake. Coho juveniles were generally abundant in tributaries, the Noaukta Sough, and areas in the lower portions of both rivers. Observed increases in the abundance of coho in the Noaukta Slough, lower river systems and upper McArthur River probably represented a combination of movement to overwintering habitat and outmigration. The outmigration of some coho was confirmed by the collection of smolts in the lower portions of the rivers. Coho smolts were collected in the Chakachatna and McArthur River systems from early June into October.

6.2.2.6 Dolly Varden

Dolly Varden was the most widely distributed species collected in the study area and was found at almost every site at which fish were collected. They numerically dominated collections made below Chakachamna Lake. Dolly Varden may be resident or anadromous; both types are probably present within the study area. Dolly Varden were obsereved spawning from July 31 through October in the Chilligan River.

During late October, sexually mature upstream migrants were still being collected in the lower portons of the river systems, and Dolly Varden spawning was still occurring. Dolly Varden spawning was also common in the McArthur River and its tributaries during October. Some upstream migrants which spawned in the McArthur River were observed entering the river systems from the Middle River and then moving through the Chakachatna River.

Dolly Varden juveniles were widely distributed in the river systems. They were collected from every river sampled, including the the Neacola and Another Rivers. Juvenile (ages I+ to II+) appear to be common throughout the river system with larger, older fish, including age III+, more abundant in the Noaukta Slough and lower portions of the river. Dolly Varden appear to move freely within and between the two river systems.

6.2.2.7 Rainbow Trout

Rainbow trout were regularly collected in portions of the lower river systems and tributaries. Rainbow trout

were collected most frequently in October when large numbers had moved into the lower river system.

Little is known about the spawning of rainbow trout in the Chakackatna and McArthur River systems and few rainbow trout under 10 cm (4.0 inches) were collected.

The distribution of rainbow trout in the Chakachatna River appears to be limited to areas below the Chakachatna River Canyon. During the summer and fall of 1982, juvenile rainbow trout were collected in the Straight Creek clearwater tributary (19), in the McArthur River (Stations 13, and 11) and in the lower Chakachatna River (Stations 3, 4, and 6). Rainbow trout are a resident species and therefore rear in freshwater throughout the year. Based upon tag return data, rainbow trout appear to move freely within and between the middle and lower portions of both river systems.

EVALUATION OF ALTERNATIVES

7.0 EVALUATION OF ALTERNATIVES

7.1 Engineering Evaluation

7.1.1 General

The figures quoted in this section of the report for the estimated cost of energy are considered to be conservative for two basic reasons, the first being that in the power studies for Alternatives A, B, C and D, the maximum lake level was taken as elevation 1128 which had been reported as the approximate invert elevation of the natural lake outlet channel. The natural maximum lake water level is reported to have been at about elevation 1155 and the records show that the lake rose to that level or within about 5-feet of it each year. No credit has been taken in the calculations for any additional energy that would accrue from the higher heads that would temporarily be available when the lake water level exceeded elevation 1128. There is also the possibility that once diversion of water for power generation begins, the outlet channel may choke and its invert may rise above its present elevation thus creating a higher head for power generation. If the maximum water level is taken, as elevation 1142, the installed capacity for Alternative B would increase from 330 MW to 350 MW and the average annual energy would rise by 6% from 1446 GWh to 1533 GWh.

The second reason which applies to Alternatives A, B, C, D and E, is because of the realistic approach taken to estimating the cost of constructing each of the alternatives. Analyses were made of bids received for

projects involving similar types of construction and the unit prices used in the estimates are consistent with those that have been received in recent competitive bidding in cases where the analyses have permitted such comparisons to be drawn. Furthermore, although the estimates make allowances for certain lengths of the tunnels where production may slip and costs may increase due to adverse rock conditions, an overall 20% contingency allowance over and above the estimated cost of construction, engineering and construction management has been included in arriving at the estimated total project costs.

7.1.2 Chakachatna Dam

On the basis of what was seen in surface exposures during reconnaisances of the Chakachatna Valley, little encouragement could be found for pursuing a course based on the concept of siting a dam anywhere in the valley downstream from the lake outlet. Although the possibility has not been completely ruled out, it is considered most unlikely that justification for siting a dam here could be confirmed.

7.1.3 Alternative A

This alternative, which would take all controlled water from Chakachamna Lake for the generation of electrical power in a powerplant located in the McArthur Valley, is the most advantageous identified by the present studies when regarded strictly from the point of view of power generation. As may be seen by reference to Table 7-1, the powerplant would have the maximum installed capacity (400 MW), and would yield the maximum average annual firm

TABLE 7-1

COST OF ENERGY

Alternative	A	B	C	D	E
Installed capacity-MW	400	330	300	300	330
Annual generation-GWh	1752	1446	1314	1314	1301
Deduct 5% for transmission losses and station service-GWh	88	72	66	66	65
Firm annual energy-GWh	1664	1374	1248	1248	1236
Capital cost including IDC at 3% - $Billions (1)	1.5	1.45	1.6	1.65	1.32
Annual cost 3.99% including interest, amortization and insurance for 50-year project life - $Millions	59.9	57.9	63.8	65.8	52.7
Net cost of energy - Mills/kWh	36	42	51	53	43
O&M - Mills/kWh	1.5	1.5	1.5	1.5	1.5
Total cost of energy - Mills/kWh	37.5	43.5	52.5	54.5	44.5

(1) Excluding Owner's costs and escalation.

energy (1664 GWh) at the lowest unit cost (37.5 mills per kWh). It is considered that these figures can safely be regarded as conservative for the reasons set forth in Section 7.1.1 above.

This alternative would provide neither instream flow releases nor fish passage facilities at the lake outlet and should, therefore, be regarded as a hypothetical case giving the theoretical maximum energy potential that could be developed.

7.1.4 Alternative B

This alternative follows the same basic layout as that for Alternative A, but approximately 19% of the average annual flow of water into Chakachamna Lake, during the period of outflow gauge records, would be reserved for release into the Chakachamna River near the lake outlet, to satisfy the tentative minimum instream flow requirements discussed in Section 7.3.2 of this report. This would cause the installed capacity to be reduced from 400 MW to 330 MW. The average annual firm energy would reduce to 1374 GWh at a unit rate of 43.5 mills/kWh. This is 16% higher in cost than for Alternative A but is still significantly less than the 55.6 mills/kWh which is the estimated cost of energy from the most competitive thermal source, a coal fired plant, as discussed in Section 9.4 of this report. Alternative B has the advantage that instream flows are provided in the Chakachamna River for support of its fishery and based on the tentative amount of water reserved for these instream flow requirements, the project would still be an economically viable source of energy.

Alternative B does not include a design concept for a fish passage facility that would maintain a means of entry into and exit from Chakachamna Lake for migrating fish but an allowance for the cost of one was included in the estimate. A concept was developed in the 1982 studies and is discussed below in Section 7.1.6, Alternative E.

7.1.5 Alternatives C and D

Both of these alternatives would divert water from Chakachamna Lake to a powerplant located near the downstream end of the Chakachamna Valley. For Alternative C, all controlled water would be used for power generation. For Alternative D, water required to meet the instream flow releases discussed in Section 7.3.3 of the report would not be available for power generation. This water amounts to 30 cubic feet per second average annually, which is less than 1% of the total water supply. Being that small, it can be ignored at the present level of study.

As may be seen from Table 7-1, the installed capacity for both Alternatives C and D would be 300 MW. The average annual firm energy would be 1314 GWh at 52.5 mills/kWh for Alternative C and 54.5 mills/kWh for Alternative D. The installed capacity and energy that would be generated by Alternatives C and D are significantly less than in the case of both Alternatives A and B, and the cost of energy is significantly higher. Alternatives C and D are inferior in comparison with Alternatives A and B as sources of hydro power. At 55.6 mills/kWh, energy from a coal fired plant would be only marginally more expensive than the energy that could be generated by implementing Alternatives C or D.

7.1.6 Alternative E

This alternative incorporates all the principal features of the power facilities for Alternative B. In addition, the normal maximum oprating water level in Chakachamna Lake would be raised to El. 1155, which is reported as the high lake water level under natural conditions, by constructing an overflow rockfill dike in the natural outlet channel. The dike will provide an artificial barrier such as the natural barriers that have built up in the past for various periods of time before they were washed away during the passage of lake outbreak floods. The artificial barrier would be protected against overtopping by an unlined spillway channel excavated in rock on the right abutment. Material excavated to form this channel would be used to construct the dike. The discharge capacity of the channel would be in the order of 50,000-60,000 cfs but future studies of flood hydrology are needed to establish the appropriate capacity. Flood discharges exceeding the designed channel capacity would be discharged over and through the rockfill dike.

Since the only foundation available for a dike at this location is the glacial deposited rock and gravel which undergoes small movements, intermittent maintenance will be required. This could be performed each year, or as required, during the spring while the lake level is drawn down below the level of the dike foundation.

The normal operating range of lake level will be 72 feet, from El. 1155 to El. 1083. This will support a capacity of 330 MW at 50% load factor except for 1-month during

the 31 year extended hydrological record, or a true firm capacity of 330 MW at 45% load factor throughout the entire period. The average annual firm energy will be 1301 GWh at a unit cost of 44.5 mills/kWh. Facilities will be provided for the discharge of instream flow releases to the Chakachatna River, and for the upstream and downstream passage of fish into and out of the lake over the full operating range of lake water level.

7.2 Geological Evaluation

7.2.1 Chakachatna Dam

Although suitable dam sites might appear to exist in the canyon like topography along the Chakachatna River about six miles downstream from Chakachamna Lake, the geologic characteristics of the canyon suggest that construction of a major dam there is unlikely to prove feasible, and if such construction is attempted, it is likely to be very costly and a complex engineering problem for the reasons discussed below.

As discussed in Section 5.2.2, there is a marked difference in the bedrock from one side of the Chakachatna Canyon to the other. The south side of the canyon consists of a steep wall of glaciated granite, which appears to be well suited for a dam abutment. In contrast, the north wall of the canyon exposes a complex of geologic units dominated by lava flows, pyroclastics, and volcaniclastics, but including outwash and fill. If the ideas presented in Section 5.2.2.2 are basically correct, the volcanics may overlie alluvium below the present valley floor; both the volcanics and the alluvium

rest on granitic bedrock at an unknown depth below the valley floor. In addition to specific adverse foundation conditions suggested by deposits found on the north valley wall (e.g. high permeabilities, low strength), the chaotic character of those deposits would make the prediction of foundation conditions at a given site very difficult.

Any impoundment in the Chakachatna Canyon will be subject to the volcanic hazards associated with Mt. Spurr (Section 5.2.2.2). The youthfulness of Mt. Spurr, as a whole, and the fact that it has been active in historic time suggest that continued eruptive activity should be factored in as a design consideration for any facilities in the Chakachatna Canyon.

7.2.2 Alternative A

On the basis of the observations made during the 1981 field program, it is possible to comment on several geologic factors that may influence consideration of Alternatives A, B and E, (see also Sections 5.2.1.6, 5.2.2.3, 5.2.3.4, and 5.2.3.3.).

(1) Although any lake tap site between the lake outlet and First Point Glacier would be subject to impact from a very large eruption of Mt. Spurr, no site in that area is likely to be disturbed by Crater Peak type events (Section 5.2.2.2).

(2) The bedrock characteristics pertinent to tunnelling have not been specifically studied;

this should be a subject of future study. General observations in the Chakachatna Canyon, aerial observations of snow-and-ice-free bedrock exposures between the Chakachatna and McArthur canyons, and general observations in the McArthur Canyon suggest that bedrock conditions are likely to be well suited to tunnel construction, with the exception of the lowermost portion of the canyon, near the Castle Mountain fault. The Castle Mountain fault, which has had Holocene activity along at least part of its length, is present near the mouth of the canyon and has apparently disrupted the bedrock (shears, intense jointing) in the lower reaches of the canyon. For any project facilities constructed in the fault zone, there would be a risk associated with fault rupture; large ground motions would likely occur during an earthquake on the fault. One of the design alternatives presented in this report include facilities in the fault zone, as it is now known. Additional work is needed in future explorations of this area.

(3) Slope conditions above both the proposed lake tap site and outlet portal site are generally similar in that there is no evidence of large-scale slope movements in the recent past and rockfall appears to be the dominant slope process. Talus at the base of the slope at the proposed outlet portal/powerhouse site (Figures 3-1, 3-2) suggests a significant amount of rockfall activity in post-glacial time.

(4) As discussed in Section 5.2.1.4, a significant advance of Blockade Glacier could disrupt drainage in and near the lower reaches of the McArthur Canyon. There was no evidence identified during the 1981 field work to suggest that such an event is likely in the near future.

7.2.3 Alternative B

The comments in Section 7.2.2 apply to this alternative, also.

7.2.4 Alternatives C and D

On the basis of the observations made during the 1981 field program, it is possible to comment on several geologic factors that may influence consideration of Design Alternative C (and D); see also Sections 5.2.1.6, 5.2.2.3, 5.2.3.4, and 5.3.3.3.

(1) In this alternative, both ends of the hydroelectric system would be subject to the volcanic hazards associated with Mt. Spurr. Comment No. 1 for Alternative A (Section 7.2.2) applies here, also. Volcanically-induced flooding is judged to be the volcanic hazard most likely to affect the outlet portal/powerhouse site (Figure 3-3) in the Chakachatna canyon.

(2) On the basis of general observations (i.e., not observations specifically designed to assess tunnelling conditions), the granitic rock types that predominate in the area of the proposed

tunnel alignment (Figure 3-3) are generally well suited for tunnelling. Local zones of intensive weathering, alteration, or extensive jointing and shearing may provide poor tunnelling conditions.

(3) The slopes above both the lake tap and outlet portal sites consist of glaciated granitic bedrock. No evidence of large-scale slope failure was observed during the 1981 reconnaissance field work. Rockfall appears to be the dominant slope process.

7.2.5 Alternative E

The comments regarding the power facilities in Section 7.2.2 apply equally to this alternative. The following comments apply to the facilities proposed to be located in the general vicinity of the lake outlet.

(1) The inlet portal for the structures required for instream flow releases and fish passage facilities will be located in glaciated granitic bedrock. No evidence of large-scale slope failure was observed in this area.

(2) The spillway channel will be excavated in the same glaciated granitic bedrock.

(3) The approach channels to the fish passage facilities and spillway will be excavated in fluvial sediments deposited in a fan to the south of the lake outlet.

(4) Tunnelling conditions for the fish passage flumes and instream flow releases will be as described in Section 7.2.4 (2) for the power tunnel in Alternatives C and D.

(5) The outlet structure and lower part of the fish passage flumes downstream from the tunnel portal will be constructed as a cut and cover structure in outwash materials and alluvium.

(6) The left abutment and river channel section of the dike will be constructed on debris covered glacial ice. The right abutment will be on glaciated granitic rock.

7.3 Environmental Evaluation

The preliminary environmental overviews presented in the following sections for each project alternative are based on data obtained from agency personnel, available literature, and the information collected during the 1981 and 1982 field programs. Although a complete evaluation of all influences of each alternative is not included in this section, the anticipated major effects of each alternative are presented. These potential effects should not be considered definitive, and are only included at this time to facilitate comparisons of the alternatives. The recommended Alternative E is discussed in more detail and the effects on aquatic and terrestrial biological resources are identified.

7.3.1 Chakachatna Dam Alternative

If a dam was constructed and operated on the Chakachatna River, it is likely that substantive adverse impacts would be inflicted on fish of the Chakachatna drainage. A fish passage facility, somewhat similar to that described for Alternative E, would be necessary to preserve stocks of anadromous fish which spawn above Chakachamna Lake. If such passage was not provided the 41,000 sockeye which are estimated to spawn above the lake (Section 6.8.3) and their contribution to the Cook Inlet Fishery would be lost. The Dolly Varden population which migrate to and spawn in tributaries above Chakachamna Lake would also be lost. If passage was maintained impacts to those populations could be similar to Alternative E.

Siting of the dam at the mouth of the canyon would result in the loss of slough spawning habitat for coho, pink, sockeye, and chum salmon and Dolly Varden in that area (Section 6.8.3).

Due to the water quality alterations in the river downstream from the dam, the use of some fish migratory and rearing habitat may be reduced. This, in turn, could adversely impact Cook Inlet commercial fishery resources.

If a large decline in the lake fishery occurred, wolves, bears, and eagles would probably migrate to lower elevations, thus increasing the density of animals in the remaining forage areas. Other large mammals that ordinarily utilize the Chakachatna River canyon for migration to and from summer and winter range would

probably also be impacted. Since the canyon area upstream from the dam would be flooded, a high quality visual resource will be affected by the loss of the white-water reach of the river. In addition, fluctuating Chakachamna Lake water levels associated with all alternatives will impact the scenic quality of the lake shoreline. If the lake levels are raised so that the tributary deltas are inundated, additional juvenile rearing and spawning areas may be created for resident lake fish, (primarily lake trout) and anadromous fish if passage past the dam is maintained.

Although fishing and hunting access to the lake by wheeled airplanes would be reduced, access by float plane will be unaffected.

Construction impacts due to this alternative would be more extensive than other alternatives where less area would be affected and where the need for such large volumes of construction materials is not required. Although the impacts from this alternative may be severe in that a major fishery could be adversely affected or lost, many of the impacts, including the damage to the aquatic resources, potentially could be mitigated, primarily through the installation of appropriate fish passage structures.

7.3.2 McArthur Tunnel Alternatives A and B

Through the implementation of Alternatives A or B, the impacts resulting from construction and logistical support activities would be very similar. In these alternatives, although the major impacts most likely will

be inflicted on local fish and wildlife, human and visual resources will also be affected. For example, with increased access to the McArthur Canyon and Chakachamna Lake, important visual resources as well as fisheries and wildlife habitat may be degraded.

Once in operation, the increased flows in the McArthur River may result in changes in water quality and alterations in the chemical cues that direct anadromous fish to their spawning grounds. This could cause additional losses of spawning adults through or reduce the productivity of spawning areas through crowding and redd superimposition. Although the possibility also exists that the population of salmon will increase in the McArthur River, predation may also increase. If large mammals begin to concentrate in these high density fish areas, sport and subsistence hunting pressure will probably also increase.

The major difference in these McArthur tunnel alternatives is that in Alternative A, no water would be provided in the upper reaches of the Chakachatna River, while in Alternative B, some flow would be maintained. Alternative A would likely result in a total loss of the population of sockeye salmon which spawn upstream of Chakachamna Lake. The estimated escapement of sockeye upstream of the lake was 41,000 fish during 1982. This would also cause the loss of their contribution (presently unknown) to the Cook Inlet fishery. In addition, because no maintenance flows would be provided below the lake, the spawning, rearing and migration of salmon and resident fish in the Chakachatna River drainage would likely be significantly and adversely affected. Estimated escapement of salmon below the lake

is over 16,000 fish (Section 6.8.3) which could be lost. In Alternative A there is a significant potential to drastically reduce the populations of salmon which are represented by the estimated escapement of over 57,000 salmon in the Chakachatna drainage.

Alternative A provides no fish passage to and from the lake. The sockeye salmon and Dolly Varden which spawn above the lake would not be able to ascend to the lake unless the lake level exceeded the present channel invert (El. 1128) by at least 1 ft at the lake outlet. Downstream migrants could not pass from the lake unless the water was at this level or if they passed through an outlet structure which would provide the mitigative flow. The impact of this alternative without provision for a fish passage structure could be substantial.

Alternative B would provide for year round flow releases to the Chakachatna River (Table 7.2). The amounts of instream flows selected are approximately 30 percent of the average annual flow during May through September and between approximately 10 percent of the average annual flow during the winter months, October through March. April flows are intermediate. These flow quantities are very tentative and the final recommendations regarding flows to be released to mitigate potential adverse impacts will be based on further studies to be performed in the future, and may be greater or less than the values presented herein. The implementation of Alternative B should inflict less adverse impact on the fish which

Table 7.2 Natural and Alternative B regulated mean monthly and mean annual flow at the Chakachamna Lake outlet.

Month	Mean Monthly Flows Natural (cfs)	Regulated[a] (cfs)
Jan	613	365
Feb	505	343
Mar	445	345
Apr	441	536
May	1,042	1,094
Jun	5,875	1,094
Jul	11,950	1,094
Aug	12,000	1,094
Sep	6,042	1,094
Oct	2,468	365
Nov	813	365
Dec	1,206	360
Mean Annual Flow	3,645	679

a Regulated flows were estimated using the Montana Method as described in Section 6.2.2.1

spawn and rear below the lake, than Alternative A. The severity of adverse effects upstream of the lake would depend on reservoir operation and the mitigative measures taken. While no specific design concept was developed for fish passage facilities that would permit fish to pass into and out of the lake, an allowance was included in the estimates for the cost of one. The influence on the human resources will probably also be less severe since the commercial fishery will probably not be as heavily impacted, but the impact due to the loss of a portion of the lake tributary spawning could be substantial.

While the impacts related to Alternative A affecting local resources would be difficult to mitigate and significant changes in both the distribution and abundance of fish and wildlife populations would almost certainly occur, the impacts resulting from Alternative B would be less severe primarily through the installation of fish passage structures and maintenance of adequate downstream discharge.

It should be noted, however, that while not directly stated, the loss of spawning areas, and juvenile habitat due to any of the project alternatives will most likely eventually manifest itself as a decline in the population of adult fish as well. In addition, since eggs, fry, and juveniles of all species provide food (prey) for other species, losses of spawning and nursery areas will almost certainly result in eventual reductions in the standing crop of their predators. For example, losses of juvenile sockeye salmon in Chakachamna Lake would probably also result in an overall decline in lake trout.

Potentially, one of the more substantial influences to important floodplain riparian habitats and wildlife distributions from the McArthur alternatives is the disposal of large quantities of waste rock in the McArthur valley. Without proper site selection, stockpile design, and erosion control, this disposal could significantly alter valuable riparian habitats, and detrimentally affect wildlife species that rely upon these habitats. Moose, ptarmigan, small mammals, and passerine birds would be most likely affected from substantial floodplain habitat alterations.

7.3.3 Chakachatna Tunnel Alternatives C and D

Through the implementation of Alternatives C or D, the impacts resulting from logistical support or construction activities would be similar. However, since all activities are restricted to the Chakachatna flood-plain in these alternatives, the resources in the McArthur drainage will not be affected. Although impacts on the wildlife populations may occur, significant impacts will occur to the fisheries. Since access to Chakachamna Lake will be increased, sport and subsistence fishing pressure may increase. With the road, campsite and disposal site for rock excavated from the tunnel, all located in the Chakachatna canyon, an important visual resource will be modified. In addition the presence and activity associated with these facilities may impede large mammal movements through the canyon temporarily during construction of the project. Depending upon facility locations and activity levels, large mammal movement patterns may also be affected during project operation.

During the pre-operational phases, the fishery in the Chakachamna drainage will probably only be impacted to a small extent over a relatively short term. Above the powerhouse, the impact on the Chakachatna River and Chakachamna Lake fishery will be dependent on whether flows are maintained and fish passage facilities provided. Alternative C does not allow for these mitigative measures. Therefore, the impacts to the fishery in or above the lake, and thus the wildlife and commercial fishery in the surrounding area will be similar to that inflicted through Alternative A. Since Alternative D does provide flows (Table 7.3) and migratory passages, the impacts would be similar to those described for Alternative B, but with substantially less adverse impact below the powerhouse due to the higher flows released by that facility.

Within the project area, some resources will be affected no matter which alternative is chosen. This is particularly true of scioeconomic, land use, and transportation characteristics. Through the implementation of mitigative measures, it may be possible to offset many of the adverse impacts. However, the mitigation technniques outlined will probably not restore the environment to pre-operational condition.

Table 7.3 Natural and Alternative D regulated mean monthly and mean annual flows at the Chakachamna Lake outlet.

Month	Mean Monthly Flows Natural (cfs)	Regulated[a] (cfs)
Jan	613	30
Feb	505	30
Mar	445	39
Apr	441	30
May	1,042	30
Jun	5,875	30
Jul	11,950	30
Aug	12,000	30
Sep	6,042	30
Oct	2,468	30
Nov	1,206	30
Dec	1,206	30
Mean Annual Flow	3,645	30

a Regulated flows were assumed to be sufficient minimum flows to maintain migratory passage as described in Section 6.2.2.1.

7.3.4 Recommended McArthur Tunnel Alternative E

This section presents an identification of some potential effects of the recommended project alternative, Alternative E. The identification of effects is based upon data developed during the course of studies carried out during 1981 and 1982. This evaluation addresses the potential effects of project construction and operation on the aquatic, wildlife and botanical resources of the site area. Evaluations of potential effects on aquatic habitats and aquatic biota are based upon hydrological and fisheries studies conducted during 1981 and 1982. Evaluations of potential project effects on terrestrial biota are based on 1981 reconnaissance data. The larger data base available on the hydrology and fishery resources of the study area allowed a more detailed examination of potential effects on these resources.

7.3.4.1 Potential Effects on Aquatic Biota

Construction and operation of the proposed Chakachamna Hydroelectric Project will result in changes to the aquatic habitat and associated fishery resources in the McArthur and Chakachatna Rivers, Lake Chakachamna, and tributaries upstream of Lake Chakachamna, such as the Chilligan and Igitna Rivers. This section examines potential effects of project Alternative E on the aquatic biota.

In this section the term "impact" refers to both direct and indirect effects on fish and aquatic biota, including the utilization of aquatic habitats resulting from project-induced changes in the physical characteristics of the environment. Impacts on the fishery can be either beneficial or adverse.

The description of anticipated effects presented below is a generic identification of changes to fish habitat and direct effects on the fishery likely to occur during the construction and operation of this project. It is based on available baseline information on the biology of the fishery resources found in the McArthur and Chakachatna systems, identification of potential changes in physical characteristics, and the effect of habitat alterations from similar activities as found in the literature.

7.3.4.1.1 Construction of the Chakachamna Hydroelectric Project and Related Facilities

The construction effects that could potentially result in changes to the fishery resource fall into three major areas of construction-related activity:

- Effects of permanent or temporary alterations to water bodies (i.e., dewatering, alteration of flow regime, or alteration of channels);
- Changes in water quality associated with alterations to the water body, or with effluent discharges and hazardous material spills; and
- Direct effects of the construction activities (i.e., use of chemicals, noise, heavy equipment operation, etc.).

Alteration of Water Bodies. Few alterations of water bodies are expected during the construction phase of the project. However, alterations may be associated with the following construction activities:

- o Installation of bridges or culverts for roads and rights-of-way;

- o Re-routing of runoff from camps and materials storage areas; and

- o Re-routing of flow in areas of near-stream or in-stream construction.

Bridges and/or culverts will need to be installed to provide road access over streams and other waterways. Properly designed bridges and culverts, installed so as to prevent perching and high water velocities should have few adverse impacts on waterways. During construction or installation of the bridges/culverts, some local increases in turbidity and localized disturbance would be expected, but these should be of relatively short duration. Potential impacts of temporary increases in turbidity on aquatic biota are discussed under water quality (below).

Alteration of waterbodies resulting from the logistical support activities associated with the Chakachamna Hydroelectric Project will most likely be small in areal extent although the specific extent and potential for impact will be dependent upon the period of construction and the mitigative measures used.

Re-routing of runoff from camps, materials storage areas and construction sites is expected to affect small areas, primarily in the McArthur River canyon. The re-routing is expected to primarily involve re-routing of surface run-off, where silt and soluble materials would otherwise be carried into the waterbody. Some re-routing of in-channel flows may be necessary to allow construction activities in certain

site areas. Presently, there are insufficient data to identify the extent of these areas. For example, in the McArthur River canyon in-channel re-routing may be necessary to allow the construction of the powerhouse and tailrace, and disposal of tunneling spoils. Such re-routing should only affect a small area in the immediate area of construction. The resulting impacts could include a potential loss of some spawning and rearing habitat and some degradation of downstream habitats. The extent of this loss cannot be determined at this time. The channel structure in this immediate area does not appear to be very stable, and therefore the significance of the loss is unclear. The re-routing of flow in some construction and camp areas may be permanent.

Changes In Water Quality. There are a variety of water quality impacts that could potentially occur during construction. These generally involve the discharge of silt-laden waters from various areas and effluents. Peters (1979) noted that under present environmental legislation and by use of current engineering practices, most impacts due to such discharges can be mitigated, if not eliminated altogether.

Silt-laden waters from collected run-off and from excavation of facilities, could represent a considerable source of silt and turbidity to the river unless they are held in detention ponds before being discharged. Spoils will be disposed of or stored at the headwater area of the Chakachatna and McArthur Rivers. Spoil at the upper McArthur River canyon will result from tunneling and powerhouse excavation. Much of this will be used for construction of river training works needed to protect the

powerhouse tailrace channel from erosion and damage by the river. The disposal area for excess spoil will be located so as to avoid significant adverse effects. Spoils in the Chakachatna drainage would include materials removed from the spillway channel, gate shaft excavation, fish passage facilities and tunnel excavation. Some spoil will be used to construct the outlet structure dike, while the excess will be disposed of in location yet to be determined and selected so as to minimize adverse environmental impact. Disposal areas will be diked, and run-off controlled to minimize sediment discharge into waterways. Settling ponds will be used for sedimentation of suspended silts prior to discharge to reduce potential impacts.

The primary change in water quality that may occur from construction is increased turbidity. This may be produced by increased erosion associated with disposal of tunnel spoils and construction activities. Turbidity originating from run-off and construction is often associated only with actual clearing activities and rainfall events. The increases in turbidity in the Chakachatna disposal area would occur near maximum lake levels (El. 1140). Increases in turbidity would vary with the type, extent and duration of construction activity, but would be expected to be local in nature and of relatively short duration.

Increased turbidity can reduce visibility and decrease the ability of sight-feeding fish (e.g. salmonids) to obtain food (Hynes, 1966 and Pentlow, 1949). In addition, salmonids may avoid spawning in turbid waters (Dehoney and Mancini, 1982), and many fish, particularly older life-stages, may completely avoid waters containing high turbidity. However, the turbidity increases in mainstem areas of the

Chakachatna and McArthur Rivers would be expected to have a lower potential for adverse effect on fish due to the naturally high turbidity levels found in these water bodies.

Siltation (sedimentation) is often associated with construction activities. There is a considerable amount of literature dealing with the effects of siltation on aquatic biota (Burns, 1970; Shaw and Maga, 1943; Ward and Stanford, 1979), particularly the effect of siltation on salmonid spawning and incubation. A general conclusion reached by a review of the literature (Dehoney and Mancini, 1982) is that siltation and turbidity impacts have their greatest adverse effects on eggs and larval fish. In general, siltation can cause a significant loss of incubating eggs and pre-emergent fry in redds. This is generally a result of interference with water and oxygen exchange in redds. Upwelling flow in affected areas may tend to reduce such impacts by reducing the amount of sediment which settles into the redd.

Release of suspended materials can also affect other water quality parameters including dissolved oxygen, BOD, trace metals, and pH (Pierce et al., 1970).

The production of concrete for construction of the fish passage facility and powerhouse may result in the production of concrete batching waste. Peters (1979) points out that the discharge of this waste, if untreated, could lead to detrimental effects on fish populations and habitat. A particular problem with this waste is its high pH (10+) and the need to neutralize it (pH 7) prior to discharge. It is expected that this waste will be treated as required by the anticipated project NPDES permit.

During peak construction activity, facilities to house workers will be located primarily in the McArthur floodplain. The housing and supply storage area will occupy 20 to 30 acres. Due to the presence of a large construction force in the area, sanitary waste will need to be treated and discharged. The extent of treatment of sanitary waste, its volume, and the point of discharge will control the extent of potential impact. Wastewater effluents can affect BOD, and therefore the dissolved oxygen, pH, nutrients, trace metals, and buffering capacity of the receiving water. Such effluents can thus affect the water quality of the fish habitat (USEPA, 1976; AFS, 1979; Hynes, 1966).

Hazardous materials may also be used during construction activities of the project. Although hazardous material spills are generally of short duration, they may have severe impacts depending upon the substance spilled. A number of factors will affect the severity of a spill on fish:

- The toxicity of the substance spilled,
- The duration and frequency of the spill,
- The quantity spilled,
- The fish species present,
- The fish life stages present,
- The season (time), in which the spill occurred, and
- Mitigation and clean-up provisions.

Any substance used around the site, or waste produced on-site, could potentially be spilled directly into a waterbody. In general liquids used in large quantities and over greater areas, including fuels and lubricating oils, would be more likely to be involved

in spills. Diesel oil, for example, will be used and stored in large quantities on-site. In general, spills will be most serious if they occur in areas of high biological (e.g., spawning) activity and are not dissipated quickly, or if a large area is affected.

As in the case of siltation and turbidity, the less mobile life stages are most likely to be adversely affected, since older juvenile and adult fish can usually leave an affected area. Good engineering practices, and a thorough spill control plan should greatly reduce the potential for such impacts.

Direct Construction Activities. Direct construction activities include activities that can be expected to occur throughout the construction of the project. These activities, for the most part, will be confined to specific areas.

During construction, some of the first activities to occur will include the construction of access roads, clearing of construction areas, stockpiling of construction materials and fuel, movement of heavy equipment, and construction of support facilities. Activities associated with support facility construction will include cutting and clearing in areas near several streams.

The removal of ground cover during this project will be minor but may locally increase the potential for greater run-off, erosion, increased turbidity and increased dissolved solids (Likens et al., 1970, Boreman et al., 1970 and Pierce et al., 1970). The extent of impacts can be minimized through the use of mitigative practices to control erosion and related sedimentation and turbidity.

The removal of bank cover may locally increase the exposure of fish to terrestrial predators and lead to a decrease in their populations (Joyce et al, 1980).

There are no plans for regular operations of heavy machinery in streams. The primary use of heavy machinery would be during the re-routing of flow. The extent of potential impacts due to siltation and turbidity should be short-term and dependent upon the extent of machinery operation and the type of substrate in the streams affected (Burns 1970). Smaller substrates tend to be more affected (Burns, 1970). However, if water velocities are sufficiently high, the deposition of suspended sediments may not occur locally, and the effects could be minor (Shaw and Maga, 1943).

Current construction plans do not require in-stream blasting.

As part of the construction activities, water will be diverted from the streams in the construction area to be used for dust control, drinking water, fire-fighting water, sanitary water, concrete batching, and wet processing of gravel among other uses. The diversions will probably be accomplished by pumping from local stream segments and intakes will be screened and designed to use very low velocities to avoid fish impingement and entrainment.

Operation of the camps will also result in increased access to an area that has previously experienced relatively little fishing pressure. The areas potentially affected would be those stretches of the McArthur River and its tributaries that are easily accessible by foot from the camp.

7.3.4.1.2 Operation of the Chakachamna Hydroelectric Project and Related Facilities

Potential impacts of the operation of the project (Alternative E) are expected to occur to the aquatic biota through:

- o Changes in aquatic habitat,
- o Direct effects on aquatic biota, and
- o Effects on fish passage into Chakachamna Lake.

Effects are expected to vary between waterbodies and can be evaluated separately for the following:

- o Chakachamna Lake and tributaries,
- o Chakachatna River, and
- o McArthur River.

Hydrological alterations are discussed first, and are then followed by the effects of those alterations on the aquatic biota.

Chakachamna Lake and Tributaries. Chakachamna Lake will be affected by a 72 ft annual water level fluctuation during proposed project operation. The maximum proposed reservoir level of 1155 ft is near the maximum historical lake level; this level will occur seasonally under post-project conditions. Minimum reservoir levels will be approximately 45 ft below pre-project minimum levels. Such a drawdown will expose lake shoreline and stream deltas which are normally inundated. Lake levels will vary in Chakachamna Lake and will result in increased inundation of lakeshore and delta areas during high reservoir levels; dewatering of submerged shoreline would occur during periods of drawdown.

The project effects on the water quality of Lake Chakachamna may include increased suspended sediment and turbidity concentrations near tributary mouths. The potential sediment inflow from the tributaries is discussed below.

The channel gradient of the Chakachamna Lake tributaries will be affected by the drawdown and fluctuation of the reservoir level. Maximum water levels will cause inundation of the lower reaches of streams which are not normally affected; minimum water levels will expose the entire stream delta surface and the upper portion of the steep delta front. Resulting changes in stream gradient will be progressive and sequential. These will likely be similar at the mouths of all tributaries, but to different degrees. The anticipated changes due to seasonal minimum reservoir levels include:

- Dewatering of over 7 mi^2 of delta area;
- Increase in stream gradient and accompanying erosion where the stream flows down the front of deltas;
- Development of new deltas;
- Eventual channel degradation at the tributary mouths to near the lowest regulated reservoir level; and
- Degradation upstream as far as is required for the stream to reach equilibrium between the streamflow regime during low reservoir levels and the materials through which it is flowing; possibly

resulting in localized rapids during the low water period, if erosion resistant materials are reached.

Maximum reservoir levels can cause deposition of stream-borne sediments in those reaches of stream affected by backwater from the reservoir. Some of the deposited sediments would likely be eroded as the reservoir level drops through the winter. Break-up flows may remove the rest of the deposits.

According to the proposed reservoir operation schedule, the reservoir will be at maximum level during September and drawn down to lower levels over the winter with a minimum level occurring during April or May.

Habitat Effects - The operation of the reservoir should have effects on the fish rearing habitat within the lake. During open water, juvenile sockeye, lake trout, round whitefish and Dolly Varden are found throughout the lake with many fish found offshore along steep drop-offs and just under the ice in winter. It is unclear what the effect of changing water levels may have on winter water temperatures or habitat use, particularly near shore.

At high reservoir levels (during October and November) lakeshore areas may be used as spawning habitat by lake trout. After reservoir levels drop, incubating eggs and fry may be exposed to freezing or dessication. Relatively immobile invertebrates which reproduce in shoreline areas may also be affected. There are, presently, insufficient data to assess the impact of such effects on lake trout populations and standing crop of benthic invertebrates, although the effects could be substantial.

Lake levels will be near minimum level at break-up, at which time the principal movement of fish consists of emergent fry moving from their tributary rearing areas to the lake. It is not expected that the high gradients to the lake will adversely affect these migrants.

During the period in which sockeye salmon and Dolly Varden spawn in tributaries above the lake, reservoir levels will be greater than pre-project lake levels. This will potentially result in lake water flooding downstream areas of the Chilligan River and the Kenibuna Lake/Shamrock Lake rapids. The effect of the lake water on the utilization of the lower areas of the Chilligan River is not presently known but there is some evidence (which follows) that this may not be an important effect. The area at the mouth of the river contained a low density of spawning sockeye compared to areas further upstream. It was used extensively as a milling area. During September 1982, lake water inundated the area without apparent impact on either sockeye or Dolly Varden spawning. Adverse effects would be expected if flooding of the lower Chilligan River resulted in increased siltation which could affect hatching success (see Water Quality, above).

Direct Effects - The lake-tap (or multiple lake-taps) will withdraw water at approximately El. 974. The submergence depth would vary between 109 ft and 181 ft. Fish that are entrained into the lake tap would be exposed to turbine passage at the powerhouse and most would be expected to be killed by the turbines, or during passage through the pressure

differential between the depth of the lake-tap and the power plant. Juvenile sockeye and both juvenile and adult lake trout, Dolly Varden, and round whitefish may be vulnerable.

Hydroacoustic observations of fish distribution in the lake have indicated that most fish were detected well above the depth of the lake tap. During the winter, over 99 percent of fish were detected in the upper 50 ft of the water column. During September, 1982 over 88 percent of the fish detected were in water at least 60 ft above the proposed lake-tap (at that time of year it would have been located at 181 ft) with no fish detected below 161 ft. Thus, potential loss of fish due to the lake tap based upon current data would be relatively low. However, additional seasonal information would be needed to quantify potential losses.

Fish Passage - Chakachamna Lake - Alternative E includes a fish passage facility which is designed to permit upstream migrants to ascend from the Chakachatna River to the lake and to allow downstream migrants to pass from the lake to the Chakachatna River. The fish passage facilities are described in Section 3.5. Detailed design of the fish passage facility and its hydraulics has not been completed. The upstream passage facility consists of a pool and weir fishway constructed in an underground facility at the lake outlet, and is connected to the Chakachatna River downstream of the facility by a tunnel and smaller fishway. Downstream migrants will be passed through a wheel gate into a stilling basin and from there into a tunnel which connects with the Chakachatna River downstream. A grate at the

downstream end would prevent the entrance of upstream migrants into this facility.

The facility is composed of components found in a variety of existing fish passage facilities. Presently, there are insufficient data available to assess the potential effects of this facility on migrating fish in a quantitative manner.

Sockeye salmon and Dolly Varden would be expected to use this facility, as both have been observed to spawn above the lake. Escapement estimates of sockeye indicate that (based upon 1982 data), over 41,000 sockeye (possibly more depending upon yearly variation) would need to successfully pass through the facility to migrate upstream. Since the percentage of the run successfully reaching the Chilligan and Igitna Rivers is not known, the true extent of the sockeye salmon resource can only be estimated. From 10 to more than 100 times as many sockeye can be expected to migrate downstream due to the normally higher production of young fish (Foerster 1968). A smaller number of downstream Dolly Varden would also be expected to pass through the facility. If the facility works as planned the impact to the sockeye run should be low.

If the facility did not successfully allow the migration of sockeye <u>both</u> upstream as adults and downstream as juveniles then some part of the estimated adult spawning population would be expected to be lost, as well as a portion of its presently unknown contribution to the Cook Inlet fishery. As design details are determined, the fish passage facilities will need to be re-assessed in a more detailed fashion.

The release of water from Chakachamna Lake into the McArthur system could potentially result in impacts to fish which would normally spawn in Chakachamna Lake and tributaries above it. While the "homing" of salmon is not completely understood, the orientation of upstream migrants to olfactory cues originating in natal streams has been considered to be a principal factor (Hasler, 1971). Fish entering the system through the Middle River should not be affected by the McArthur release. Fish entering the system through the mouth of the McArthur River may encounter olfactory cues from flows entering the McArthur River at the confluence of the lower Chakachatna with the McArthur River, from the confluence of the Noaukta Slough with the McArthur River, and from water discharged from the tailrace of the power plant located in the McArthur canyon. Fish that entered the Chakachatna River either at the lower river confluence, or the Noaukta Slough would be following what is hypothesized to be the present migratory pathway and would not be expected to be significantly affected by the other power plant discharge; some delay due to confusion may occur. There is a potential for some of the upstream migrants to be attracted to the tailrace in the McArthur canyon. Since the fish could not migrate further upstream into Chakachamna Lake, three basic scenarios could develop:

- The fish could back down the system until they detect alternate olfactory cues (i.e., at the Noaukta Slough) and then migrate up the Chakachatna River,

- The fish could mill in the tail race until sexually matured and then back down the system until alternate cues were detected, or

o The fish could spawn in the McArthur Canyon.

The significance of a delay in migration is not presently known. However, the spawning of large numbers of lake tributary origin sockeye in the McArthur River canyon area could result in low egg hatching success due to high densities of spawning fish and resulting redd superimposition, the use of poor spawning habitat, or females not spawning (Bell 1980). In addition, the rearing habitat in the McArthur canyon is probably less suitable for sockeye salmon than in Chakachamna Lake. Thus, if increased spawning occurred in this area, rearing would probably be less successful.

Chakachatna River. Water releases will be made to the Chakachatna River below the fish passage facility. The quantity of the actual releases is not presently known, and will be based upon future studies. However, preliminary release flows have been estimated as a starting point for analysis (Table 7.4). Such flows constitute a relatively small percentage of pre-project annual flow. Tributary inflow downstream from the lake contributes relatively small quantities of flow compared with pre-project flows at the lake outlet. However, depending upon the time of year, the tributary inflow may substantially increase post-project flows downstream of the release structure. Historical low flows will be substantially reduced by project operation during October through March. Ten percent of the average annual flow is considered to be the minimum for short-term survival of fish and other aquatic organisms (Tennant, 1975). However, in this system, post-project releases from January through April may be less than 10 percent but

Table 7.4 Natural and Alternative E regulated mean monthly and mean annual flow at the Chakachamna Lake outlet.

Month	Natural (cfs)	Regulated[a] (cfs)
Jan	613	365
Feb	505	357
Mar	445	358
Apr	441	582
May	1,042	1,094
Jun	5,875	1,094
Jul	11,950	1,094
Aug	12,000	1,094
Sep	6,042	1,094
Oct	2,468	365
Nov	1,206	365
Dec	813	363
Mean Annual Flow	3,645	685

[a]Regulated flows were estimated using the Montana Method as described in Section 6.2.2.1.

still represent between 60 and 122 percent of pre-project average monthly flows, respectively.

Flood flows would be modified in the regulated flow regime. Chakachatna River flood flows would be smaller in magnitude than past events, but would exhibit a greater variation around a mean flood value due to the relatively small influence of Chakachamna Lake on the post-project river system. The seasonal distribution and hydrograph shape of the annual floods may shift from the mid-summer, long duration floods under the natural flow regime, toward a fall, short duration flood more typical of basins without the storage effects of lakes and glaciers.

The sedimentation characteristics of the Chakachatna River system will change with the regulated flow regime. Sediment transport will decrease in response to decreased flows.

The configuration of certain stream reaches would likely change as a result of the flow alteration associated with the project. The mountainous reaches on the Chakachatna River would retain a single channel steep gradient condition, although it would be carrying less flow. Split channel reaches would likely assume more of a meandering configuration. The braided reaches above Straight Creek and in Noaukta Slough would likely become more stable and the flow would be carried by fewer channels which are characteristics of a split configuration. The lower reaches of the Chakachatna and Middle Rivers would likely retain their meandering configuration.

Ice formation and breakup processes will also likely be affected by the project. The evaluation of the

nature and extent of these effects requires further study.

Mainstem Habitats - The physical effects of the proposed flow reductions are described above. The mainstem habitats appear to be currently used as migratory pathways, rearing areas for sub-adult and resident fish, and there appears to be a small amount of side channel spawning associated with areas of upwelling or slough flow. Table 7.5 lists estimated escapements of fish species for water bodies in the Chakachatna River drainage, classified as to whether the waterbody is likely to be affected by the reduced mainstem flow. The tributary water bodies are not expected to be significantly affected by reduced flows.

Side channels in the Straight Creek mouth area and at station 17 are expected to be most affected. Observations during 1982 have indicated that these areas will probably not be dewatered or perched. The observations have indicated that turbid mainstem overflow, which is present in these areas during higher flows, would be absent. Without the cover provided by this turbid flow, fish spawning in these areas may be more vulnerable to predation. Side channel spawning in both areas represents less than 50 percent of observed spawning at each site. Depth of water at entry points to side channels at station 17 would be expected to be shallow and may adversely affect fish entry.

Based upon 1982 observations, the milling areas at Tributary C1 and at the mouth of the Chakachatna Canyon Sloughs would be significantly less turbid than at present. This may also increase potential

Table 7.5. Estimated escapement of important fish species in the Chakachatna River system by waterbody classified by potential effects of decreased flow of water from Chakachamna Lake.

Species	POTENTIALLY AFFECTED WATERBODIES				POTENTIALLY NON-AFFECTED WATERBODIES			
	More Affected		Less Affected					
	Straight Creek Mouth	Chakachatna Bridge Side Channels and Sloughs	Chakachatna Canyon Sloughs	Chakachatna Tributary (C1)	Igitna River	Chilligan River	Straight Creek	Straight Creek Clearwater Tributary
Sockeye[1] Salmon	203	1,193	392	238	2,781	38,576	0	254
Chinook[2] Salmon	0	0	0	0	0	0	0	1,422
Pink[3] Salmon	0	59	279	0	0	0	0	7,925
Chum[4] Salmon	152	1,482	121	165	0	0	0	0
Coho[5] Salmon	76	1,560	608	183	0	0	0	172
Dolly[6] Varden		X	X	X	X	X		X

[1]Fig. 6.132 and Sections 6.8.3, 6.8.6.1-.5

[2]Fig. 6.134 and Sections 6.8.3, 6.8.6.1-.5

[3]Fig. 6.136 and Sections 6.8.3, 6.8.6.1-.5

[4]Fig. 6.137 and Sections 6.8.3, 6.8.6.1-.5

[5]Fig. 6.138 and Sections 6.8.3, 6.8.6.1-.5

[6]Fig. 6.141 and Section 6.8.6.6

X = Used as spawning areas.

vulnerability to increased predation. The extent of the potential increase in vulnerability to predation of spawning adults at these sites will need to be assessed after more data are collected.

There are a number of fish species which use mainstem and side channel areas as rearing habitat. The effect of decreased flow on the availability and suitability of this habitat can not be determined at this time. While decreased flow will decrease the wetted perimeter and therefore the area of a stream, the decrease is not linearly proportional to the decrease in flow (Tennant, 1975). Additional sources of inflow, including sloughs and tributaries such as Straight Creek, should result in somewhat increased flow downstream of the outlet structure. The additional water sources (Straight Creek, various sloughs, and unnamed tributaries) will reduce effects of the decrease in upstream releases. In areas where pre-project water velocities are too great to contain suitable rearing habitat, decreased velocities could potentially increase suitable habitat. Presently, there are insufficient data to evaluate all expected change.

Decreased flows during winter may cause changes in the ice conditions and also result in decreased overwintering habitat. The actual nature and extent of effects cannot be determined from available data but a significant decrease in mainstem overwintering habitat is likely during the early winter.

Sloughs - Observations made during March and October 1982 have indicated that flow in sloughs located in the Chakachatna River canyon and at station 17 appear to be independent of river flow. It is not expected

that reduced flow in the river will have an adverse effect on these waterbodies. This will need to be confirmed through more detailed study. The overwintering habitat in sloughs should not be affected by reduced flow in the mainstem of the river.

Downstream migrants originating in the Chakachatna drainage may require high seasonal break-up flows to trigger their migration; proposed post-project discharges may not be sufficient to trigger this behavior. However, post-project releases during April and May are greater than pre-project flows and depending upon the timing of outmigration may be sufficient to trigger the downstream movement. Data collected during 1982 suggest that outmigration of chum salmon and some sockeye occurs during late May and early June. Collections made during the summer and fall and in the Susitna drainage suggest downstream migration and smoltification of coho, chinook and sockeye salmon continues throughout the summer and fall.

Some data in the literature indicates that swimming activity, downstream migration, and smoltification of some species may also be controlled by photoperiod (Lorz, 1973; Godin, 1980). If the outmigration is photoperiod controlled, high break-up flows would not necessarily be required. Overall, available data do not suggest that an adverse effect would be expected on stimulation of downstream migration.

McArthur River. The McArthur River will receive flows from the powerhouse ranging from a minimum of approximately 4600 cfs in July to a maximum of approximately 7500 cfs in December. Present flows in the upper McArthur River near the powerhouse are

estimated to average about 600 cfs in July and 30 cfs in December. Thus, flows in this upper section will be substantially increased by the operation of the project during the entire year. The relative magnitude of increase will be less downstream of its confluence with the Blockade Glacier channels. Post-project summer flow in the McArthur River downstream of its confluence with the Noaukta Slough will be less than pre-project conditions due to the substantial decrease in flow through Noaukta Slough.

Floods on the McArthur River upstream of Noaukta Slough would be increased by the operation of the project. The amount of increase will be roughly equivalent to the modification of the base flows upon which the floods are superimposed. That is, the source of the flood waters remains unchanged, but the flow in the McArthur River as the flood begins will be greater. The relative increase in flow would decrease in a downstream direction along the McArthur River. Below its confluence with Noaukta Slough, the McArthur River would likely experience a reduced flood magnitude. This is due to the decrease of inflow from Noaukta Slough during the summer as compared with the inflow under pre-project conditions. Noaukta Slough contributes a greater mean daily flow to the McArthur River from mid-June through mid-September under pre-project conditions than the maximum that will be diverted to the McArthur River for power generation during project operation.

The upper McArthur River will experience increased sediment transport loads due to the larger discharges in the channel. The upstream reaches will likely scour the channel bed to reduce its gradient. In addition, bank erosion will likely increase its rate

and areal extent as a result of the increased flow. Flood discharges in mid-September 1982 caused bed scour and bank erosion, and transported large quantities of sediments along its channel. The magnitude of this short-duration event was approximately 50 percent greater than those expected on a daily basis under post-project conditions.

The increased post-project flows in the McArthur River are not anticipated to cause significant changes in channel configuration. However, some meandering reaches, especially toward the upstream end, may assume split channel characteristics. Further analysis is required to ascertain the effects on channel configuration, of the increased sediment transport into the lower reaches of the McArthur River.

The ice processes in the McArthur River will also likely be affected by the project. Ice formation may be reduced or possibly eliminated by the increased quantity and temperature of flow. Evaluation of these effects requires further study.

Turbidity in the McArthur River canyon would be expected to increase during the winter months. Pre-project winter flow in that area appears to be derived from upwelling and is clear. Water from the powerhouse tailrace would be expected to have a higher turbidity as is normally found in Chakachamna Lake. Turbidity in the lake varies with depth during certain times of the year but is generally similar to that measured near the powerhouse location in the McArthur River. Below the McArthur Canyon, flow from the Blockade Glacier channel is also turbid and therefore

effects below the confluence of that channel should be minimal.

Mainstem Habitat - Mainstem areas of the McArthur River appear to be used as migratory pathways for sub-adult and residential adult rearing, and for spawning in the McArthur River canyon.

Table 7.6 lists escapement estimates of major species that spawn in the McArthur River drainage by waterbody. The only area in which spawning habitat of these species is likely to be affected is in the McArthur canyon. All other listed areas are tributaries. Spawning habitat in sloughs and side channels of the McArthur canyon occur upstream of the powerhouse tailrace. It is unlikely that these areas will be significantly affected. Based upon 1982 escapement estimates, a relatively small percentage of spawning salmon will be vulnerable to changes in mainstem flow. Some fish that normally spawn above Chakachamna Lake may be attracted to the powerhouse tailrace which may affect spawning adults of McArthur origin (see above).

The redistribution of substrate in the powerhouse area may also affect spawning. Presently, there are insufficient data to determine if the effect would be beneficial or adverse to the availability of habitat to spawning adults.

Eulachon spawn in the lower reaches of the McArthur River mainstem, below the Noaukta Slough. Flow alterations are not expected to affect spawning of this species because during the period of eulachon spawning, the continued post-project McArthur River

Table 7.6. Estimate escapement of important fish species in the McArthur River system by waterbody classified by potential of increased flow of water.

	POTENTIALLY AFFECTED AREA	POTENTIALLY NON-AFFECTED AREAS							
					Streams				
Species	McArthur Canyon	Stream 13X	Stream 13U	Combined	12.1	12.2	12.3	12.4	12.5
Sockeye Salmon	666[5]	5,416[6]	1,213[6]	27,636[6]	16,711[1]	6,085[1]	2,512[1]	2,328[1]	-
Chinook Salmon	0[7]	452[7]	1,633[7]	22[7]	-	22[2]	-	-	-
Pink Salmon	60[8]	4,225[8]	5,402[8]	10,090[8]	8,499[3]	1,566[3]	4[3]	18[3]	3[3]
Chum Salmon	1[9]	0[9]	23[9]	5[9]	4[4]	-	-	1[4]	-
Coho Salmon	1,182[10]	1,378[10]	32[10]	2,137[10]	2,000[5]	46[5]	89[5]	-	-
Dolly Varden	X	X	X	X	X	X	X	X	X

X= Probable Spawning areas.

[1]Based on 6 day stream life Table 6.35, Section 6.8.3.

[2]Based on count of live and dead fish Table 6.34, Section 6.8.3.

[3]Based on 6 day stream life Table 6.36, Section 6.8.3.

[4]Based on peak on total counts Table 6.37, Section 6.8.3.

[5]Based on 10 day stream life Table 6.38, Section 6.8.3.

[6]Fig. 6.132

[7]Fig. 6.34

[8]Fig. 6.36.

[9]Based upon 10 day stream life Table 6.37.

[10]Based upon 10 day stream life Table 6.38.

and Noaukta Slough flows are expected to be similar to pre-project flows.

Increased post-project flows will occur above the Noaukta Slough confluence on the McArthur River. The lower post-project flows below the Noaukta Slough confluence during June through September should not have a significant effect on fish passage. It is not clear at this time if the upstream migrants above the slough will even be exposed to significantly higher velocities than they are exposed to by pre-project flows. This will need to be assessed in the future.

Pre-project water temperatures in the vicinity of the proposed powerhouse location have a wide diurnal variation during the open water season. The discharge of Chakachamna Lake water during operation would tend to stabilize the temperatures. Water temperatures at the proposed lake tap depth were as follows:

March	2.1°C
August	6.5°C
September	6.2°C

The temperature of discharged water should be fairly constant and should reduce diurnal variation and maintain temperatures closer to optimal ranges for spawning and incubation for many of the species present (Bell, 1980).

There are a number of fish species which use mainstem habitats in the McArthur River for rearing habitat. Presently, the effect of changes in the flow regime in different reaches of the river at different times of year cannot be determined. Changes in wetted perimeter, depth and velocity for different areas will

affect the overall total suitable area for each species and lifestage. Thus, suitable habitat may increase, decrease, or remain the same. This will also need to be assessed.

Increased flow in the McArthur canyon from the powerplant discharge may affect available overwintering habitat in the McArthur drainage. Data collected during 1982 indicate that the McArthur canyon and areas below it (station 13) may be used as overwintering areas. Increased flow and depth may increase the overwintering area available. Insufficient data are available to assess such changes.

Water discharged from the powerhouse will probably be warmer than water of McArthur origin; 2.1°C, as compared with 1.2°C, respectively, during March 1982. This may result in greater metabolic activity by fish and other aquatic biota during the winter, and result in more rapid incubation and earlier emergence times for McArthur canyon fish. Such emergence times would be similar to those found in the Chakachatna River. It is unclear from present data whether this will have an adverse effect.

Increased post-project turbidity during the winter months should not have a significant adverse effect on fish in the McArthur Canyon. Turbidity levels should be similar to those measured in this area during the spring through fall, and it would be expected that fish are well adapted to them.

There may be a potential for the discharge of dissolved gases at levels greater than 100 percent of gas saturation at the powerhouse. Water discharged at the

powerhouse, entrained at lake tap depths of more than 100 ft, will undergo a pressure change of more than 3 atmospheres. The change in pressure will reduce the amount of gas that the water will hold thus creating the potential for supersaturation to occur. Evidence of a potential for supersaturation was detected during sampling in September 1982. If supersaturation occurs it could have adverse effects on fish in the immediate area of the discharge unless mitigative measures are taken. (Merrell et al. 1971; Blahm et al. 1975, Fickeisen and Schneider, 1976, Bell, 1980).

Sloughs - Some sloughs in the immediate vicinity of the tailrace of the powerplant may become inundated and water velocities may increase. These changes may affect the suitability of these habitats. The extent of such changes cannot be determined at this time.

Tributaries - No significant changes would be expected in McArthur River tributaries due to post-operational flows based upon current data.

7.3.4.1.3 Summary of Potential Effects

Potential effects of the proposed project alternative on the aquatic biota will vary depending upon waterbody and location. Potential effects of construction are likely to be limited in extent and of short duration.Effects may include:

- o Local increases in turbidity, unlikely to affect fish significantly due to already high ambient levels;

- Local increases in siltation and possible degradation of some spawning habitat;

- Local clearing of banks with some increases in water temperatures;

- Re-routing of flow with potential redistribution or loss of existing habitat; and

- Potential spills of materials, which although of brief duration may adversely affect biota.

Operational effects differ according to the waterbody considered. Potential changes in Chakachamna Lake include:

- Potential loss of some lake trout spawning area and fry;

- Seasonal variation in available rearing habitat;

- Flooding of the downstream area of the Chilligan River and some loss of spawning habitat through siltation; and

- Potential fish loss through turbine passage.

The successful operation of the fish passage facility will be necessary for the continuation of the population of sockeye salmon which spawns above Chakachamna Lake. Insufficient data are available to properly assess the operational characteristics of the current design.

Flow reductions in the Chakachatna River will potentially have significant effects on mainstem and

side channel habitats. There are insufficient data to assess potential changes in the suitability of habitat and the net loss or gain of rearing habitat. Some potential effects that can be identified include:

- Decrease in cover provided by turbid water in some side channel spawning areas downstream of sloughs;
- Decrease in cover in some side channel milling areas downstream of sloughs;
- Potential changes in distribution of fish with changes in habitat; and
- Potential loss of some overwintering habitat.

Potential effects of the increased water release in the McArthur River include:

- Potential mis-cueing, straying, and/or delay of fish that normally spawn above Chakachamna Lake through the release of olfactory cues at the McArthur powerplant tailrace;
- Potential loss of some spawning habitat in the McArthur River canyon;
- Potential habitat changes in upper reaches of the McArthur River; the specific nature and extent of such changes cannot be determined at this time;
- Potential decrease in temperature variation in the upper McArthur River resulting in more optimal temperatures for spawning and incubation of some species; and

- o Potential release of gas supersaturated water which could adversely affect fish in the immediate vicinity of the tailrace.

7.3.4.2 Potential Effects on Botanical Resources

The development of a hydroelectric power project at Chakachamna Lake, will result in changes in the distribution and species composition of vegetative communities. Based upon current designs for Alternative E, these changes would occur over a relatively small portion of the project area. Changes that do occur may be beneficial or detrimental to the biota depending upon the type of changes as well as the location, duration and magnitude of change.

7.3.4.2.1 Direct Habitat Loss

Construction of a rockfill dyke and fish passage facility in the upper Chakachatna River canyon and a powerhouse in the McArthur River canyon will necessitate the removal of vegetation over a relatively small area. The powerhouse and fish passage facility will be primarily underground, thus minimizing surface disturbance. The rockfill dyke will be sited in the upper reach of the Chakachatna canyon where the floodplain is unvegetated and the canyon walls and glacial moraine support Sitka alder and willow which are abundant throughout the project area. The areal extent of vegetation removal during road, camp, airstrip, and borrow pit development is not yet known because the location and size of these facilities have not been sufficiently defined.

7.3.4.2.2 Indirect Habitat Alteration

The most notable changes in the distribution of vegetation will likely occur in the lower McArthur River and Chakachatna River canyons. In the lower McArthur canyon, increased flows emanating from the tailrace and the deposition of excavated materials within the floodplain near the powerhouse may reduce the extent of riparian vegetation. In the Chakachatna canyon below the dyke, reduced flows may enable riparian vegetation to become established within what is now the active floodplain. In time, if these riparian thickets do expand, additional habitat for moose, songbirds and furbearers may be provided.

Disposal of materials excavated from the power tunnel and fish passage facility will be stockpiled in the floodplain above the dyke. When the dyke is completed and the lake level raised to an elevation of 1155 ft, this disposal area, as well as portions of the lake shore will be flooded. In the area subjected to the annual fluctuations of lake water levels, portions of the Nagishlamina, Chilligan and other smaller lake tributary deltas will most likely realize a change in their vegetative cover. Vegetation may recede due to inundation and shoreline destabilization. However, such changes are expected to influence only a small area since under pre-project conditions, the lake level only occasionally reaches elevations at or near 1155 ft. Above the high water level, the shore may also develop a different species composition; one more representative of early seral stages and wetter soil conditions (Newburg and Malaher, 1972). The anticipated changes in riparian and shoreline vegetation cannot be further refined until site-specific, field verified, habitat maps have been prepared and the operating reservoir levels better defined.

Downstream from the McArthur and Chakachatna canyons, the influence of altered flows, either increased or decreased, on riparian vegetation will depend upon the direction and magnitude of channel migrations and the amount of floodplain area removed from the influence of flood events. Based upon current information, the McArthur River channel above Noaukta Slough has been naturally migrating and some rechanneling has occurred in the slough under normal flow conditions. Sustained higher flows in the upper McArthur River may result in accelerating this migration. The extent of channel migration is also dependent upon floodplain substrate and bank composition. Until information is available on these parameters, the speed, direction, and magnitude of migration in the upper McArthur River cannot be assessed. The influence of reduced flows in the Chakachatna River and Noaukta Slough may be to reduce the frequency and magnitude of rechanneling in the slough and to remove portions of the now active floodplain from the influence of flood events. Based upon current information, it is not possible at this time to estimate the location, extent or timing of revegetation.

The influence of wind or vehicle-generated dust emanating from cleared areas, roads, and borrow pits may influence the vegetative community composition in the immediate vicinity of these facilities. Accumulations of dust may accelerate the rate at which snow melts (Drake, 1981) and affect the growth of cottongrass and mosses (CRREL, 1980). The extent of vegetation changes due to accumulations of dust will be dependent upon the methods and level of effort exerted to reduce dust.

Off-road use of vehicles in the project area may affect vegetation depending upon the type of vehicle, the time of year, and soil moisture conditions (Sparrow et al., 1978). Currently, no policy exists to control or permit off-road use of the site.

To assess the influences on vegetation of constructing and maintaining a transmission line, the vegetative species composition, transmission line design, and construction and maintenance techniques will need to be established. Since this information is not currently available, the effects of a transmission line on vegetation cannot be evaluated.

7.3.4.2.3 Summary of Potential Effects

Potential effects of the proposed project alternative on the botanical resources will vary depending upon location. Small areas adjacent to project facilities will be influenced by the construction and operation of the project. Such influences may include:

- Increases in bank erosion along the upper McArthur River due to increased channel migration;
- Increases in the extent of riparian vegetation in areas removed from the active floodplain by reduced flows in the Chakachatna River;
- Altered distributions of vegetation along the lake shore and deltas due to higher, fluctuating lake levels; and
- Reductions in vegetative cover and changes in species composition in areas cleared for the roads, airstrip, and borrow pits.

Although it is likely that these vegetation changes will occur, the extent of the change is less than that typically associated with the development of a hydroelectric project. This is because designs for this project have incorporated a lake tap rather than a reservoir and thus:

- Considerably less vegetation needs to be cleared;
- Effects of change in albedo should be negligible;
- The incidence of fire and vegetative disease should be reduced since it will not be necessary to stockpile large amounts of cleared vegetation; and
- The amount of wind-generated dust should be less since a much smaller area will be cleared.

Vegetation in the project area has been dramatically changed through prior development. Roads provide unrestricted access to the lower portions of the area, extensive timber harvesting has greatly reduced the vegetative cover over a large area near the Chakachatna River, and an underground pipeline has been sited on the shore of Trading Bay. It is unlikely that the development of the Chakachamna Lake hydroelectric project would influence vegetative communities to the extent of these prior developments.

7.3.4.3 Potential Effects on Wildlife Resources and Habitats

The construction and operation of the Chakachamna Lake Hydroelectric project will affect the wildlife resources of the area. One means by which wildlife may be affected is through habitat loss due to facility siting. Because the area actually occupied

by a facility is usually small when compared to the total area encompassed by a particular habitat type, unless a facility is sited within a special use area (e.g. calving, nesting, or molting areas), the loss of a small amount of habitat is usually not critical to the future viability of a population.

A second means by which the biological resources may be affected is through habitat alteration. In this case, some phase of development is usually responsible for altering the physical or vegetative conditions. Examples of this include the alteration of river hydraulics, lake morphology, coastal sedimentation, and biological community dynamics. Often when such changes occur, the existing wildlife resources respond with changes in species composition, diversity, and distribution.

The third type of habitat change may occur as a result of an influx of support services. Typically this equates to an increase in the local human population, increases in traffic levels (including air and ground), and increases in noise. These conditions may result in decreased use of adjacent areas by wildlife.

Regardless of which type of habitat change occurs, the response of wildlife will vary with the time of year and the species involved. If the habitat lost is of minor importance and the extent is small, wildlife populations may only abandon or discontinue their use of the affected habitat while remaining in the general vicinity. However, the effect on population levels may be severe if habitats used for important life functions are rendered unusable by intense activity, or large scale habitat loss or change. These important areas include the land and water used for

breeding, nesting, calving, staging, wintering and denning.

7.3.4.3.1 Direct Habitat Loss

Through development of the Chakachamna Hydroelectric Project, direct habitat losses due to facility siting will occur with construction of the dyke, disposal areas, powerhouse, fish passage facility, camps, roads, airstrip, port and docking facilities, and borrow pits. The influence of this habitat loss on wildlife populations should be negligible. The dyke will be sited at the outlet of Chakachamna Lake; an area that receives little use by birds and mammals. The powerhouse and fish passage facility will be located in the McArthur River and Chakachatna River canyons, respectively. Because these facilities will be primarily underground, relatively small quantities of surface habitat will be lost. Although the exact size and precise location of the remaining facilities have not been determined, each will occupy a relatively small amount of habitat in an area that is not considered to be essential to any species of bird or mammal. It is assumed that development of disposal areas in both the McArthur and Chakachatna floodplains will result in the largest habitat loss, and greatest disturbance to birds and mammals.

7.3.4.3.2 Indirect Habitat Alteration

Chakachamna Lake. Habitat alteration and disturbance due to the construction and operation of the project could influence the distribution of some wildlife populations. In the vicinity of the lake above the dyke, fluctuating water levels may have several implications. As the lake level is lowered during the

winter, ice along the shore will most likely fracture, eventually resulting in a zone of broken ice that may prevent some large mammals from venturing out onto the frozen lake surface. Moose, bears, wolves, and small mammals are the primary inhabitants of the lake shore during winter. However, the degree to which these mammals use the frozen lake surface will need to be established. During the ice-free period, a variety of birds and mammals use the shore of the lake. The higher, fluctuating water level during this period may alter small areas of shoreline habitat but should not significantly influence the overall use of the shore by these wildlife.

Chakachatna and McArthur River Canyons. Construction activities occurring in the Chakachatna River and McArthur River canyons may influence the apparently limited use of the canyons by mammals and birds. The canyons are used by eagles, bears, furbearers, moose, and passerine birds. Near the construction sites, increased levels of noise from heavy equipment and blasting may discourage eagles, moose and bears from using adjacent areas (Roseneau et al., 1981, McCourt et al., 1974). However, other mammals, including furbearers and small birds appear to have a higher tolerance for human disturbance and may not substantially alter their distributions (Penner, 1976, Clark and Cambell, 1977). This influence of noise and disturbance on wildlife populations in the canyons should be limited to the construction period.

Chakachatna and McArthur River Floodplains. Below the canyons, wildlife activity is more abundant and diverse. In these areas, a variety of wildlife species could be influenced by construction activities. Due to increased levels of noise and

disturbance, sensitive species such as moose, grizzly bears, gray wolves, eagles, and swans may discontinue their use of the affected area (Roseneau et al., 1981, McCourt et al., 1974, Hampton, 1981). Other species, including coyotes, ducks, and other small birds, are more tolerant of disturbance and will probably not alter their distribution (Penner, 1976, Gollop et al., 1974, Schweinsburg et al., 1974, Ferris, 1979). If avoidance of a construction area occurred it would most likely be temporary with individuals returning to the area soon after noise and activity levels subsided. However, if areas used by wildlife for important life functions are abandoned, a decrease in the abundance of some local species may be noted. To evaluate which species may be affected and to what extent, it will be necessary to establish the use and importance of the Chakachatna and McArthur floodplains to wildlife.

The alteration of habitat and wildlife distributions below the canyons during the operation of the project may be evident as a result of changes in the vegetation communities or as changes in the abundance or distribution of prey (particularly anadromous fish). Changes in the distribution of vegetation (as described under Potential Effects to Botanical Resources) will probably not result in significant changes in the distribution of wildlife populations. Channel migration along the upper McArthur River and rechanneling in Noaukta Slough may erode relatively small areas of riparian vegetation. This may displace a few individuals, but overall abundance of a wildlife population in the project area should not be significantly changed. Likewise, a small increase in the abundance of floodplain riparian vegetation along the Chakachatna River will probably not result in a

significant change in wildlife species diversity or abundance in this drainage. The anticipated changes may be more clearly defined by acquiring information on the extent of channel migration, revegetation, and the use of riparian areas for denning, wintering, breeding, and calving.

It is unlikely that minor changes in anadromous fish abundance and distribution (described in Section 7.1) will have a significant effect on the distribution of either birds or mammals. Several species of wildlife feed on anadromous fish. Although bears and eagles are the most visible, mink, harbor seals, and beluga whales also consume fish originating in the Chakachatna or McArthur drainages. The degree to which these species will be affected can be evaluated by investigating the anticipated changes in fish distribution or abundance and the reliance of wildlife on this resource (Miller and McAllister, 1982). Based upon the anticipated change in anadromous fish abundance and the opportunistic nature of the wildlife species involved, no significant change in the abundance or distribution of wildlife is currently expected to occur in either the Chakachatna or McArthur drainage as a result of this project.

Increased access to the area will affect wildlife populations by two means; increased disturbance from construction activities, and increased local hunting (sport and subsistence) pressure. By utilizing the existing road network for construction and operation in the Chakachatna drainage, only a slight increase in vehicle-related disturbance to wildlife should occur. However, through the construction and use of two road extensions to access the McArthur drainage and Chakachatna canyons, there will likely be a short-term

reduction in the use of areas adjacent to these roads by species that are sensitive to traffic, particularly moose, bears, wolves, eagles, and swans (Roseneau et al., 1981, McCourt et al., 1974, Hampton, 1981, Goddard, 1970, Elgmark, 1976, Carbyn, 1974). The extent of this influence will depend upon the location of moose wintering and calving grounds, the location of brown bear, black bear, wolf, and wolverine denning sites, and the location of swan and eagle nesting, brood rearing, and fall staging areas. Future studies will be needed to identify the locations of these important habitats and to allow for more definitive assessments.

Whether local wildlife populations are influenced by increased hunting pressure will depend upon the magnitude of the hunting increase and the level of road access allowed. Currently no policy affecting access of the project area has been outlined.

The influence on wildlife of constructing and maintaining a transmission line and the likelihood of bird collisions or electrocutions with the lines will be dependent upon the species inhabiting the area, transmission line design, and construction and maintenance techniques. Until this information is available, these effects cannot be assessed.

7.3.4.3.3 Summary of Potential Effects

Wildlife populations within the project area may be influenced during the construction and operation of the facility. The direct loss of habitat by facility siting will most likely not significantly affect the abundance or distribution of any wildlife population.

Habitat alteration, however, may result in some minor changes which include the following:

- Reduced access for moose, wolves, bears, and caribou to the frozen lake surface during the winter due to fractured ice along the shore;

- Reduced utilization by sensitive species (such as wolves, moose, bears, eagles, and swans) of the areas near the construction sites, camps, and roads due to increased levels of noise and disturbance;

- Increased hunting pressure on large mammals and birds allowed by the presence of road extensions to the Chakachatna canyon and McArthur drainage; and

- Increased mortality of birds due to collisions or electrocutions from transmission lines.

Although these changes are likely to occur, the magnitude of the influences are less than those usually associated with the construction and operation of a hydroelectric facility. This is because designs for this project have incorporated an underground powerhouse, and a lake tap rather than a reservoir and thus:

- Potentially important habitat, including large mammal migration routes, moose wintering and calving areas, bear and furbearer denning and feeding areas, and bird nesting areas do not have to be inundated to create a reservoir;

- The disturbance associated with clearing large expanses of land will be absent; and

- Surface noise and disturbance associated with the construction of a dam will be significantly reduced.

Wildlife distributions within the project area have been influenced in the past by large scale timber harvesting, road construction, relatively high levels of hunting pressure, and the construction of an underground pipeline on the shore of Trading Bay. It is unlikely that the development of the Chakachamna Lake project would influence wildlife populations to the extent of these prior developments.

7.4 Project Risk Evaluation

Development of the project would be attended by a number of risks associated with the physical layout of the project structures and natural phenomena occurring within and adjacent to the project area. Some of these could directly impact the cost of constructing the project while others could either impair its output or add to the cost of maintaining the designed energy generation and peaking capability. Typical among these aspects are the following:

Project Layout

- Lake tapping
- Tunnel alignment - rock conditions
- Underground powerhouse site

Natural Phenomena

- Barrier Glacier
- Blockade Glacier
- McArthur Glacier
- Mt. Spurr, Volcano
- Lake Clark - Castle Mountain Fault
- Faulting in Chakachatna Valley
- Bruin Bay Fault

The above items are treated individually in the paragraphs that follow.

7.4.1 Lake Tapping

At this stage of the project studies, it has been necessary to presume that a location can be defined by exploration where the rock conditions will be suitable

for constructing the lake tapping. Based on examination of rock conditions above the lake water level, the above presumption seems to be reasonable but a significant amount of exploration will be required to define suitable rock. Furthermore, as far as it has been possible to ascertain from reviewing the technical press, the combination of diameter and depth needed for the Chakachamna Lake tapping is without precedent and considerable modification of the tentative arrangement, developed as shown for preliminary estimating purposes on Figure 3-4, may be necessary before an acceptable design concept is reached. Specifically, the length of the final plug may need to be increased or multiple smaller diameter openings may be required to penetrate from the underground excavations out into the lake. The length of the chamber between the bottom of the intake gate shaft and the lake may need to be increased. Factors such as these cannot be finally determined until some design phase subsurface exploration has been performed.

7.4.2 Tunnel Alignment Rock Conditions

As set forth in Section 7.2.2, bedrock characteristics, as they may affect tunnelling conditions, have not been specifically studied within the scope of studies thus far completed. No geological mapping has been done along the proposed tunnel alignment. However, aerial observations of rock exposed along the tunnel alignment and in the walls of the Mc Arthur canyon lead to the indication that suitable tunnelling conditions should be encountered. This expectation needs to be qualified to the extent that the rock overlying about 25% of the length of the tunnel is concealed by glacial ice and its surface features cannot be seen. The depth of rock cover and ruggedness

of terrain over the tunnel alignment virtually rule out the practicability of conducting any subsurface explorations at tunnel grade, except in the vicinity of the upstream and downstream ends. The depth of cover exceeds 3000 feet over about 40% of the tunnel length and it exceeds 2000 feet over about 66% of the length. (Figure 3-3). With such depths of cover, ground water under high pressure could be encountered where the tunnel penetrates permeable fissures or water bearing joints.

Some dramatic changes in relief occur at several locations along the tunnel alignment. These could give rise to the presence of troublesome stress concentrations particularly, for example, where a deeply incised U-shaped valley runs perpendicularly to the major principal stress of the in-situ bedrock stress field. Furthermore, due to the nearby presence of the Castle-Mountain-Lake Clark fault and the depth of cover over much of the tunnel alignment, there is the possibility that in-situ rock stresses may be high and that rock bursts may be a factor to contend with during excavation of the tunnel.

High pressure ground water and adverse rock conditions are factors which could add to the cost of constructing the power tunnel. The great depth of rock cover prevents exploration at tunnel grade except near the two ends. In the absence of exploration over so much of the tunnel length, more water at high pressure, and more highly stressed rock than anticipated, might be encountered during construction of the tunnel, and in that case, the constructed cost could exceed the cost that was estimated at the present stage of the investigations.

7.4.3 Underground Powerhouse Site

Final determination and confirmation of the location of the underground powerhouse site should preferably await design level exploration, the construction of an exploratory adit and laboratory and in-situ measurement of the engineering properties of the rock. The walls of the McArthur canyon afford good rock exposures and allow a more meaningful assessment to be made of the rock quality than any number of drill holes. There is again, however, the nearby presence of the Lake Clark-Castle Mountain fault and the possibility that high in-situ rock stresses may occur near the fault. If so, rock bursts could occur during excavation of the powerhouse cavern and associated underground excavations.

7.4.4 Barrier Glacier

This is the glacier that contains Chakachamna Lake and controls its water level. It descends the southerly slopes of Mt. Spurr to the Chakachatna Valley, which it crosses, and thrusts against the steep face of the Chigmit Mountains that forms the south wall of the valley. During the summer of 1981, the U.S. Geological Survey conducted some measurements of ice thickness in connection with an evaluation of the volcanic hazards posed by Mt. Spurr. Many of the field data are still in raw form, but in the floor of the Chakachatna Valley, the thickness of ice in the Barrier Glacier was believed to be in the order of 500-600 feet (Mayo, U.S.G.S. Fairbanks, verbal communication, 1982). The depth of water in Chakachamna Lake is about 300 feet.

The natural outflow from the lake discharges via a channel eroded through the glacial ice along its contact with the mountain wall on the south side of the valley. The channel is armored with large boulders which are carried along by the glacial ice and are deposited in the channel as the ice melts. Over the years, the channel bed apparently aggrades, and the lake water level rises until there develops a combination of circumstances that produces an outbreak flood which erodes the channel bed and lowers the lake water level. The last known event of this nature took place on or about August 11, 1971. The flood peak was estimated to be in the order of 470,000 cfs and the lake level dropped about 14 feet. (Lamke 1972). Only unsubstantiated reports and fragmentary evidence exist of previous outbreak floods. It is, however, rather evident that these would be cyclic events having uncontrolled and indeterminate periods, and that the lake outlet is in a state of changing equilibrium that among other things is strongly affected by the rate at which the Barrier Glacier advances towards the south valley wall, and the annual runoff from the watershed area discharging into the lake.

No evidence of surging has been reported in Barrier Glacier though Pothole and Harpoon Glaciers, nearby to the north, have both been identified as surging glaciers (Section 5.2.1.5). Barrier Glacier has, however, gone through various cycles of advance and retreat in recent time, and may reasonably be expected to continue to do so in the future. The extent to which such cycles might affect the lake level, and thus the amount of regulatory storage available for power generation, cannot be predicted with certainty.

7.4.5 Blockade Glacier

This glacier is fed by large snow fields high on the southerly slopes of the Chigmit Mountains to the south of the McArthur canyon. At about 1700 feet elevation, the glacier splits into two forks, one flowing southwesterly and the other northeasterly towards the McArthur River. The glacier impounds Blockade Lake beyond the terminus of the soutwesterly lobe. As set forth in Section 5.2.1.4 of this report, Blockade Lake is the source of outburst floods that discharge into the McArthur River.

The present terminal moraine of the northeasterly flowing lobe of Blockade Glacier lies within about 1-1/2 miles of the mouth of the McArthur canyon. If the Blockade Glacier were to advance during the life of the project, it is conceivable that the morainal material could also advance toward the McArthur River and cause the river bed to aggrade downstream of the mouth of the canyon. This could cause a rise in tailwater level to occur at the power plant site with the extreme consequence being a flooding of the powerhouse if a channel were not mechanically excavated through this material.

As summarized in the closing paragraphs of Section 5.2.1.4 of this report, Blockade Glacier's recent history has clearly been one of recession, and it is believed that it began to withdraw from its most recent maximum advance within the last few hundred years. At that maximum advance, melt water from the glacier joined the McArthur River near the canyon mouth and outwash may have caused some aggradation of the river bed in the lower reaches of the canyon. Surging of the Blockade Glacier is

considered to be the most likely mechanism that could be expected to produce an advance of the glacier that might impact on the proposed McArthur powerhouse site. No evidence suggestive of recent surging was, however, observed during the field studies.

The possibility that climatological changes and consequent changes in mass ice balance may trigger surging of the Blockade Glacier during the life of the project is a remote possibility that cannot be forecast or evaluated with any degree of certainty.

7.4.6 McArthur Glacier

The terminus of this glacier lies in the McArthur canyon about 5 miles upstream from the proposed powerhouse site. An advance of the glacier over that distance would endanger the tailrace channel and portals of the tailrace tunnel and access tunnel to the underground powerhouse. Such an advance would, however, involve almost doubling the existing length of the glacier and is, therefore, most unlikely to occur. Since the Blockade and McArthur glaciers are fed by adjacent snow fields, a change in snow supply needed to cause a five mile advance in the McArthur Glacier would create an even greater problem due to advancement of the Blockade Glacier.

7.4.7 Mt. Spurr Volcano

The summit of Mt. Spurr rises to elevation 11,070 feet above sea level and lies about 7 miles northeasterly from the outlet of Chakachamna Lake and 7-1/2 miles from the proposed power intake site. The intake could be located

further to the west to increase its distance from the volcano but this would increase the length and cost of the power tunnel, and also the difficulty and cost of access to the intake site along the precipitous mountain slopes on the south side of the lake.

Mt. Spurr's last major eruption occurred on July 9, 1953. It ejected a large ash cloud which reached an altitude of approximately 70,000 feet, darkened Anchorage and deposited about 1/4 inch of volcanic ash on the city (Juhle and Coulter 1955).

The source of the eruption was reported to have been Crater Peak, a subsidiary vent at 7575 feet altitude on the southerly slopes of the volcano. The eruption triggered a mud slide that dammed the Chakachatna River about 6 miles downstream from the outlet of Chakachamna Lake. The river backed up nearly 5 miles, overtopped the dam and has since partially eroded its way down through the debris. Abundant evidence exists along the northerly slopes of the Chakachatna Valley of a long history of violent volcanic activity. Large deposits of mud flow materials and pyroclastic breccias occur for several miles along its length. Examination of aerial photographs taken in 1954, 1957 and 1978 suggest the possibility that some minor mud flows may have occurred on the slopes below Crater Peak since the 1953 eruption.

The U.S. Geological Survey undertook a limited micro-seismic study of the Mt. Spurr area during the summer of 1982. The results have not yet been published but they are planned to be the subject of a report scheduled to be released during 1983.

Mt. Spurr is regarded by some volcanologists to be similar, in several respects, to Mt. St. Helens in the State of Washington whose May 18, 1980 eruption devastated a 200 square mile area. In the path of the main blast, devastation of forest land was complete as far as 18 miles from the crater.

Present technology for predicting volcanic activity is limited to the short term, and there is no way to forecast when Mt. Spurr will next erupt, or whether it might erupt during the life of the project. A catastrophic blast, such as occurred at Mt. St. Helens is a rare event but of course cannot be ruled out at Mt. Spurr. As discussed in Section 5.2.2.2 of this report, the general direction of a future blast at Mt. Spurr is expected to be in the southeasterly quadrant, or directly across and down the Chakachatna Valley. The proposed power intake site on Chakachamna Lake could be an area of ash deposition. It could also be affected by a large landslide or mudflow, or by hot blasts from pyroclastic flows if such were to occur, and the evidence is that these have occurred in the past, particularly in the Chakachatna Valley.

While future events similar to the 1953 Crater Peak eruption would probably have little effect on the ability of the power facilities to continue in operation, they could readily put the fish passage facilities out of service. Another mud flow could dam the river below Crater Peak thus causing it to back up and flood the proposed structure at the downstream end of the fish passage facilities. The reduced flow in the Chakachatna River would not have the same erosive power to cut its

way down through the debris dam and it could well become necessary to mechanically excavate a channel through the debris to lower the water level and return the fish passage facilities into operation. A catastrophic event of the Mt. St. Helens type, if directed towards the lake outlet and intake structure, could have very serious consequences and possibly bury both the upstream and downstream ends of the fish passage facilities, and the power intake, beneath a massive mud flow. The tremendous amounts of heat released by pyroclastic ash flows could melt ice in the lower parts of the Barrier Glacier and interfere with the glacier's ability to continue to contain Chakachamna Lake.

The powerhouse and associated structures in its vicinity would probably not be significantly affected by volcanic activity at Mt. Spurr because they are shielded from the direct effects of a volcanic blast by the high mountains between the Chakachatna and McArthur Valleys. Depending on wind direction at the time of the eruption, ash deposition is probably the main effect that would occur near the powerhouse site and this could lead to temporary interruptions in power supply. Similar outages could be caused by ash accumulating on transmission line insulators.

Volcanic events are risks that would be associated with development of the project. The probability of major events occurring during the project's life is small, but the probability or effects on the project cannot be predicted with certainty.

7.4.8 Seismic Risk

The site lies within a zone of high seismic risk. As set forth in Section 5.3.3.3 of this report, potential seismic sources which may affect the project site are the subduction zone, faults in the crustal seismic zone and severe volcanic activity. The Lake Clark-Castle Mountain fault (crustal source) and the megathrust segment of the subduction zone are considered the most critical with respect to peak ground acceleration and duration of strong shaking at the site. The maximum probable or operating basis earthquake for the site, defined as the earthquake that can reasonably be expected to occur during the life of the project has not yet been defined. The probability that the vibratory ground motion of the operating basis earthquake will be exceeded during the life of the project can be calculated by using generally accepted techniques. Thus, the seismic risks associated with the site can probably be submitted to more rational risk analysis than can the risks associated with glaciology or volcanism, principally because much more data is available on the frequency of occurrence of seismic events in the region than is available on the frequency of significant volcanic events from Mt. Spurr or the frequency of aberrations in glacial activity at the site.

7.4.8.1 Lake Clark - Castle Mountain Fault

This is a major regional fault that has been traced for over 300 miles. (Magoon et al 1976). It extends from its northerly end near the Copper River basin about 120 miles to the northeast of Anchorage (Figure 5-9), to the

southerly end in the Lake Clark area. It crosses the McArthur Canyon at the canyon mouth where a prominent rift can be seen in the mountainside. The northerly parts of the Lake Clark-Castle Mountain fault have been extensively studied and evidence of recent displacement has been documented near the Susitna Valley. Less is known about the southerly portion of the fault but it is considered to be capable of causing a large earthquake and of experiencing significant displacement during the life of the Project. For this reason, and for reasons of improvement in rock quality with distance from the fault, the proposed powerhouse is shown as being upstream from the mouth of the canyon, although this results in some head not being developed.

At least one crossing of the fault by the power transmission line cannot be avoided; this will be in the vicinity of the mouth of the McArthur Canyon. The powerhouse switchyard also would be in this vicinity. Thus, some of the transmission towers and switchyard structures would be subjected to very strong shaking in the event of a major earthquake on the fault near the McArthur Canyon. Underground structures will probably be less vulnerable to damage than surface structures. The structures can be designed to withstand the strongest lateral forces expected to occur, but it is not possible to design against significant displacement in the foundation at any given structure site. Consequently structures should not be located in the fault zone.

7.4.8.2 Bruin Bay Fault

This is one of the major regional faults in Southern Alaska. In the vicinity of the project site, it is

inferred to occur more or less parallel to the Cook Inlet coastline about 20 miles southeast of the mouth of the McArthur Canyon (Figure 5-9). But, its trace in that area is obscured by glacial diposits and its relationship to the Castle Mountain Fault is not known.

7.4.9 Faults in Chakachatna Valley

Four features which may be significant to the Project have been identified in the Chakachatna Valley (Figure 5-9), and are discussed in Section 5.3.3.3 of this report. Based on the 1981 geologic investigations which were limited to study of remote sensing imagery and of aerial (helicopter) observations, it was concluded that these features include faults which may offset Holocene deposits (less than about 2 million years old); also, one of the features trends toward the site of the proposed power intake structure. Further study of the Project should include evaluation of the age and extent of faulting which is related to these features, in order to better assess the potential for fault displacement at or near Project structures.

7.5 References

Juhle, Werner and Coulter, Henry, 1955, The Mt. Spurr Eruption, July 9, 1953: American Geophysical Union, Transactions, Vol.36, Number 2, Pages 199-202.

Lamke, Robert D., 1972, Floods of the Summer of 1971 in South-Central Alaska: U.S. Geological Survey Open File Report.

Magoon, L.B., Adkison, W.L., and Egbert, R.M. 1976, USGS Map No. 1-1019 Showing Geology, Wildcat Wells, Tertiary Plant Fossil Localities, K-Ar, Age Dates and Petroleum Operations, Cook Inlet Area, Alaska.

CONSTRUCTION COSTS AND SCHEDULES

8.0 CONSTRUCTION COSTS AND SCHEDULES

8.1 Estimates of Cost

Estimates of construction costs have been prepared for the following alternatives for project development:

Alternative A - 400 MW McArthur tunnel development

Alternative B - 330 MW McArthur tunnel development

Alternative C & D - 300 MW Chakachatna tunnel development

Alternative E - 330 MW McArthur tunnel development

The estimates are based on schedules of quantities of materials and equipment needed for the major features of each alternative to the extent permitted by the drawings for Section 3.0 of this report. In some cases, quantities were proportioned from the construction records of other projects bearing significant similarity of structures and conditions expected to be encountered during construction of the Chakachamna Hydroelectric Project. Unit prices developed for this and other projects involving similar types of construction and from analyses of bids received for the construction of similar types of projects in Alaska, adjusted as necessary to reflect January 1982 price levels, were then applied to the schedules of quantities to arrive at the estimated costs set forth in the Conceptual Estimate Summaries, sheets 1 of 2 and 2 of 2. The summaries show the

CHAKACHAMNA HYDROELECTRIC PROJECT
CONCEPTUAL ESTIMATE SUMMARIES – SHEET 1 OF 2

ALTERNATIVES	ESTIMATED COSTS IN THOUSANDS OF DOLLARS									
	A		B		C		D		E	
LAND AND LAND RIGHTS	Not included	0	Not included	0	Not included	0	Not included	0	Not included	
POWER PLANT STRUCTURE AND IMPROVEMENTS										
Valve Chamber	5,600		5,500		5,600		5,600		5,500	
Underground Power House	26,200		25,200		26,200		26,200		25,200	
Bus Galleries	200		200		200		200		200	
Transformer Gallery	4,600		4,300		4,300		4,300		4,300	
Valve Chamber and Transformer Gallery – Access Tunnel	400		400		400		400		400	
P. H. Access Tunnel	13,500		13,500		13,500		13,500		13,500	
Cable Way	800		800		800		800		800	
		51,300		49,900		51,000		51,000		49,900
RESERVOIR, DAM AND WATERWAYS										
Reservoir	100		100		100		100		100	
Intake Structure	10,400		9,300		10,400		10,400		9,300	
Intake Gate Shaft	13,200		12,400		13,200		13,200		17,600	
Fish Facilities	–		–		–		–		85,400	
Dike & Spillway	–		–		–		–		9,100	
Access Tunnel										
– At Intake	21,600		19,100		21,600		21,600		0	
– At Surge Chamber, No. 3	6,600		5,900		8,900		8,900		5,900	
– At Mile 3, 5, No. 1	0		0		20,800		20,800		0	
– At Mile 7, 5, No. 2	0		0		14,500		14,500		0	
Power Tunnel	626,800		580,400		712,500		712,500		447,800	
Surge Chamber – Upper	12,900		11,000		12,900		12,900		18,900	
Penstock – Inclined Section	18,000		16,500		15,400		15,400		0	
– Horizontal Section and Elbow	6,700		6,000		6,700		6,700		6,000	
– Wye Branches to Valve Chamber	13,200		11,900		12,100		12,100		11,900	
– Between Valve Chamber & Power House	800		600		800		800		600	
Draft Tube Tunnels	1,900		1,700		1,900		1,900		1,700	
Surge Chamber – Tailrace	2,400		2,400		2,400		2,400		2,400	
Tailrace Tunnel and Structure	10,300		9,600		10,300		10,300		9,600	
Tailrace Channel	900		700		900		900		700	
River Training Works	500		500		500		500		500	
Miscellaneous Mechanical and Electrical	7,100		6,100		5,700		5,700		6,100	
		753,400		694,200		871,600		871,600		633,600

A, B – McArthur development, high level tunnel excavated by drilling and blasting
C, D – Chacackatna valley development excavated by drilling and blasting
E – Mc Arthur development, low level tunnel excavated by boring machine

CHAKACHAMNA HYDROELECTRIC PROJECT
CONCEPTUAL ESTIMATE SUMMARIES – SHEET 2 OF 2

ALTERNATIVES	ESTIMATED COSTS IN THOUSANDS OF DOLLARS				
	A	B	C	D	E
TURBINES AND GENERATORS	67,900	57,900	54,500	54,500	57,900
ACCESSORY ELECTRICAL EQUIPMENT	11,200	9,500	9,000	9,000	9,500
MISCELLANEOUS POWER PLANT EQUIPMENT	8,600	7,300	6,900	6,900	7,300
SWITCHYARD STRUCTURES	3,600	3,600	3,600	3,600	3,600
SWITCHYARD EQUIPMENT	13,800	12,500	12,100	12,100	12,500
COMM. SUPV. CONTROL EQUIPMENT	1,600	1,600	1,600	1,600	1,600
TRANSPORTATION FACILITIES					
Port	4,600	4,600	4,600	4,600	4,600
Airport	2,000	2,000	2,000	2,000	2,000
Access and Construction Roads	59,600	59,600	44,100	44,100	59,600
	66,200	66,200	50,700	50,700	66,200
TRANSMISSION LINE & CABLE CROSSING	63,200	63,200	56,500	56,500	63,200
TOTAL SPECIFIC CONSTRUCTION COST AT JANUARY 1982 PRICE LEVELS	1,040,800	965,900	1,117,500	1,117,500	905,300
ENGINEERING & CONSTRUCTION MANAGEMENT	124,900	115,900	134,100	134,100	108,700
SUBTOTAL	1,165,700	1,081,800	1,251,600	1,251,600	1,014,000
CONTINGENCY @ 20%	233,100	216,400	250,300	250,300	203,000
ESCALATION	Not Incl.	Not Incl.	Not Incl.	Not Incl.	Not Incl.
INTEREST DURING CONST. @ 3% PER ANNUM	111,900	104,100	101,400	101,400	97,400
OWNER'S COSTS	Not Incl.	Not Incl.	Not Incl.	Not Incl.	Not Incl.
ALLOWANCE FOR FISH PASSAGE FACILITIES	–	50,000	–	50,000	Under Reservoir Item
TOTAL PROJECT COST AT JANUARY, 1982 PRICE LEVELS	1,510,700	1,452,300	1,603,300	1,653,300	1,314,400
USE	1,500,000	1,450,000	1,600,000	1,650,000	1,314,000

A, B – McArthur development, high level tunnel excavated by drilling and blasting
C, D – Chacackatna valley development excavated by drilling and blasting
E – Mc Arthur development, low level tunnel excavated by boring machine

following estimated project costs excluding owner's costs and escalation:

Alternative A	$1.5 billion
Alternative B	$1.45 billion
Alternative C	$1.6 billion
Alternative D	$1.65 billion
Alternative E	$1.32 billion

The above costs include a 20% contingency added to the specific construction cost plus engineering and construction management, and interest during construction. The costs for Alternatives B and D additionally include a provisional allowance of $50 million for fish passage facilities at the lake outlet. Costs for Alternative E include a constant grade tunnel from powerhouse level at the McArthur River to the base of the intake gate shaft at Chakachamna Lake, and pending the completion of geological studies of the tunnel alignment, the assumption is made that this tunnel will be driven by a boring machine. Included also in Alternative E is the estimated cost of proposed fish facilities at the Chakachamna Lake outlet as described elsewhere in this report and shown on drawings. The estimated project costs are considered to be conservative because of the conservative assumptions made regarding the amount of rock support required in the underground excavations.

For all of the alternatives, the principal structures consist of the following:

- Intake structure at Chakachamna Lake with underwater lake tapping, and control gate shaft.

- Concrete lined power tunnel with construction access adits.

- Surge chamber and except for Alternative E, emergency closure gates at the downstream end of the power tunnel.

- Underground concrete lined pressure penstock and manifold.

- Concrete and steel lined penstock branches leading to a valve chamber and the turbines.

- Four unit underground powerhouse with exploratory adit (to become the ventilation tunnel) and main access tunnel.

- Underground transformer vaults and high voltage cable gallery.

- Tailrace tunnel and surge chamber.

- Tailrace outlet channel and river protection works.

- High voltage cable terminals and switchyard.

- Transmission lines to northerly shore of Knik Arm.

- High Voltage submarine cable crossing of Knik Arm.

In addition, for Alternative E the following principal structures are included:

- Concrete lined surge shaft connecting surge chamber and downstream end of power tunnel.
- Rockfill dike at Chakachamna Lake outlet.
- Spillway at lake outlet.
- Fish passage facilities at lake outlet for both upstream and downstream migrants.

8.1.1 Power Tunnel

The cost of constructing the power tunnel is the dominant feature, representing more than half the estimated cost of constructing each alternative. Detailed evaluations were made of all operations and the direct costs considered necessary to construct the 25-foot diameter concrete lined power tunnel for Alternatives A, C and D, using both rubber tired and rail haulage equipment. The difference in cost between the two was found to be small. Thus, the choice of haulage equipment will probably be determined by other considerations such as for example, whether excavation and concrete placement would be scheduled by a Contractor to take place concurrently in a given tunnel heading. This can be accomplished if necessary in a 25-foot diameter tunnel with either rail haulage or rubber tired equipment.

The estimated cost of constructing the 23-foot diameter tunnel required for Alternative B was first proportioned from the estimated unit costs per lineal foot for constructing the 25-foot diameter tunnels for Alternatives A, C and D using the same construction

methods of drilling and blasting. These costs are indicated in the summary schedule for Alternative B at the end of this chapter as $580,400,000.

For Alternative E, an alternative method of driving the tunnel by a boring machine was considered as well as a modification of the profile of the tunnel using uniform grade from near the base of the intake shaft to the powerhouse. Two surface samples of rock collected from the general vicinity of the power intake site at Chakachamna Lake and one sample collected from the surface in the vicinity of the powerhouse site near the McArthur River were tested for compressive strength, indentation, point load, quartz content and cutter penetration rate at The Robbins Company laboratory in Kent, Washington. Although test data obtained from surface samples can sometimes be misleading when compared to comparable data obtained from fresh rock samples taken at depth, the data were used with appropriate conservatism to estimate the rate of penetration of a tunnel boring machine working in this rock. The use of a boring machine for excavating showed a saving in costs of $126,700,000. Changing the grade of the tunnel showed an additional saving of $5,000,000. The total cost of constructing the tunnel was thus reduced from $580,400,000 to $448,700,000. This cost was used in the summary schedule for Alternative E, the recommended alternative.

The estimated tunnel construction costs are based on the following items:

- Excavation for Alternatives A, B, C and D would be by conventional drilling and blasting generally with full face excavation, drilling 12-foot depth rounds. Allowance is included for a nominal length of tunnel where the depth of rounds might have to be reduced, or where top heading and bench techniques might have to be used temporarily, if less favorable ground conditions are encountered.

- Excavation for Alternative E would be by a boring machine to 27-foot boring diameter which after lining would be hydraulically equivalent to the 23-foot diameter horseshoe for Alternative B driven by conventional methods. The rate of advance was estimated at 50 feet per day calculated on the basis of a similar project in similar rock formation. Assumptions for support were conservatively left the same as for the conventionally driven tunnel, although it is realized that some savings would probably result in actual operation. Also, sections of the tunnel may be left unlined because the boring machine provides a smoother excavated surface than conventional methods, thus reducing tunnel friction losses.

- The assumptions are made that 25% of the tunnel length would require steel rib support, 25% would be supported by patterned rock bolts and 50% would be unsupported.

- Chain link mesh for the protection of workmen from rock falls is provided above the spring line over the full tunnel length.

- o Estimated excavation costs include provision for handling and removing 2000 gallons per minute of groundwater inflow in each tunnel heading.

- o Excavation and concrete lining would proceed on a 3-shift basis, 6 days per week.

- o Construction access adits would be located near the upstream and downstream ends of each tunnel alternative. In addition two intermediate adits would be provided for Alternatives C and D.

8.1.2 Underground Powerhouse and Associated Structures

For purposes of the current estimates, the powerhouse has been taken as an underground installation for each alternative, with a high pressure penstock shaft and low pressure tailrace tunnel. The estimates of cost are based on the following conditions:

- o All excavation and concrete work would proceed on a 3-shift, 6 days per week basis.

- o The powerhouse cavern, valve chamber and tailrace tunnel would be excavated by top heading and bench.

- o The penstock and surge shafts would be excavated first by pilot raise, then by downward slashing to full diameter.

- o Excavation for the horizontal penstock and manifold, access tunnel, cable gallery and draft tubes would be full face.

- o Chain link mesh is provided for protection of workmen over the upper perimeter of all excavations exceeding 12 feet in height.

- o All permanent excavations would be supported as determined necessary by patterned rock bolts.

- o Allowance is included for lining the upper perimeters of all caverns, chambers and galleries required for permanent access and those housing vulnerable generating or accessory equipment with wire mesh reinforced shotcrete (this may only be needed locally according to rock conditions exposed during construction).

- o Excavation of an exploratory adit, and a program of core drilling and rock testing will precede and confirm the suitability of the site for the underground powerhouse complex during the design phase and the costs thereof are included in the estimates.

- o The costs included for the major items of mechanical and electrical equipment are based on current data with added allowance for delivery and transportation to the powerhouse site. Installation costs are also included.

- o Costs of mechanical and electrical auxiliary equipment and systems, control and protective equipment are included.

8.1.3 Tailrace Channel

The estimates include a monetary allowance for the construction of an outlet channel and river training

works to protect it from damage during floods in the river. Details of such requirements are not well defined at the present stage but it is contemplated that extensive use would be made of rock spoil from excavation of the powerhouse complex for these purposes.

River gravels excavated from the tailrace channel would be processed and used to the maximum extent possible for concrete aggregate.

8.1.4 Switchyard

In each alternative, due to space limitations, the switchyard would be located outside the mouth of the canyon on gently sloping land and an appropriate allowance is included in the estimates for their cost.

8.1.5 Transmission Line and Cable Crossing

Field data acquisition has not been performed and information regarding construction conditions is limited to aerial observation of the proposed transmission line alignment and cable crossing. The cost allowed in the estimate for the transmission line is based on experience and includes the estimated cost of the submarine cable crossing to a dead end structure on the Anchorage Shore of Knik Arm.

8.1.6 Site Access and Development

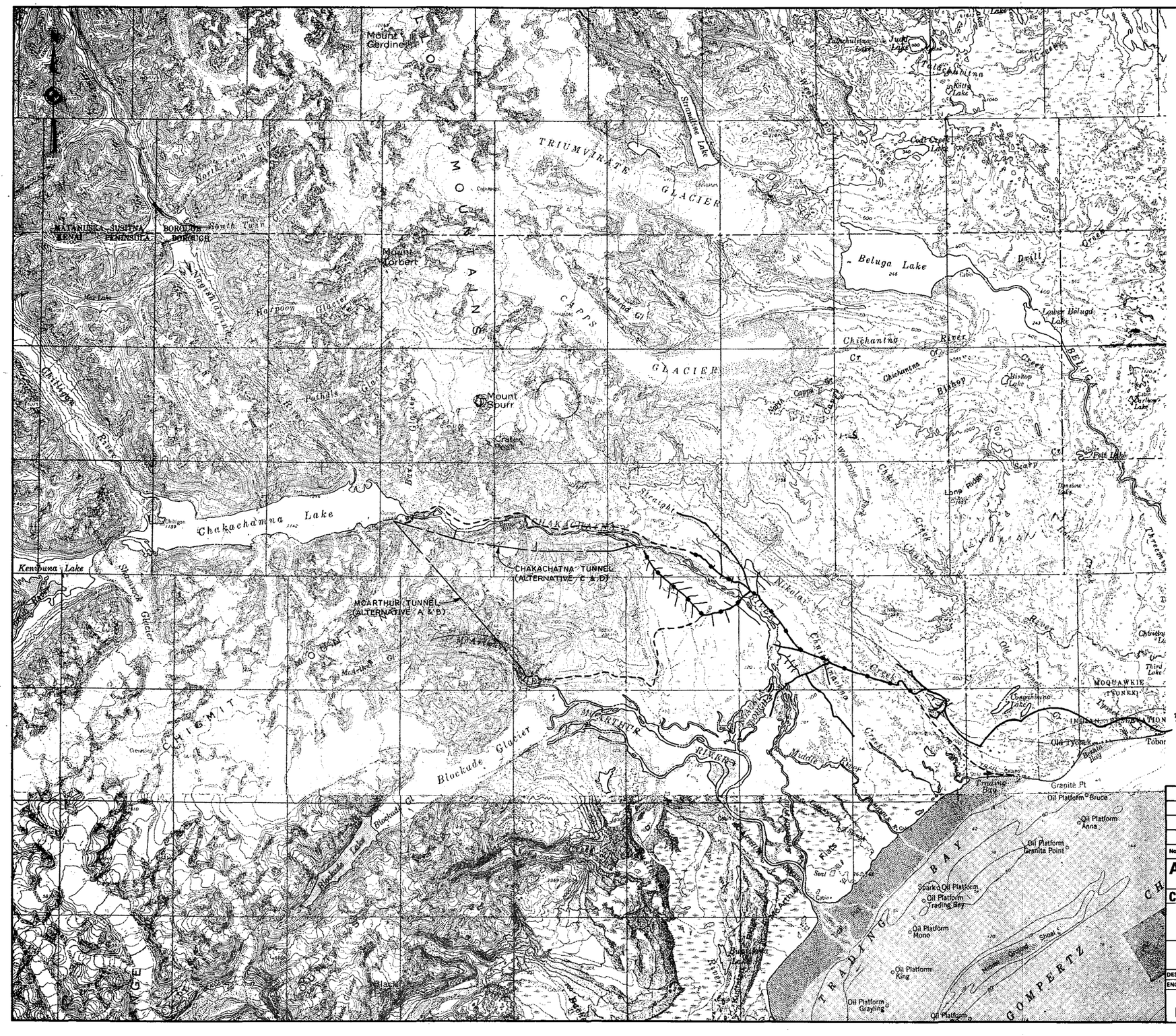
The estimates include costs of constructing access and support facilities needed for construction of the permanent works. These would consist basically of the following installations:

- Unloading facility on tidewater at Trading Bay, complete with receiving and warehousing provisions, bulk cement and petroleum fuels storage plus a small camp for operating staff.

- Gravel surfaced all-weather access roads to construction sites (Figure 8-1). It has been assumed that where existing roads are suitably located, permission to use them could be negotiated with their owners in exchange for improvements that would include widening them to full two-way traffic roads. Bridges and culverts would be provided at all streams and water courses and where needed for drainage. Year-round maintenance costs are included throughout the construction period.

- An aircraft landing facility with a runway of sufficient length to handle aircraft up to DC-9 and 737 types, and ground support facilities.

- For Alternatives A, B and E, major construction camps would be located outside but close to the mouth of the McArthur Canyon to accommodate workers employed on the downstream heading of the power tunnel, the powerhouse and associated structures. A second camp for workmen employed on the upstream heading of the power tunnel and intake works would be provided just east of the Barrier Glacier on the northerly side of the river. This camp will also be used for construction of the lake outlet works and fish facilities for Alternative E.



NOTES:

1.) TOPOGRAPHY IS FROM USGS QUADRANGLE MAPS

2.) HORIZONTAL GRID IS UNIVERSAL TRANSVERSE MECATOR PROJECTION, 1927 NORTH AMERICAN DATUM.

3.) VERTICAL DATUM IS MEAN LOWER LOW WATER.

LEGEND:

- EXISTING ROAD TO BE IMPROVED
- EXISTING ROAD
- NEW ACCESS ROAD

2 0 2 4 MILES

SCALE : 1" = 2 MILES

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

ACCESS ROAD

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 8-1	B

- For Alternatives C and D the main construction camp would be located outside the mouth of the Chakachatna Canyon for workers employed on the downstream heading of the power tunnel, the powerhouse and associated structures and also for the second intermediate access adit to the power tunnel. A second camp for workers employed on the upstream heading of the power tunnel, intake works and headings driven from the first intermediate access adit to the power tunnel would be located east of the Barrier Glacier.

- The construction camps would be self-contained with all needed support facilities which would include water supply sewage treatment, solid waste disposal, catering and medical services.

- Electrical power during construction is provided for on the assumption that diesel driven equipment would be used.

- Major compressed air facilities would be required for the excavation work and their cost is provided for in the estimates.

- Camps needed to accommodate transmission line workers would be light weight "fly camps". Much of the line work would be undertaken in winter and would be avoided during waterfowl nesting periods.

As construction work approaches completion, all temporary facilities will be dismantled and removed from the site, which will be restored insofar as is

possible to its original condition, and the cost of such demobilization and site restoration is included in the estimates.

8.2 Exclusions from Estimates

The estimates of construction costs do not include provision for the costs of the following items:

- Owner's administrative costs.
- Financing charges.
- Escalation (Estimated costs are "overnight costs" at January 1982 price levels.
- Land and Land Rights.
- Water Rights.
- Permits, licenses and fees.
- Switchyard at the Anchorage transmission line terminal.

8.3 Construction Schedules

Typical construction schedules are shown on Figure 8-2 for Alternatives A and B, on Figure 8-3 for Alternatives C and D, and on Figure 8-4 for Alternative E. These schedules have as their beginnings the existing schedule for completion of the project feasibility study and preparation of the application to the Federal Energy Regulatory Commission (FERC) for a license to construct the project.

CHAKACHAMNA HYDROELECTRIC PROJECT
PROJECT SCHEDULE
ALTERNATIVES A AND B

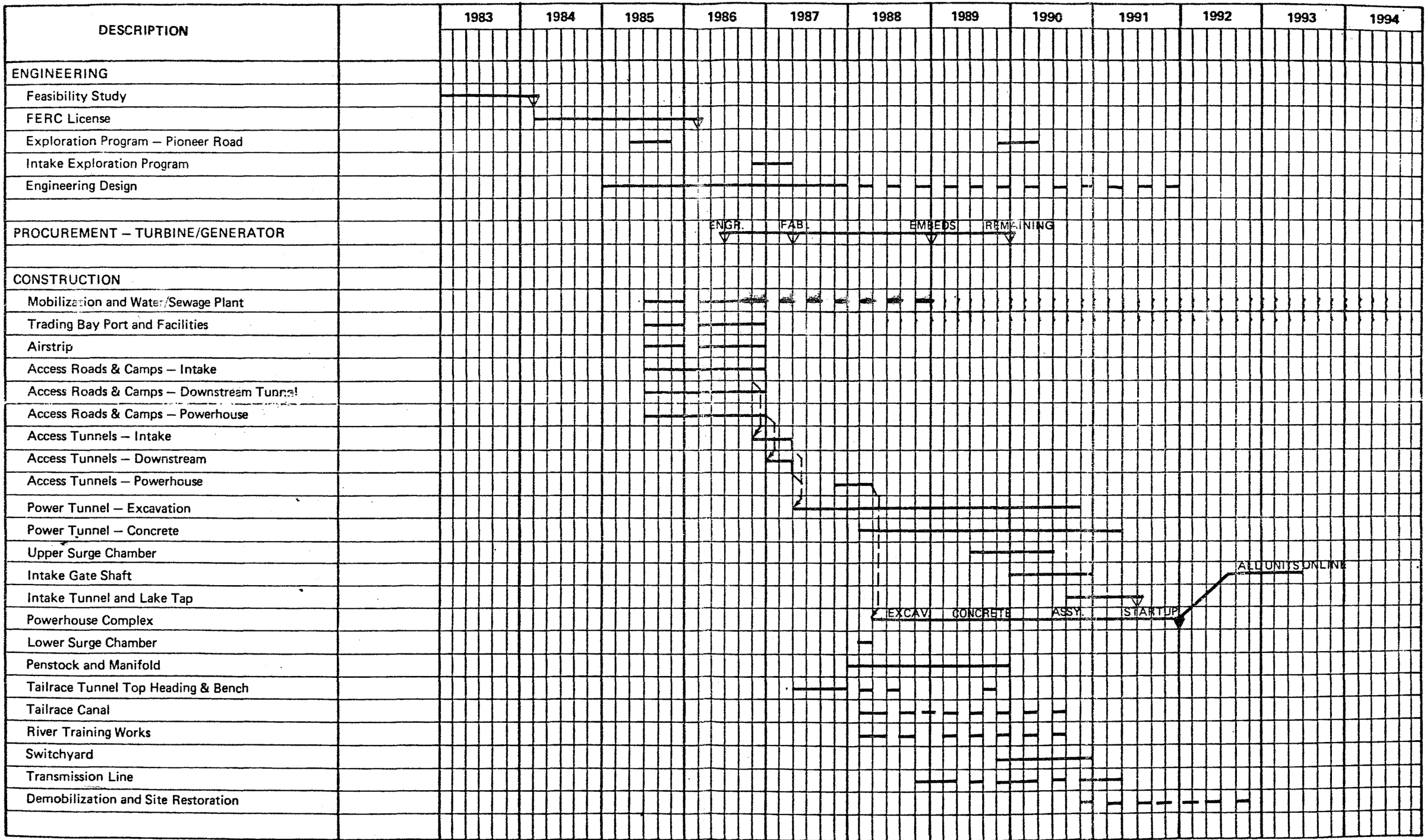


FIGURE 8-2

CHAKACHAMNA HYDROELECTRIC PROJECT
PROJECT SCHEDULE
ALTERNATIVES C AND D

DESCRIPTION	
ENGINEERING	
Feasibility Study	
FERC License	
Exploration Program–Pioneer Road	
Intake Exploration Program	
Engineering Design	
PROCUREMENT – TURBINE/GENERATOR	
CONSTRUCTION	
Mobilization and Water/Sewage Plant	
Trading Bay Port and Facilities	
Airstrip	
Access Roads & Camps – Intake & P.H.	
Access Tunnels – Intake	
Access Tunnels – Mile 3.5	
Access Tunnels – Mile 7.5	
Access Tunnels – Downstream	
Access Tunnels – Powerhouse	
Power Tunnel – Excavate	
Power Tunnel – Concrete	
Upper Surge Chamber	
Intake Gate Shaft	
Intake Tunnel & Lake Tap	
Powerhouse Complex	
Lower Surge Chamber	
Penstock and Manifold	
Tailrace Tunnel Top Heading & Bench	
Tailrace Canal	
River Training Works	
Switchyard	
Transmission Line	
Demobilization & Site Restoration	

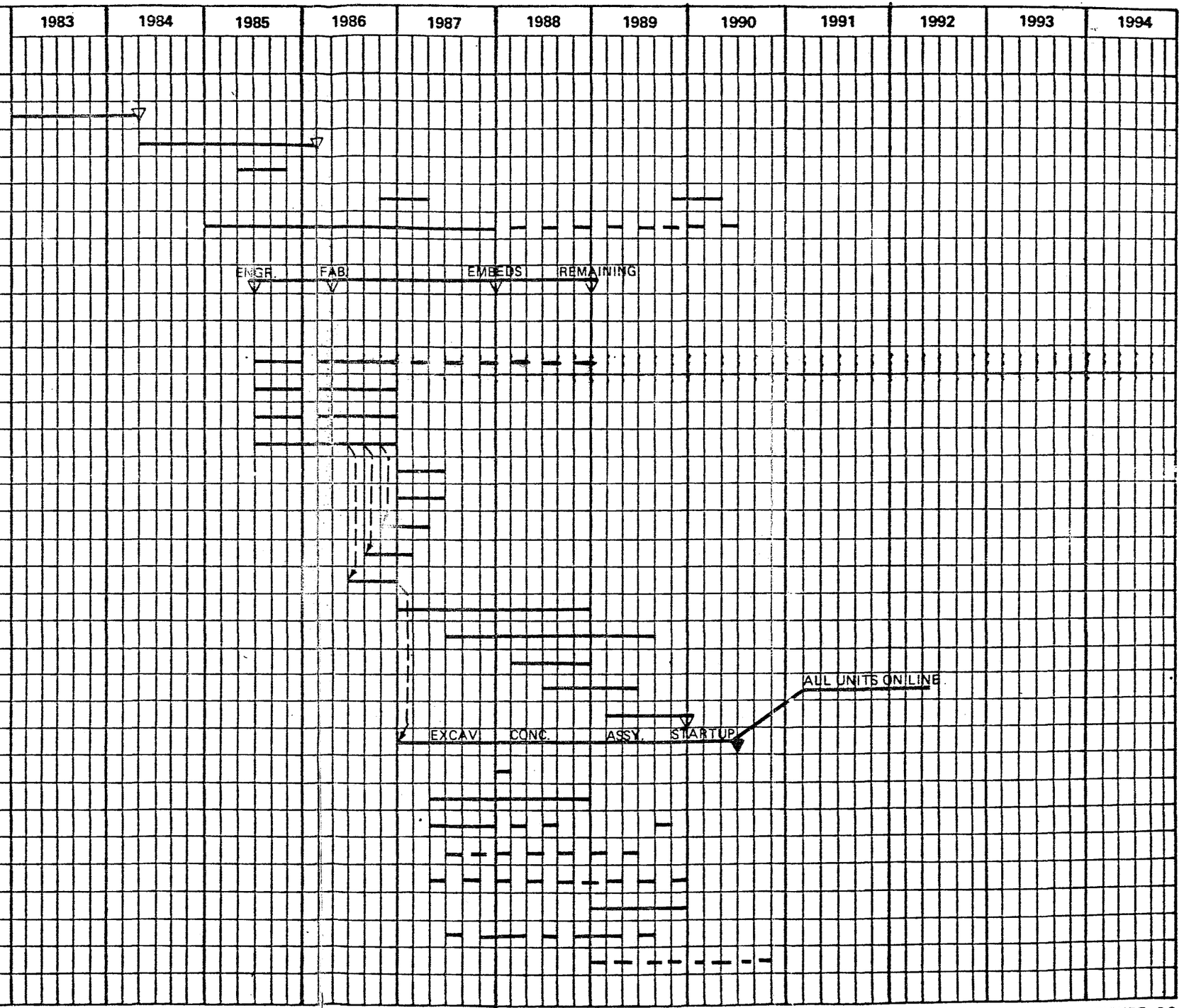


FIGURE 8-3

CHAKACHAMNA HYDROELECTRIC PROJECT
PROJECT SCHEDULE
ALTERNATIVE E

DESCRIPTION
ENGINEERING
Feasibility Study
FERC License
Exploration Program – Pioneer Road
Intake Exploration Program
Engineering Design
PROCUREMENT – TURBINE/GENERATOR
CONSTRUCTION
Mobilization and Water/Sewage Plant
Trading Bay Port and Facilities
Airstrip
Access Roads & Camps – Intake
Access Roads & Camps – Downstream Tunnel
Access Roads & Camps – Powerhouse
Access Tunnels – Intake
Access Tunnels – Downstream
Access Tunnels – Powerhouse
Fish Facilities
Chakachatna Dike and Spillway
Power Tunnel – Excavation
Power Tunnel – Concrete
Upper Surge Chamber
Intake Gate Shaft
Intake Tunnel and Lake Tap
Powerhouse Complex
Lower Surge Chamber
Penstock and Manifold
Tailrace Tunnel Top Heading & Bench
Tailrace Canal
River Training Works
Switchyard
Transmission Line
Demobilization and Site Restoration

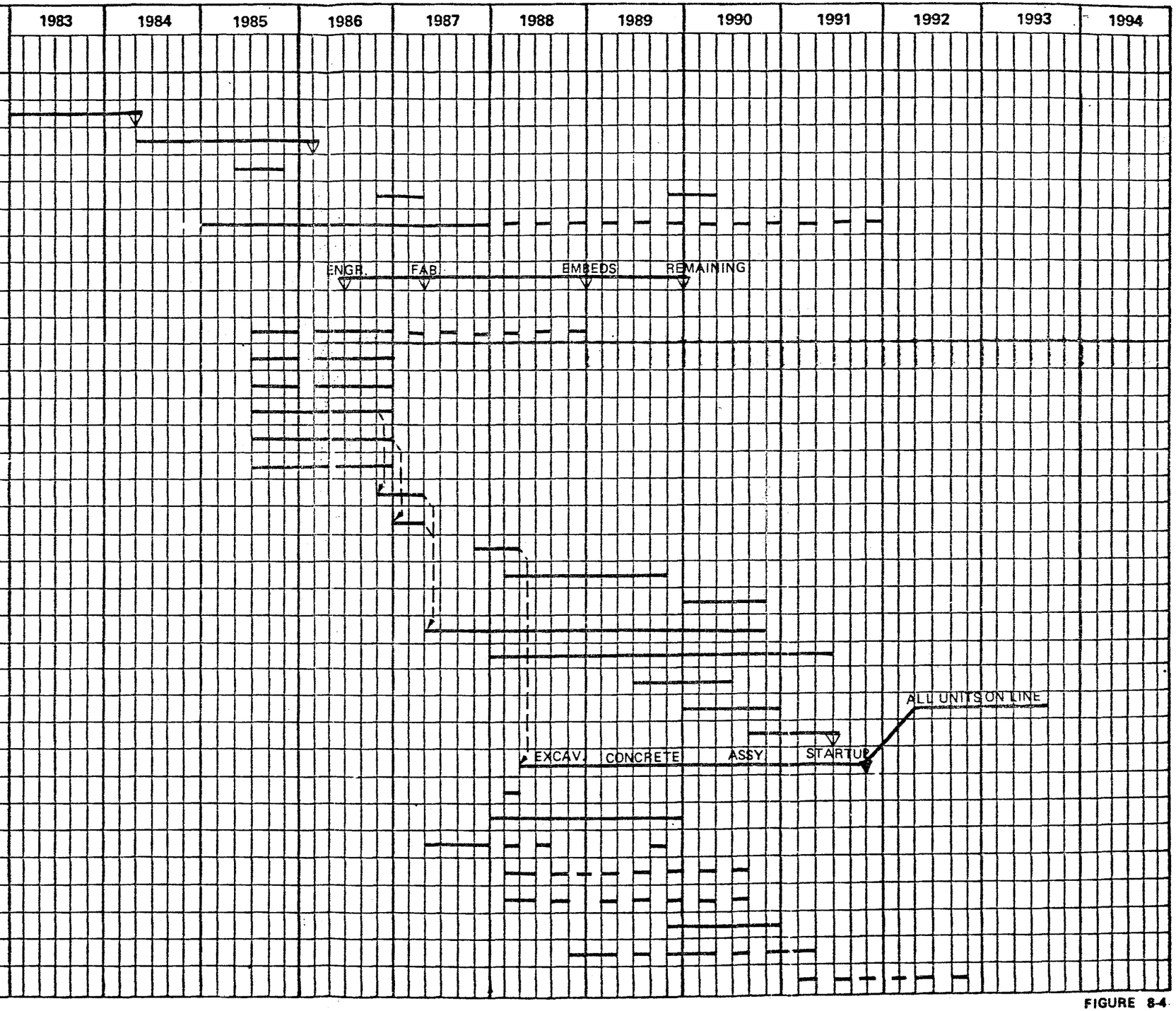


FIGURE 8-4

The assumption has been made that the license application would be submitted to FERC March 1, 1984. Assuming also that the FERC licensing process continues in much the same manner as it does at the present time, an early step will be the preparation of an environmental assessment of the project by FERC staff. This generally takes about 12 months following which is a 60-day period for review and comment by interested agencies. Thus, by the end of April, 1985, it should have become clear whether there are any outstanding unresolved issues. If there are not, then it would be possible to forecast with reasonable certainty that the FERC license would be issued in early 1986, in which event there would not appear to be any reason why the construction of access facilities and camp installations could not commence by June 1, 1985. In order to provide adequate lead time to commence design and prepare plans and specifications for the construction of access facilities, design engineering of the project would need to commence at the beginning of 1985.

Noting that there is a possibility that FERC might also require completion of an exploratory adit and rock testing program at the powerhouse site before issuing the project license, June 1, 1984 would appear to be a logical time to commence that program. Making an early start in the manner described above would permit the plant to commence commercial operation a year earlier than if the design of the project and construction of infrastructure did not commence until after the FERC license had been issued.

Construction of the power tunnel lies on the critical path for completion of development via the McArthur River in Alternatives A, B, and E. For conventional excavation methods assumed for Alternatives A and B the schedule was based on tunnel excavation advancement at an average rate of 26 feet per day in each heading. At that rate, excavation would be completed in approximately 3-1/2 years.

For excavation by boring machine assumed for Alternative E the schedule was based on net advancement of 50 feet per day from one heading at which rate the excavation would be completed in approximately the same time.

Placement of the concrete lining would proceed generally concurrently with the excavation. Total construction time for the tunnel is thus 50 months and the first unit in the powerhouse could be started up by August 1, 1991.

As discussed above a saving in time might be effected if any sections of the tunnel can be left unlined as a result of smoother boring machine excavation and reduction of rock shattering.

For development via the Chakachatna River in Alternatives C and D, the ability to provide two intermediate construction access adits enables the tunnel construction to be completed within 32 months, or 18 months less than for the McArthur tunnel. Timely delivery of the turbines and generators, and construction of the powerhouse complex becomes more critical. Assuming an early start on site access and

development as described above for Alternatives A and B, the first unit in Alternatives C and D could be started up by February 1, 1990, or 18 months earlier than would be the case with Alternatives A, B and E.

ECONOMIC EVALUATION

9.0 ECONOMIC EVALUATION

9.1 General

During the initial project studies carried out in 1981, an evaluation was made of the economic tunnel diameter and economic tunnel length for the four basic alternative schemes developed at that time, Alternatives A, B, C & D (described in Section 3). This economic study was made using tunnel costs calculated for tunnel excavation by conventional drill and shoot methods. Subsequent studies performed in 1982 indicated that cost savings will be achieved if the tunnel would be driven by tunnel-boring machine. Alternative E is based on tunnel boring machine excavation. These studies are discussed in Section 8. No re-examination of the economic tunnel diameter or length has been made using these modified tunnel costs, but any change in economic diameter or length of tunnel is considered to be small.

Determination of the economic tunnel diameter involves comparing the construction costs of tunnels of varying diameters, with the present worth of the difference in power produced over the life of the project as a result of the changes in hydraulic loss in the tunnel as the diameter is varied. The economic tunnel length is determined from an economic balance between the cost of increasing the tunnel length to develop additional head on the powerhouse, and the present worth of the additional power produced by the higher head over the life of the project.

It should be noted that these economic evaluation studies were based on economic parameters prevailing in 1981. These parameters which include capital costs of thermal generating plants and fuel costs for both coal and natural gas have, of course, now been superseded. In

future studies, the influence of updated economic parameters on the economic tunnel diameter and length should be made.

9.2 Parameters for Economic Evaluation

Alaska Power Authority has developed the following parameters for economic analyses of hydroelectric projects.

Inflation Rate	0%
Real Discount Rate	3%
Economic Life of Hydroelectric Projects	50 years
Economic life of thermal plants (conventional coal fired or combined cycle)	30 years

In sizing the various project elements, i.e., tunnel diameter and length, the value of power generated by the hydroelectric project has been considered equal to the cost of the equivalent power generated thermally by coal fired plant or by natural gas fired combined cycle plant.

As agreed with APA, in order to arrive at a project cost which can be readily compared with that for the Susitna Project a 50% plant factor has been used for determining the installed capacity of the power plants discussed in this report. Future studies should concentrate on refining the preferred plant factor for the project.

9.3 Cost of Power from Alternative Sources

9.3.1 General

To ensure uniformity of data between the various feasibility studies of hydroelectric projects which are currently in progress, including the Susitna Hydroelectric Project, APA requested that the following

sources be used for the development of cost of power from alternative thermal generation:

(1) Acres American Incorporated report "Susitna Hydroelectric Project" Task 6 Development Selection Report, Appendices A through I, July 1981 for construction cost of coal fired and combined cycle thermal plants.

(2) Battelle Pacific Northwest Laboratories, for the cost of operation and maintenance and fuel for coal fired and combined cycle thermal plants. Data on these items were obtained during a visit to Battelle's office on September 1, 1981.

9.3.2 Construction Cost

(a) Coal fired thermal plant:

The Acres American report referred to above develops the construction cost of a 250-MW coal fired thermal plant at Beluga in 1980 dollars to be $439,200,000 direct construction cost and $627,650,000 total cost including 16% contingency, 10% for construction facilities and utilities and 12% for Engineering and Administration, but not including interest during construction. This total cost corresponds to $2510/kW. Including interest during construction at 3 percent per year for a 6 year construction period, the total cost amounts to $2706/kW. (This differs but little from the $2744/kW value given in Table B.13 of the Acres Report apparently because of some rounding of numbers in the Acres calculation and apparently slight difference in cash flow during the construction period.)

(b) Combined Cycle Plant

The Acres American report also develops the construction cost of a 250-MW combined cycle plant in 1980 dollars to be $121,830,000 direct construction cost and $174,130,000 total cost including 16% contingency 10% for construction facilities and utilities and 12% for Engineering and Administration, but not including interest during construction. This corresponds to $697/kW. When interest during construction is added at 3 percent per year, the total cost is $707.5/kW.

9.3.3 Operation & Maintenance Cost

Data obtained from Battelle is summarized below for 1980 price levels.

(a) Coal-fired Thermal Plant

Fixed Operation and Maintenance $16.71/kW/year
Variable Operation and Maintenance 0.6 mills/kWh.
Escalation above general inflation rate 1.9% until year 2012 with no escalation after 2012.

(b) Combined Cycle Plant

Fixed Operation and Maintenance $35.00/kW/year
Variable Operation and Maintenance 0 mills/kWh.
Escalation above general inflation rate 1.9% until year 2012 with no escalation after 2012.

9.3.4 Fuel Cost

Data obtained from Battelle is summarized below for 1980 price levels

(a) Coal from Beluga

Fuel cost $1.09/mill. BTU
Escalation above general inflation rate 1.5% until year 2012 with no escalation after 2012.
Heat Rate 10,000 BTU/kWh.

(b) Natural Gas - Combined Cycle Plant

The natural gas prices as estimated by Battelle for the future years are given in Table 9-1.

Heat rate 7500 BTU/kWh.

TABLE 9-1

NEW CONTRACT GAS PRICE (AML&P)-ANCHORAGE

Year	Gas Price $/Mill BTU
1980	1.08
1981	1.08
1982	1.09
1983	1.09
1984	1.09
1985	1.09
1986	1.35
1987	1.56
1988	1.65
1989	1.89
1990	2.11
1991	3.62

1992	3.74
1993	3.86
1994	3.98
1995	4.11

Forecast escalation after 1995 = 3% per year until the year 2012, and no escalation thereafter.

9.4 Value of Hydro Generation

The value of the hydro generation is established by determining the cost of generating power from alternative sources. For the purpose of this study an analysis has been made of the cost of alternative coal-fired and combined cycle generation, using the basic cost data presented previously in Section 9.3.

The annual cost of interest, depreciation and insurance for the alternative thermal plants were calculated on the following basis:

Interest	3.0%
Depreciation (30 year life)	2.1%
Insurance	0.25%
Annual Charge on Capital Cost	5.35%

Based on an arbitrary selection of 1990 as the in-service date for the Chakachamna Project and examining a fifty year period, equal to the economic life of the hydro plant, and using the unit costs for thermal generation discussed above, comparative costs were prepared for each year of the 50 year period of the cost of generating power at 50% load factor by each of the two alternatives, conventional thermal using Beluga coal and combined cycle

using gas. These annual costs over the 50 year period were then used to determine their present worths at the first year of generation taken as 1990. The calculations were performed on a cost per kWh basis and are presented in Tables 9-2 & 9-3 for the conventional coal fired and combined cycle cases respectively.

The levelized annual cost of generation by a coal fired plant using Beluga coal is calculated to be 55.60 mills per kWh compared with 75.21 mills per kWh for the combined cycle plant, based on 50% load factor generation. The higher cost for the combined cycle plant is due primarily to a higher initial fuel cost, a much higher escalation on the cost of fuel, and somewhat higher operation and maintenance cost. Taken collectively these more than offset the much lower annual charge on the capital cost of constructing the combined cycle plant. The cost of power produced by the coal fired plant was therefore adopted as the alternative for establishing the value of hydro generation.

The capital cost of a hydro plant which gives a levelized annual cost over the 50 year life equal to the levelized annual cost of the coal fired thermal plant of 55.60 mills per kWh, based on 50% plant factor, and including a credit of 5% less installed capacity required in a hydro plant because of the reduced system reserve requirements with hydro generation, is calculated to be $6,117 per kW. This total cost includes contingency, construction camp facilities, engineering, and construction management and interest during construction.

TABLE 9-2 (Sheet 1 of 2)

COAL FIRED PLANT

COST OF GENERATING POWER AT 50% LOAD FACTOR

Year	Amortization & Insurance	O&M	Fuel	Total	Present Worth
1	33.02	5.32	12.65	50.99	49.50
2	33.02	5.42	12.84	51.28	48.34
3	33.02	5.52	13.03	51.57	47.19
4	33.02	5.63	13.23	51.88	46.09
5	33.02	5.74	13.43	52.19	45.02
6	33.02	5.84	13.63	52.49	43.96
7	33.02	5.96	13.83	52.81	42.94
8	33.02	6.07	14.04	53.13	41.94
9	33.02	6.18	14.25	53.45	40.96
10	33.02	6.30	14.46	53.78	40.02
11	33.02	6.42	14.68	54.12	39.10
12	33.02	6.54	14.90	54.46	38.20
13	33.02	6.67	15.12	54.81	37.32
14	33.02	6.79	15.35	55.16	36.47
15	33.02	6.92	15.58	55.52	35.64
16	33.02	7.06	15.82	55.90	34.84
17	33.02	7.19	16.05	56.26	34.04
18	33.02	7.33	16.29	56.64	33.27
19	33.02	7.47	16.54	57.03	32.52
20	33.02	7.61	16.79	57.42	31.79
21	33.02	7.75	17.04	57.81	31.08
22	33.02	7.90	17.29	58.21	30.38
23	33.02	7.90	17.29	58.21	29.49
24	33.02	7.90	17.29	58.21	28.64
25	33.02	7.90	17.29	58.21	27.80
					946.54

NOTE: Escalation rates above the general escalation rate are as follows.

Amortization & Insurance - Nil.

Operation & Maintenance - 1.9% for first 22 years only.

Fuel - 1.5% for first 22 years only.

TABLE 9-2 (Sheet 2 of 2)

COAL FIRED PLANT

COST OF GENERATING POWER AT 50% LOAD FACTOR

Year	Amortization & Insurance	O&M	Fuel	Total	Present Worth
					Fwd. 946.54
26	33.02	7.90	17.29	58.21	26.99
27	33.02	7.90	17.29	58.21	26.21
28	33.02	7.90	17.29	58.21	25.44
29	33.02	7.90	17.29	58.21	24.70
30	33.02	7.90	17.29	58.21	23.98
31	33.02	7.90	17.29	58.21	23.28
32	33.02	7.90	17.29	58.21	22.61
33	33.02	7.90	17.29	58.21	21.95
34	33.02	7.90	17.29	58.21	21.31
35	33.02	7.90	17.29	58.21	20.69
36	33.02	7.90	17.29	58.21	20.08
37	33.02	7.90	17.29	58.21	19.50
38	33.02	7.90	17.29	58.21	18.93
39	33.02	7.90	17.29	58.21	18.38
40	33.02	7.90	17.29	58.21	17.84
41	33.02	7.90	17.29	58.21	17.32
42	33.02	7.90	17.29	58.21	16.82
43	33.02	7.90	17.29	58.21	16.33
44	33.02	7.90	17.29	58.21	15.85
45	33.02	7.90	17.29	58.21	15.39
46	33.02	7.90	17.29	58.21	14.94
47	33.02	7.90	17.29	58.21	14.51
48	33.02	7.90	17.29	58.21	14.09
49	33.02	7.90	17.29	58.21	13.68
50	33.02	7.90	17.29	58.21	13.28
					1430.64

Equivalent Levelized Annual Cost = 55.60 mills/kWh.

TABLE 9-3 (Sheet 1 of 2)

COMBINED CYCLE PLANT

COST OF GENERATING POWER AT 50% LOAD FACTOR

Year	Amortization & Insurance	O&M	Fuel	Total	Present Worth
1	8.64	9.64	21.1	39.38	38.23
2	8.64	9.82	36.2	54.66	51.52
3	8.64	10.01	37.4	56.05	51.29
4	8.64	10.20	38.6	57.44	51.03
5	8.64	10.39	39.8	58.83	50.75
6	8.64	10.59	41.1	60.33	50.53
7	8.64	10.79	42.33	61.76	50.22
8	8.64	11.00	43.60	63.24	49.92
9	8.64	11.21	44.91	64.76	49.63
10	8.64	11.42	46.26	66.32	49.35
11	8.64	11.64	47.65	67.93	49.07
12	8.64	11.86	49.08	69.58	48.80
13	8.64	12.08	50.55	71.27	48.53
14	8.64	12.31	52.06	73.01	48.27
15	8.64	12.55	53.63	74.82	48.02
16	8.64	12.78	55.23	76.65	47.77
17	8.64	13.03	56.89	78.56	47.53
18	8.64	13.28	58.60	80.52	47.30
19	8.64	13.53	60.36	82.53	47.07
20	8.64	13.78	62.17	84.59	46.84
21	8.64	14.05	64.03	86.72	46.62
22	8.64	14.31	65.95	88.90	46.40
23	8.64	14.31	65.95	88.90	45.04
24	8.64	14.31	65.95	88.90	43.73
25	8.64	14.31	65.95	88.90	42.46
					1195.92

NOTE: Escacalation rates above the general escalation rate are as follows.

Amortization & Insurance - Nil.

Operation & Maintenance - 1.9% for first 22 years only.

Fuel - 1.5% for first 22 years only.

TABLE 9-3 (Sheet 2 of 2)

COMBINED CYCLE PLANT

COST OF GENERATING POWER AT 50% LOAD FACTOR

Year	Amortization & Insurance	O&M	Fuel	Total	Present Worth
					1195.92
26	8.64	14.31	65.95	88.90	41.22
27	8.64	14.31	65.95	88.90	40.02
28	8.64	14.31	65.95	88.90	38.86
29	8.64	14.31	65.95	88.90	37.72
30	8.64	14.31	65.95	88.90	36.63
31	8.64	14.31	65.95	88.90	35.56
32	8.64	14.31	65.95	88.90	34.52
33	8.64	14.31	65.95	88.90	33.52
34	8.64	14.31	65.95	88.90	32.54
35	8.64	14.31	65.95	88.90	31.59
36	8.64	14.31	65.95	88.90	30.67
37	8.64	14.31	65.95	88.90	29.78
38	8.64	14.31	65.95	88.90	28.91
39	8.64	14.31	65.95	88.90	28.07
40	8.64	14.31	65.95	88.90	27.25
41	8.64	14.31	65.95	88.90	26.46
42	8.64	14.31	65.95	88.90	25.69
43	8.64	14.31	65.95	88.90	24.94
44	8.64	14.31	65.95	88.90	24.21
45	8.64	14.31	65.95	88.90	23.51
46	8.64	14.31	65.95	88.90	22.82
47	8.64	14.31	65.95	88.90	22.16
48	8.64	14.31	65.95	88.90	21.51
49	8.64	14.31	65.95	88.90	20.89
50	8.64	14.31	65.95	88.90	20.28
					1935.25

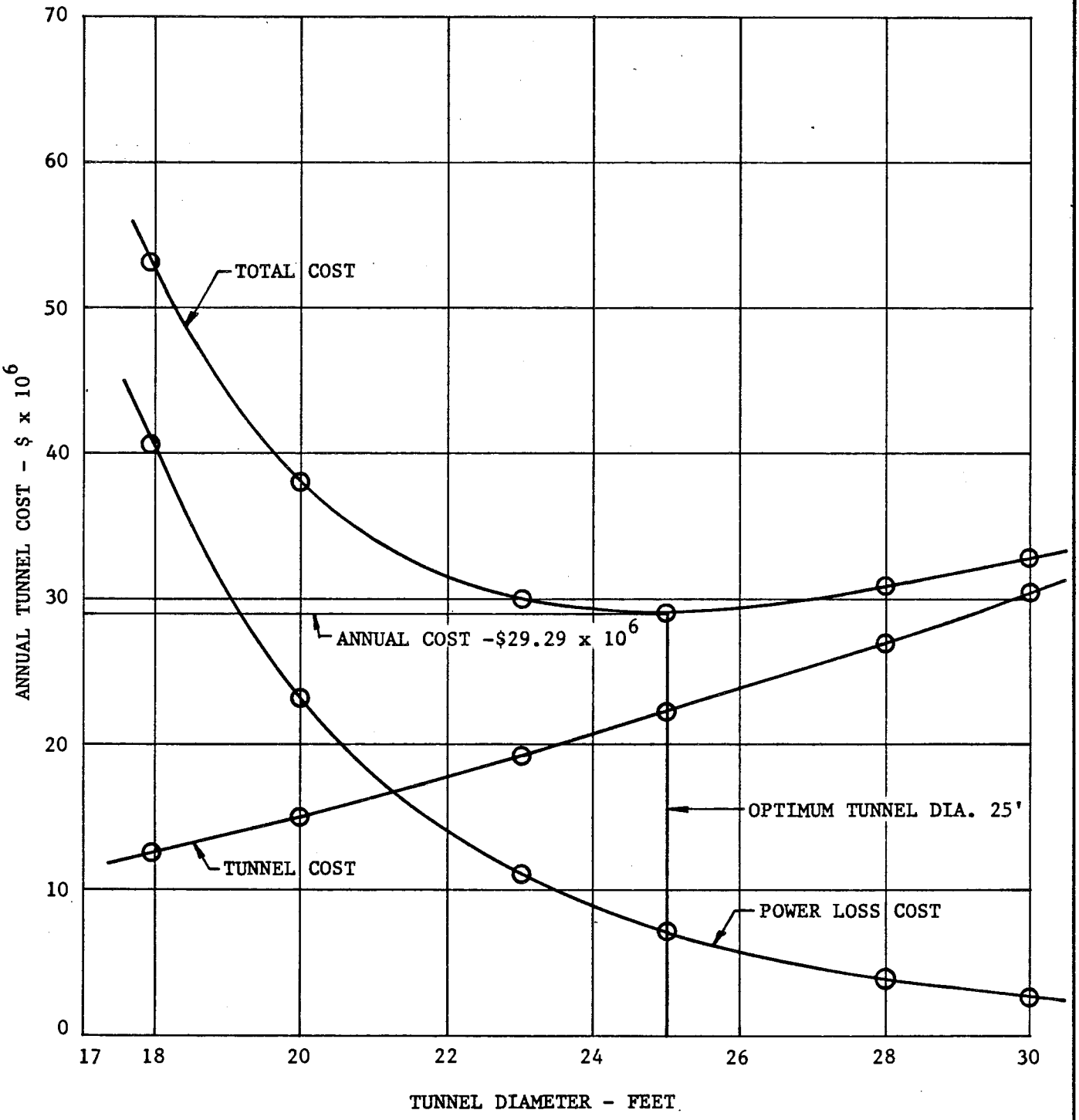
Equivalent Levelized Annual Cost = 75.21 mills/kWh.

9.5 Economic Tunnel Sizing

The economic diameter of the main power tunnel has been investigated by comparing the incremental cost of varying the tunnel diameter with the incremental value of the difference in power produced as a result of such variation in tunnel diameter. For the same powerhouse flow, increasing the tunnel diameter reduces the head losses in the tunnel thereby increasing the total head on the powerhouse with a consequent increase in power production.

In establishing the variation in estimated tunnel construction cost it has been assumed that the tunnel will be fully concrete lined with the typical horseshoe section shown in Figure 3-2 and would be excavated by conventional drill and shoot methods. Future studies should evaluate the merits of a nominally unlined tunnel. It should also be noted that when the method of driving the tunnel by tunnel boring machine was examined in 1982, no attempt was made to refine the economic tunnel diameter.

For the case of Alternatives A & C with no water release to meet instream flow requirements in the Chakachatna River (i.e., all controlled water being diverted for power production purposes), Figure 9-1 shows the plot of estimated tunnel construction cost and value of power production with variation in tunnel diameter. This curve shows that the economic diameter of a concrete lined tunnel is 25 feet. In Alternative B, with the flow diverted to a powerhouse sited on the McArthur River, but with water reserved for instream flow requirements in the Chakachatna River a separate study to establish the economic diameter was not made. Instead, as an approximation, the tunnel diameter was selected such that



ECONOMIC TUNNEL DIAMETER

FIGURE 9-1

the velocity of flow through the tunnel with the generating units operating at full output and at full level at Lake Chakachamna would be the same as that obtained under these same operating conditions in Alternative A for which the economic diameter had been calculated. This approximation gives a 23-foot horseshoe tunnel.

In the case of Alternative D where only an average release of 30 cfs flow is maintained below Chakachamna, Lake, the 25 foot diameter tunnel was retained, since the powerhouse flow differs by less than 1%.

In the case of Alternative E developed in 1982, based on driving the tunnel by tunnel boring machine, a 24 foot diameter circular tunnel was selected. This is hydraulically equivalent to the 23 foot diameter horseshoe shaped tunnel in Alternative B. If future geologic studies confirm the suitability of the rock for machine boring, the economic tunnel diameter should be re-evaluated.

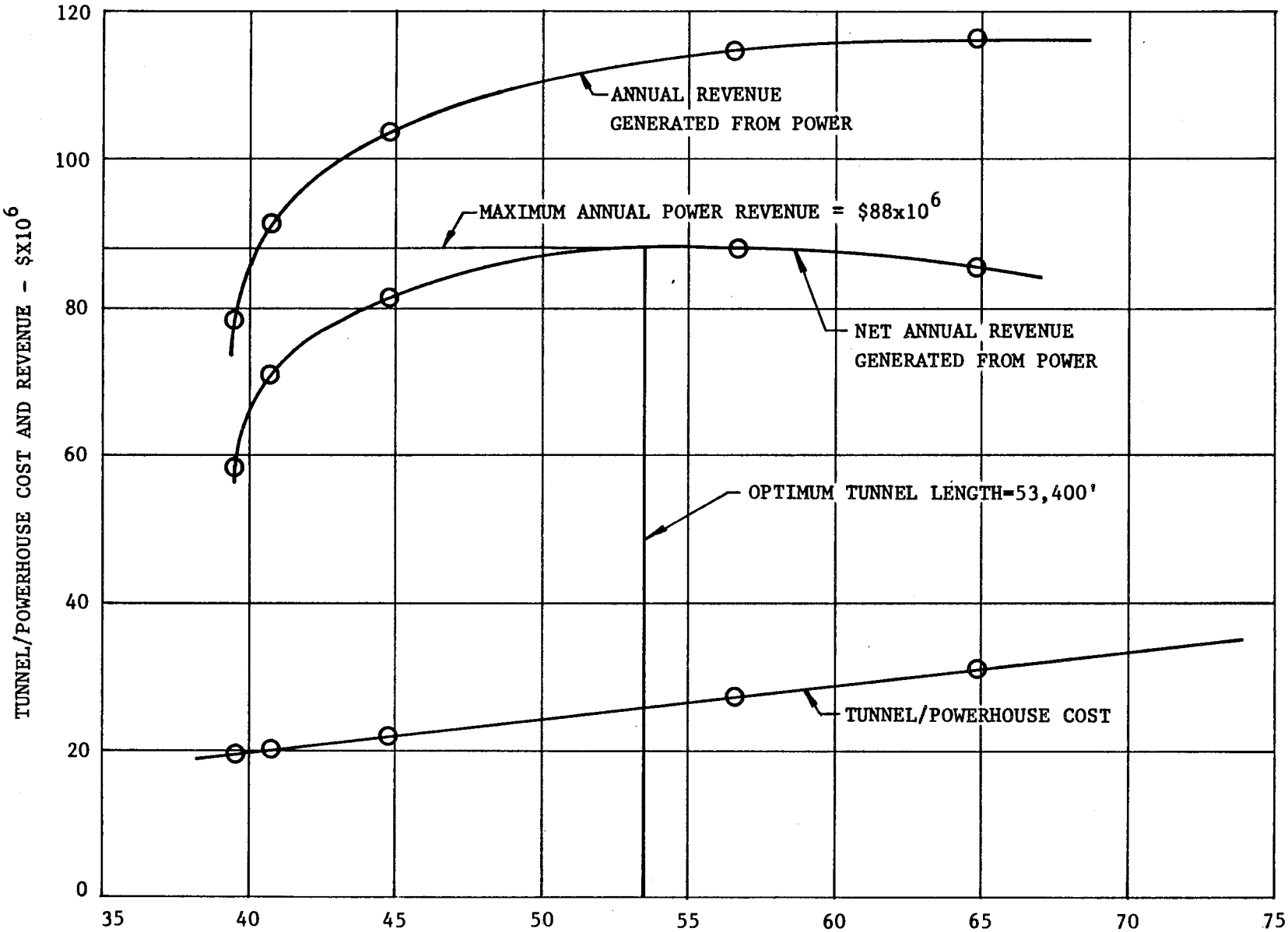
9.6 Economic Tunnel Length

For both basic alternative developments by diversion to the McArthur River or downstream along the Chakachatna River, an examination has been made of the economic tunnel length. As the powerhouse is moved downstream to develop additional head, the power tunnel becomes longer and hence more costly. The economic tunnel length is therefore determined from an economic balance of estimated tunnel construction cost and value of power produced. Based on the value of the hydro generation as discussed in Section 9.4, the present worth of the power produced by 1 foot of head when all controlled water is

used for power generation is equal to approximately $3,500,000 which corresponds to $139,000 annually over the 50 year life of the plant at 3% rate of interest.

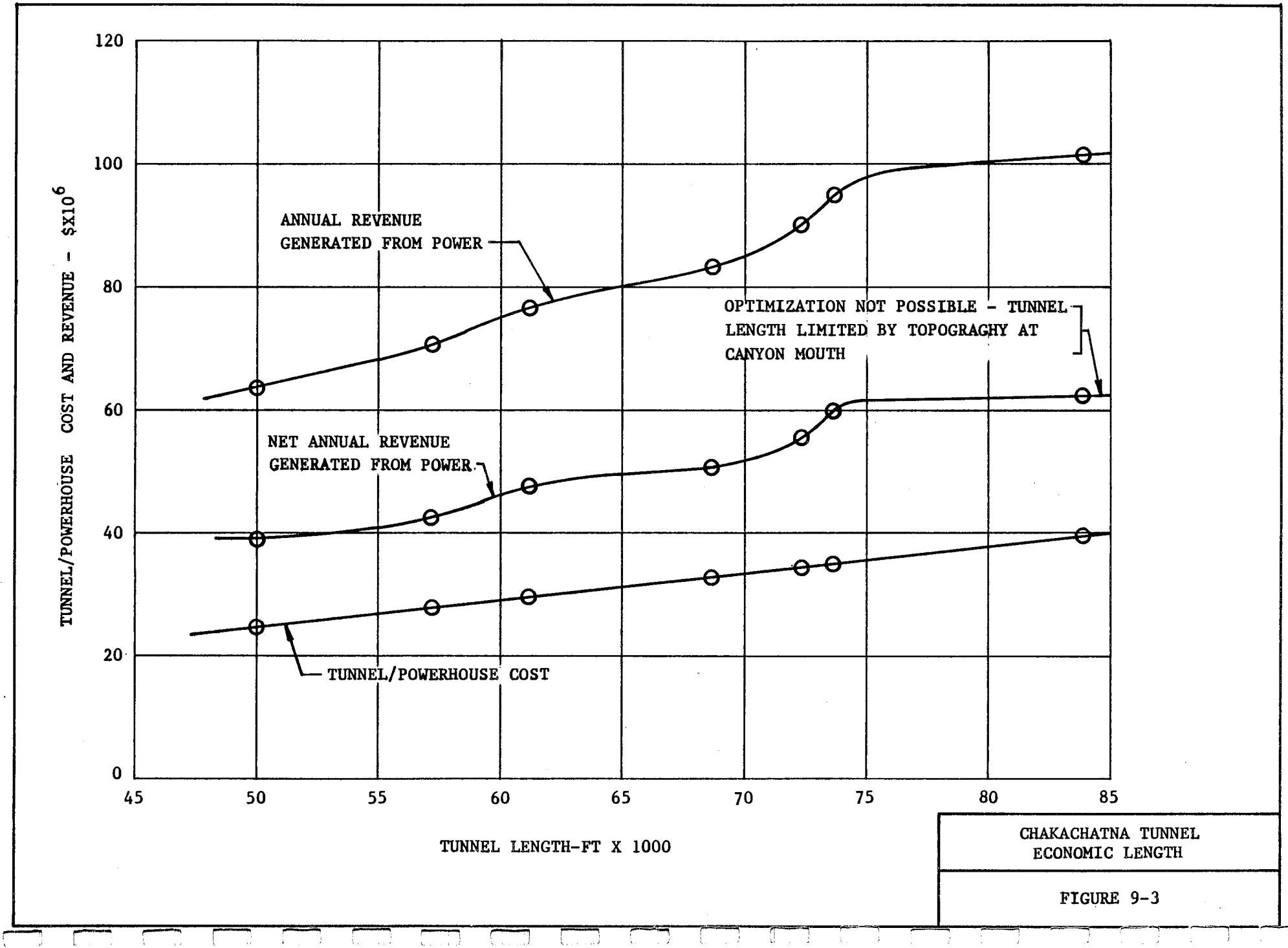
The economic balance includes consideration of the additional estimated tunnel construction cost by increasing the tunnel length, additional powerhouse cost to develop the power produced from the additional head and the value of the additional power generated by the additional head developed. The additional head is based on the increased gross head due to the lower tailwater obtained by extending the tunnel less the increased friction head loss in the longer tunnel.

Figure 9-2 and 9-3 show respectively the plots of the economic tunnel length for the development via the McArthur River and down the Chakachatna River. The final selected tunnel lengths and corresponding powerhouse locations are shown in Figures 3-2 and 3-3.



McARTHUR TUNNEL
ECONOMIC LENGTH

FIGURE 9-2



CHAKACHATNA TUNNEL
ECONOMIC LENGTH

FIGURE 9-3

COORDINATION

10.0 COORDINATION

10.1 Introduction

During the course of the project studies, coordination with various interested parties was conducted via informal contacts, written communication, and formal meetings in order to afford these parties an opportunity to make their interests in the project known and to enable the Power Authority to respond to questions and concerns about various aspects of the project. In this section of the report, copies of correspondence and meeting notes are reproduced to demonstrate coordination between the Power Authority and interested agencies.

10.2 HUMAN RESOURCES

10.2.1 Meeting - December 10, 1981

Representatives of U.S. Bureau of Land Manangement, National Park Service, and the Alaska State Archaeologist were invited to attend a meeting with representatives of Bechtel, Woodward-Clyde Consultants on December 10, 1981. A copy of the meeting notes prepared by Bechtel, Woodward-Clyde Consultants follows.

CHAKACHAMNA HYDROELECTRIC PROJECT

JOB No. 14879

MEETING NOTES

DATE: December 10, 1981

LOCATION: Business Park, Anchorage, Alaska

PARTICIPANTS:

Name	Organization
Bob Loder	Bechtel
David Cornman	Bechtel
Mike Joyce	Woodward-Clyde Consultants
Chuck Holmes	Subcontractor to Woodward-Clyde Consultants
Dave Mobraten	Anchorage District Office of the Bureau of Land Management
Bailey Breedlove	National Park Service
John Isaacs	Woodward-Clyde Consultants

SUBJECT: Human Resources Scoping Meeting.

Representatives from Bechtel Civil and Minerals and Woodward-Clyde Consultants (WCC) presented a summary of the proposed 1982 Human Resources studies and the results of the 1981 reconnaissance program to representatives of the Anchorage District Office of the Bureau of Land Management (BLM) and the National Park Service (NPS). The State Archaeologist was unable to attend the meeting.

An introduction describing the project, team organization, and potential development schemes was provided by Bob Loder. This included conceptual design and locations of the project alternatives. Mike Joyce presented a general overview of the environmental program, followed by Jon Isaacs, who discussed the 1981 Human Resources reconnaissance and the 1982 work program.

The agency representatives each had received a copy of the 1982 proposed work plan prior to the meeting. At the conclusion of the presentations, the agency representatives were asked to supply oral and subsequently written comments expressing their concerns with the proposed hydropower project and the proposed human resources work plan for 1982.

The major concerns expressed orally at this meeting are listed below:

BLM

- mineralization of the area, and potential resource extraction should be investigated.
- impacts on fish and wildlife resources are likely to be the big issue; economic impacts on the Cook Inlet fishery should be determined.

- o with regard to permits, it is likely that no permits for 1982 studies within the power site withdrawal will be required. Outside of the withdrawal, permits will be required for activities involving significant surface disturbance, such as drilling or road construction.

- o input from Cook Inlet Region Inc. (CIRI), Tyonek Native Corporation (TNC) and the State of Alaska should be solicited.

- o maps conveying land to the Native corporations and state should be checked for road and powerline easements.

- o concerning project construction and operation, waste disposal from tunnel construction will be an issue of concern. BLM would have no problems with road construction within the power site boundaries.

NPS

- o use of the project related roads and where they might put use pressure are of concern, particularly in the vicinity of Chakachamna Lake, where Lake Clark National Park could be affected.

- o the potential drawdown of Lake Kenibuna by the project needs to be investigated.

- o interest was expressed on Mt. Spurr's influence on the project.

- o potential effects to salmon runs entering Lake Clark National Park (Kenibuna Lake) will be investigated.

- o potential impacts to the project from glaciers and volcanic activity were noted.

- o situation problems similar to those anticipated on Susitna, may occur on the Chakachamna Project.

In addition to these comments, several questions where asked about the biological (winter fish distributions, peregrine falcon) and engineering (tunnel construction) aspects of the project.

10.2.2 Response

The concerns expressed by these agencies were noted and used for guidance in the planning and conduct of project studies. Fish and wildlife aspects were taken up with their respective Federal and State Agencies. Initial contacts were made with Cook Inlet Region, Inc. (CIRI) and Tyonek Native Corporation (TNC). An attempt to schedule a meeting with TNC was unsuccessful but future meetings are planned. Contacts and a meeting also took place with the National Park Service and the Superintendent of Lake Clark National Park.

10.3 Biological Studies

10.3.1 Meeting - December 11, 1981

A meeting was convened on December 11, 1981 between representatives of Alaska Department of Fish and Game, National Marine Fisheries Service, U.S. Fish and Wildlife Service and representatives of Alaska Power authority, Bechtel and Woodward-Clyde Consultants. The purpose of the meeting was to solicit and discuss verbal comments on proposed 1982 biological studies for the Chakachamna Hydroelectric Project. A copy of the meeting notes prepared by Bechtel, Woodward-Clyde is reproduced on the following pages.

CHAKACHMNA HYDROELECTRIC PROJECT

JOB 14879

MEETING NOTES

DATE: December 11, 1981

LOCATION: Business Park, Anchorage, Alaska

PARTICIPANTS:

Alaska Department of Fish & Game
Carl Yanagawa
Don McKay
Ken Tarbox
Kelly Hepler
Larry Heckart
Paul Ruesch
Ron Stanek
Tom Arminski

National Marine Fisheries Service
Brad Smith

U. S. Fish and Wildlife Service
Dave Ferrel

Alaska Power Authority
Eric Marchegiani

Bechtel
David Cornman
Bob Loder

Woodward-Clyde Consultants
Mike Joyce
Larry Rundquist
Paul Hampton
Braxton Dew
Wayne Lifton
Jon Isaacs

SUBJECT: Chakachamna Agency Scoping Meeting

Representatives from Alaska Power Authority (APA), Bechtel Civil and Minerals, and Woodward-Clyde Consultants (WCC) presented a summary of the proposed 1982 biological studies and the results of the 1981 reconnaissance efforts to representatives from the Alaska Department of Fish and Game (ADF&G), National Marine Fisheries Service (NMFS), and U.S. Fish and Wildlife Service (FWS). The purpose of the meeting was to discuss and solicit verbal comments on proposed biological studies for the 1982 Chakachamna Hydroelectric Project.

An introduction describing the project, its project team organization, and potential development scheme was provided by Eric Marchegiani, Bob Loder described the conceptual design and locations of the five project alternatives and Mike Joyce introduced the environmental presentation. The Woodward-Clyde task leaders (hydrology, aquatic, and wildlife biology) then briefly described the results of the two reconnaissance efforts in 1981 and the proposed studies for 1982.

The agency representatives each had received a copy of the 1982 proposed work plan prior to the meeting. At the conclusion of the presentations, the agency representatives were asked to supply oral and subsequently written comments expressing their concerns with the proposed hydropower project and the proposed environmental work plan for 1982.

The major concerns expressed orally at this meeting are listed below.

- Were the five reaches selected for Instream Flow Gauging chosen only on the basis of hydrologic information or was fishery information also used?

  Both hydrologic and fisheries data were used to select the number and location of critical reaches.

- Will one year of work be sufficient to accurately assess the instream flow requirements?

  One year should be sufficient because of the amount of data gathered in previous hydrologic and fisheries studies that can be compared to our data. Also, the IFG model will be verified after the initial July data are available. However, if critical data deficiencies are identified, measures will be taken to resolve such deficiencies.

- If only five critical reaches are chosen for the Instream Flow studies, will that information be sufficient to assess the impacts to the entire fishery?

Because the critical reaches include the major spawning, rearing, and migration areas, and the areas that could potentially be influenced the most by the project, we feel that the data gathered will provide enough information to assess impacts. In addition, if future studies indicate that more critical reaches are needed, we will consider including them.

- Will the distribution of age and size classes as well as the intra-areal movements of juveniles and residents be investigated?

  Through the diverse nature of the collecting gear and the number of sample sites, age and size class distribution will be investigated. Local movements of residents and juveniles within the study area will not be directly addressed, because data collected through other aspects of the program (maintenance of habitats) will be sufficient to assess project influences on local movements.

- Since the winter low flow periods are a critical time of year, will the winter studies be sufficient to evaluate the effects of altered discharge on the fish populations?

  At this time we feel that the sampling effort planned for the winter will be sufficient to assess the effects of altered discharge on the fish populations.

- Local fisherman and the resource agencies are perhaps most concerned about the cumulative effects of the Chakachamna and other Upper Cook Inlet projects on commercial fisheries.

  The comment was noted.

- Are the Habitat Evaluation Procedures being applied and what, if any, changes in the program are anticipated?

  The Habitat Evaluation Procedures are being applied. Only two changes are anticipated.

1) The change in habitat units over the life of the project will not be calculated because the potential effects of other nearby developments (Beluga Coal fields, timber harvesting, and offshore oil development) cannot be accurately assessed.

2) Because the models describing the habitat preferences of the evaluation species are based on a generalized niche concept, changes will be made, where necessary, to make the models more applicable to the preferences of the species in the study area.

- Are the transmission line corridor and road right-of-ways going to be investigated?

  Both will be evaluated by all disciplines after the general routes have been determined.

- Are any environmental studies planned for the marine or intertidal zone?

  The possibility of spawning, rearing, and migration areas in the intertidal zone will be investigated. The species composition and distribution of birds and mammals in the intertidal zone will also be investigated. No studies are planned at this time for the marine environment.

- What facilities are planned for the coast?

  At this time, the only proposed development of the coast will be a dock and an airstrip near Granite Point.

- Will the results of the 1981 investigations be available for agency review?

In January 1982, the results of the environmental studies as well as a complete project description will be sent to the agencies.

- Will a more detailed 1982 work plan be available that describes the functions that will be performed by subcontractors, who the subcontractors are, and what the approximate level of effort is for each sub-task?

  A new work plan will not be prepared. However, a list of subcontractors and their obligations will be sent to the agencies along with a schedule of the approximate level of effort apportioned to each sub-task.

- Will an Agency Task Force approach be instigated to coordinate agency input to mitigative measures?

  If the agencies choose that approach, APA, Bechtel, and Woodward-Clyde are willing to work with the Task Force.

- When, where, and how many public meetings are planned?

  No specific times, dates, places, or numbers have been determined. However, due to the special interest of the people in Soldotna, one of the meetings may be held there.

The representatives from the agencies agreed to submit further written comments after they had reviewed the results of the 1981 investigations and reviewed the preliminary project designs. They will each submit comments to their supervisor and one letter from the head of each agency will be submitted to the APA.

10.3.1.1 Response

The responses to the questions raised at the meeting are set forth in the meeting notes preceding this paragraph, immediately after each question.

10.3.2 Correspondence

The following pages display reproductions of correspondence received from the following agencies:

- o U.S. Fish and Wildlife Service, March 5, 1982, March 26, 1982
- o Alaska Department of Fish and Game, February 18, 1982
- o National Marine Fisheries Service, February 18, 1982

This correspondence relates to the 1982 work plan which was distributed to the agencies prior to the December 11, 1981 meeting as well as to the proposed project development. The comments received from the fishery agencies in these letters were taken under advisement and as guidance in defining and executing the final 1982 work plan. The implementation of many of the agencies' suggestions however, has had to be deferred until later studies. Responses by the Power Authority to the letters from the agencies immediately follow the letters from each agency.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1011 E. TUDOR RD.
ANCHORAGE, ALASKA 99503
(907) 276-3800

IN REPLY REFER TO:

WAES

Mr. Eric P. Yould
Executive Director
Alaska Power Authority
333 West 4th Avenue, Suite 31
Anchorage, Alaska 99501

05 MAR 1982

Re: Chakachamna Hydroelectric Project
1982 Work Plan, Environmental Studies

Dear Mr. Yould:

This letter transmits to the Alaska Power Authority (APA) comments and recommendations of the U.S. Fish and Wildlife Service (FWS) relative to the 1982 Work Plan, Environmental Studies for the Chakachamna Hydroelectric Project. Our comments are based on a review of the 1982 Work Plan in conjunction with a review of the Chakachamna Hydroelectric Project Interim Report dated November 30, 1981, and forwarded to us on January 9, 1982, and coordination meetings between APA, its consultant, FWS, the Alaska Department of Fish and Game (ADF&G), the National Marine Fisheries Service (NMFS), and other interested parties.

The FWS appreciates the opportunity to participate in developing the biological program for the Chakachamna Hydroelectric Feasibility Study. We feel that the 1982 Work Plan has provided an outline for some of the basic biological studies that will be required to address the effects of the Chakachamna Hydroelectric Project on fish and wildlife resources. We are providing comments specific to the 1982 Work Plan to identify the information we believe is essential to identify fish and wildlife resources of the project area, determine potential impact of the project upon those resources, evaluate alternatives to the proposed project, and formulate mitigation/enhancement measures. Our comments are as follows:

GENERAL COMMENTS

As presently conceived, the scope of studies presented in the 1982 Work Plan will not provide the data necessary to meet the study objectives as identified on Page 1. Thorough interagency coordination and comprehensive planning of biological studies is needed to insure an adequate information base for the preparation of environmental exhibits for submittal to the Federal Energy Regulatory Commission (FERC). Formal state/federal interagency coordination can best be initiated by application for a FERC preliminary permit. Advantages in applying for a preliminary permit include the early identification of all involved agency concerns as well as establishment of a formal relationship with

the FERC. The identification of agency concerns early in the planning process can prevent delays in processing the application for license and preparation of an Environmental Impact Statement (EIS). Under the FERC licensing process, the applicant may be required to collect additional data if the environmental exhibits are found to be inadequate by state and federal resource agencies.

To date, there has been only brief reconnaissance-level field investigations conducted late in the 1981 field season. We understand that field studies are scheduled to terminate in November 1982 and that, three months later, a feasibility report and FERC license application are due. Considering the complexity of the Chakachatna and McArthur River systems, the lack of basic qualitative fishery resource data, and the magnitude of the potential impacts to these resources which would result from hydroelectric development, the approximate ten months allocated to field studies and three months allocated to the analysis of the results of these studies is insufficient to adequately assess the effects this project would have on fish and wildlife resources. The impact of this proposed project upon both the Lake Clark National Park and the Trading Bay State Game Refuge adds to the complexity of the assessment.

A list of literature cited should be added to the work plan to facilitate the use of references cited.

Specific Comments

Environmental Hydrology

Regime Observations (Page 2)

We are pleased with the scope of study of this section, but question how the regime characteristics identified on pages 3 and 4 can be adequately assessed in a single remaining field season. As related to salmonid spawning habitat, a more detailed discussion is needed to show how characteristics of side channels and high water channels, tributary characteristics, and bed scour, degradation, and aggradation within the Chakachatna and McArthur River systems will be assessed. The timing and level of field effort to accomplish this need to be identified. The use of aerial photographs should not be used as a substitute for ground-level observations incorporating physical parameter measurements. The erosion studies proposed for the lake tributaries need to be explained in further detail.

Hydrology (Page 4)

We feel that reliable flow data is obtainable, in light of the 13 years of record by USGS, for the Chakachatna River. We are concerned, however, that representative flows for the McArthur River may not be. An assessment of groundwater inflow through side channels and sloughs, again in relation to salmonid spawning habitat, is needed. The evaluation of winter flow characteristics needs expansion. The expansion should include the methodologies and study site locations as well as an assessment of the correlation between these sites and fish over-wintering habitat.

We are concerned that the level of effort needed to assess the flow requirements for the maintenance of the Noaukta Slough and Trading Bay wetlands will not be met. This portion of the hydrology program needs expanson. Additionally, a water-quality program needs to be developed and the timing and level of effort identified.

Instream Flow Investigations (Page 5)

We have contacted the FWS Cooperative Instream Flow Group (CIFG), Ft. Collins, Colorado, for input into this portion of the 1982 Work Plan. Their comments, once received, will be forwarded to you for consideration into your study design. We are pleased that the IFG Incremental Methodology will be applied. However, there appears to be a limited data base to support the selection of the study sites identified in the study plan. Prior to application of the incremental methodology, a qualitative understanding of morphologic, hydraulic, and biologic characteristics of the two rivers must be obtained. The seasonal distribution and habitat utilization of fish species as well as the seasonal flow patterns and channel structure must be known before study sites can be selected.

There are a number of anadromous and resident fish in this system. A good qualitative understanding of relative abundance, seasonal habitat requirements and distribution should be obtained for all key species. However, for application of the incremental methodology, and development of habitat suitability criteria we suggest that target species be selected in consultation with state/federal resource agencies for detailed analysis.

We are concerned about the timing of the instream flow studies. These studies are generally conducted in two phases. During phase I a qualitative understanding of the biologic, hydraulic, and morphologic characteristics of a system is obtained. From this information a phase II study plan is formulated. The river is subdivided into relatively homogenous segments and study sites are selected for detailed analysis. Relationships of existing fishery resources are reviewed and target species are selected for use in the analysis. Phase II includes the collection of hydraulic calibration data, computer modeling of study sites, development of habitat suitability criteria and analysis of projected effect. Since the tasks in phase II are dependent on the results of phase I studies, we do not believe these two phases can be undertaken concurrently.

We refer you to An Assessment of Environmental Effects of Construction and Operation of the Proposed Terror Lake Hydroelectric Facility, Kodiak, Alaska, Instream Flow Studies, prepared by Arctic Environmental Information and Data Center, University of Alaska, March 1981, as a good example of an Alaskan application of instream flow techniques which required two full field seasons to obtain.

Finally, there are no data to substantiate the 19% provisional reservation of the average annual inflow to Chakachamna Lake, as presented in the Interim Report and derived by the Montana Method, to meet the instream flow requirements for fishery resources in the Chakachatna River. Because of the apparent importance of side channel habitats, the Montana Method may not be appropriate for application to the Chakachatna River. The instantaneous and seasonal flows necessary to sustain this resource should eminate from the instream flow studies planned.

Aquatic Biology

Macroinvertebrates (Page 7)

While the effort presented in this section is commendable, we consider the forage studies to be of lesser priority than the fish studies. Accordingly, the primary objective should be conducting adequate fish studies. The timing and study site locations involved in the macroinvertebrate investigations should be identified in the study plan.

Fish (Page 9)

In general, we feel that the fish studies presented in this section are one of the stronger portions of the overall 1982 Work Plan. Our major concern is that one field season will not be adequate to gather the necessary field data to adequately assess species presence, composition, and distribution; spawning habitat; migratory pathways; juvenile rearing habitat; and general habitat utilization. This may be further complicated by the fact that 1982 represents an even-year pink salmon run in Cook Inlet and returns could be substantial. The use of hydroacoustics in identifying these parameters needs further explanation and expansion. We suggest the possible use of radio-tagging techniques to further identify migratory pathways and spawning habitats. The FWS, Fisheries Research Center, Alaska Field Station, has successfully applied this technique in chinook salmon investigations on the Kenai River. Additionally, the Alaska Department of Fish and Game has applied the technique to assess chum, coho, and chinook salmon habitat in the Susitna River. It is particularly applicable in systems where visibility is a limiting factor.

Spawning (Page 9): It is necessary to identify the relative importance of different types of spawning habitats throughout the Chakachatna and McArthur Rivers and their relative contribution to the total production of the system. We are interested in the relative importance between mainstem and side channel habitats and an evaluation of incubation success in these habitats. We are particularly interested in the side channel habitat in the Chakachatna River which may be affected by reduced flows. Identification of spawning habitat in Chakachamna and Kenibuna Lakes and their tributaries is needed.

Migration (Page 11): The assessment of migratory pathways should be focused on those areas to be impacted by the project. It is important to identify the relative importance of the various migratory routes. A more detailed discussion of the sampling site locations and timing involved in this effort is needed.

Habitat Utilization (Page 12): We feel that the adequate assessment of over-wintering habitat is critical in regard to minimum flow requirements. A description of how and where this will be accomplished is lacking in this section.

Community Analyses (Page 13): A further explanation of what this section will contribute to the overall analysis of fishery resources in the Chakachatna and McArthur River systems is needed.

Impact Assessments (Page 13): It is essential for the FERC permit application to include a comprehensive mitigation plan developed in consideration of but not limited to the following: 1. Developing fish pathways at the mouth of

Chakachamna Lake to maintain outmigration and adult escapement, 2. use of artificial spawning channels to mitigate the loss of spawning habitat, 3. maintenance of migrational pathways to the tributaries of Chakachamna and Kenibuna Lakes after lake drawdown, 4. mitigation for the loss of spawning habitat along the lakeshores.

Temperature: The 1982 Work Plan lacks completely a section on the assessment of temperature regimes in the river and lake systems. We suggest a program be developed to address this issue and that the impacts of altered temperature regimes be assessed. A temperature model needs to be prepared.

Wildlife Biology (Page 14)

We are pleased that a HEP analysis is proposed. As an integral part of HEP, we encourage you to make use of a state/federal interagency team to select indicator species and technically assist in the application of HEP. In so doing you will insure that the perspectives of all agencies are included in the process, thus increasing the acceptability of the product. One indicator species, preliminarily chosen, the tule goose, has never been found to nest in the area. Its usefulness as an indicator species is questionable. We suggest that the project boundary be reevaluated to encompass not only the total land and water areas where direct impacts could occur, but where secondary impacts due to human encroachment and construction activities resulting in wildlife displacement are expected. Specifically, proposed construction camp sites, access road alignments, transmission corridor alignments, proposed airstrips, and tidewater facilities need to be assessed closely for potential impacts to wildlife migration routes as well as loss of potentially important feeding and cover habitat types. We would like to see a comparison, based on quantified habitat units, of the relative impacts of alternative access routes and alternative project designs on wildlife resources.

The mapping of vegetative habitat types should cover the entire area of project influence to a scale of 1 inch per mile. The scale should be expanded to 4 inches per mile in areas of significant alteration. We recommend this expanded scale be used to map all riparian and wetland habitat types. We are particularly concerned about potential impacts to the trumpeter swan population in the project area (143 swans reported in 1980). Potential conflicts between migration routes and transmission corridor alignments for swans and other waterfowl species need to be identified early. Additionally, potential impacts to nesting pairs of swans should be examined carefully.

Other important considerations include the identification of bear denning sites and moose and caribou calving grounds which may be within the project boundary. Particular attention should be focused on field investigatons of riparian habitat and the extensive wetland complex of Trading Bay in regard to the high use by wildlife these areas receive.

While the Wildlife Biology portion of the 1982 Work Plan identifies these concerns in general, it fails to adequately describe the timing and level of effort to be applied to comprehensively evaluate them. Additionally, we are concerned about the disposal site location for talus material from power tunnel excavation and the location of a barge facility in the tidelands of Trading Bay. Alternative locations for these project features need to be identified and relative impacts assessed.

Endangered Species

As required by the Endangered Species Act (87 Stat. 884, as amended), the FERC, or their designee, should formally request a list of threatened or endangered species from this agency. If the list indicates that these species are present in the project area, FERC is required under Section 7(c) to conduct a Biological Assessment. This assessment would identify any listed or proposed threatened or endangered species and discuss potential project related impacts. The assessment is to be completed within 180 days after receipt of the official list, unless a time extension is mutually agreed upon. No contract for physical construction may be entered into and no physical construction may begin until the Biological Assessment is completed. If the conclusions drawn from the Biological Assessment indicate that endangered or threatened species are likely to be affected by the construction project, FERC is required by Section 7(a) to request formal consultation.

Conclusion and Recommendations

The results of the 1982 field investigations will provide some of the baseline data necessary for impact assessment. We feel this data will be qualitative in nature with refinement possible only after additional study and analysis. The compressed time-frame of the feasibility study as currently proposed, however, does not allow such analysis. To date, there has been little effort given to the development of impact assessment and mitigation strategies. As planning and studies continue, we feel a more comprehensive and formal coordination process should be established and implemented between APA, the consultant, and the resource agencies. Also, there has yet to be developed a forum for public input. It is obvious that there has not been adequate time allocated for environmental studies to be conducted which are comensurate with the magnitude and complexity of the potential impacts associated with the Chakachamna Hydroelectric Project.

Accordingly, we recommend:

1. That an Interagency Task Force be established in order to technically assist in the terrestrial habitat and instream flow analyses, coordinate and review the results of further environmental studies, assess impacts, and formulate mitigation proposals;

2. that the APA apply for a FERC preliminary permit to initiate formal interagency coordination;

3. that the time-frame for the scope of the environmental studies associated with the feasibility study be expanded and that the 1982 field season be utilized to collect adequate qualitative baseline biological data of sufficient scope;

4. that a revised Work Plan for environmental studies, based on the expanded time-frame, be formulated and reviewed by the Interagency Task Force;

5 that appropriate procedures be developed for coordination between resource agencies and the APA to include coordination meetings with sufficient lead time to allow for information exchange and project review; and

6. that a forum for meaningful public input be established.

Finally, we can see no advantage in presenting an application to FERC, which will be reviewed by FWS, that does not contain an adequate assessment of project impacts to fish and wildlife resources and a comprehensive mitigation plan. Submission of environmental exhibits under such a compressed time-frame can only hinder the designing of an environmentally sound project. Accordingly, the FWS recommends the license application be delayed until sufficient biological data are available.

We look forward to continuing to work closely with the APA in the future to develop and implement a mutually acceptable feasibility study. We encourage your consultants to now contact our Western Alaska Ecological Services Field Office for technical assistance in planning for the application of HEP and Instream Flow methodology.

Sincerely,

Melvin A. Monson

Acting Assistant Regional Director

cc: FWS-ROES, WAES, CIFG
ADF&G, NMFS, EPA, BLM, USGS, NPS,
ADEC, ADNR
Mike Joyce, Woodward-Clyde
FERC, Washington, D.C.

Cirrus

United States Department of the Interior

FISH AND WILDLIFE SERVICE

IN REPLY REFER TO:

WAES

Western Alaska Ecological Services
733 W. 4th Avenue, Suite 101
Anchorage, Alaska 99501
(907) 271-4575

26 MAR 1982

APR - 5 1982

ALASKA POWER AUTHORITY

Mr. Eric Yould,
Executive Director
Alaska Power Authority
334 W. 4th Avenue
Anchorage, Alaska 99501

Re: Chakachamna Hydroelectric Project, 1982 Work Plan, Environmental Studies

Dear Mr. Yould:

This letter transmits to the Alaska Power Authority (APA) comments and recommendations of the U.S. Fish and Wildlife Service (FWS) Instream Flow and Aquatic Systems Group, Fort Collins, Colorado, relative to the 1982 Work Plan, Environmental Studies for the Chakachamna Hydroelectric Project. Previous FWS comments relative to the 1982 Work Plan, Environmental Studies, were forwarded to you on March 5, 1982. The enclosed comments are specific to the instream flow and hydrologic aspects of the 1982 Work Plan.

We look forward to continuing to work closely with the APA in the future to develop and implement a mutually acceptable feasibility study. We encourage your consultants to contact our Western Alaska Ecological Services Field Office for technical assistance in planning for the application of Instream Flow methodology for this project.

Sincerely,

Robert Bowker

Field Supervisor

Enclosure

cc: FWS-ROES, WAES, CIFG
ADF&G, NMFS, EPA, BLM, USGS, NPS
Mike Joyce-Woodward-Clyde
FERC-WDC

United States Department of the Interior

FISH AND WILDLIFE SERVICE

OFFICE OF BIOLOGICAL SERVICES
Western Energy & Land Use Team
Drake Creekside Building
2625 Redwing Road
Fort Collins, Colorado 80526

Instream Flow and Aquatic Systems Group

March 12, 1982 IFG 206

Mr. Dave Ferrell
Western Alaska Ecological Services
733 W. 4th Avenue, Suite 101
Anchorage, AK 99501

Dear Mr. Ferrell:

As per your letter of February 1, 1982 and your phone conversations with Clair Stalnaker, I have reviewed the Interim Report on Chakachamna Hydroelectric Project and the work plan for the environmental studies.

My initial reaction is that there is not enough information in the environmental work plan on which to base any comments. For instance, there is no information on water temperature aspects in the interim report and no mention of water temperature in the environmental work plan. I will return to the work plan later.

First, let us look at the interim report; the purpose of the report was to provide a preliminary evaluation of the proposed project. Consequently, all elements of the proposed project could change before construction. The Tennett (Montana) method was used to obtain some idea of the instream flows which are needed in the various streams. It is interesting that the Bechtel staff have assumed rivers of the northern great plains are representative of glacial rivers in Alaska. It is not inappropriate to use a technique that uses a fraction of the natural flow in the stream as an initial estimation of the instream flow needs. The fraction should be developed for similar geomorphology and biological conditions. In the case of the Chakachamna project; data for coastal Oregon, Washington, and British Columbia, as well as Alaska, could have been used to develop the hydrograph multipliers to estimate the instream flow needs.

If it is assumed all the information available about the fisheries aspect of the project area are covered in the report, then there is a major lack of basic data on the existing conditions which, in my opinion,

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makes it difficult to develop a work plan for environmental studies. At this point, I can only outline a few of my major concerns; these are

1. There appears to be no element in the work plan to study the streams above the lake - they should be studied.

2. The channel streams flowing into the lake are likely to change as a result of lowering the lake level - this aspect is very important and must be studied.

3. Temperature aspects should be studied.

4. The Chakachatna river channels downstream of the lake and the McArthur river channels are almost certain to change as a result of the project; an engineering study is required.

5. What habitat criteria are to be used to relate the fish species to the physical habitat; are new criteria data to be collected?

6. It is difficult for me to comment on the site selection because of the lack of information but the proposed sites do not include the channels below Noaukta Slough. I suspect the proposed project will have an impact on the channels below Noaukta Slough.

I would like to know just what "community analysis" is as described on page 13 of the work plan and how it fits in with other elements of the work plan.

If I were doing the project planning, I would consider selecting only a few sites this year for instream flow studies and spend most of the effort obtaining a clear picture of the system. The following year would be used for the more detailed studies. This way I would soon have information on the instream flow needs on which to base future planning studies and have the type of information needed for the final analysis some time later.

I hope these comments are of use to use - unfortunately I can do little more because of the lack of information in the environmental work plan.

Sincerely,

Robert Milhous
Hydrologist

ALASKA POWER AUTHORITY

334 WEST 5th AVENUE · ANCHORAGE, ALASKA 99501

Phone: (907) 277-7641
(907) 276-0001

RECEIVED
DEC 2 1982
R. T. LODER

November 26, 1982

Mr. Keith Schreiner
Regional Director
U.S. Fish & Wildlife Services
1011 East Tudor Road
Anchorage, Alaska 99503

Dear Mr. ~~Schreiner~~ Keith:

Please reference your agency's letter of March 5, 1982, concerning Chakachamna Hydroelectric Project 1982 Work Plan, Environmental Studies. The Alaska Power Authority appreciates the detailed comments your agency has provided, but due to severe budget restraints we have not yet been able to implement most of those. The Power Authority through our consultant, Bechtel/Woodward-Clyde, has collected fishery data during this past summer and fall. Your agency personnel visited the proposed project area while Woodward-Clyde was actually collecting this data during August 1982.

We would like to invite you and your staff to a meeting at 9:30 A.M. on December 9, 1982, in the new Federal Building, National Weather Service, 5th floor, East Conference Room. The purpose of the meeting will be to present information collected during the summer and fall and answer questions on an informal basis concerning the resource in the area. I have attached an agenda for the meeting.

We have requested additional funding for the FY 84 budget year in order to complete the feasibility study. Once legislative approval has been acquired, a new work plan for environmental studies will be developed taking into account concerns previously expressed by your agency and others. It is our intent to coordinate this plan with the concerned agencies.

Thank you for your continued participation in our planning activities.

Sincerely,

Eric P. Yould
Executive Director

cc: Robert Loder, Bechtel
Wayne Lifton, Woodward-Clyde
Kenneth Plumb, FERC
Gary Stackhouse, U.S. Fish & Wildlife Service
Lenny Corin, U.S. Fish & Wildlife Service

Attachment: Agenda

ATTACHMENT A

TENTATIVE AGENDA FOR DECEMBER 9 MEETING

Chakachamna Hydroelectric Project

I. Opening Remarks — Eric Marchegiani

Purpose of Meeting:

- Provide Background to New Personnel
- To Receive Agency Input
- To Keep Agencies Informed

II. Description of Project — Eric Marchegiani/Bob Loder

- Engineering Studies to Date
- Fish Passage Facility Concepts

III. Environmental Studies — Wayne Lifton

- FY 1982
- FY 1983 - scope, general objectives
- Hydrology — L. Rundquist
- Aquatic Biology — Wayne Lifton

STATE OF ALASKA

DEPARTMENT OF FISH AND GAME

OFFICE OF THE COMMISSIONER

JAY S. HAMMOND, GOVERNOR

P.O. BOX 3-2000
JUNEAU, ALASKA 99802
PHONE: 465-4100

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MAR 1 1982

ALASKA POWER AUTHORITY

February 18, 1982

Alaska Power Authority
334 W. 5th Avenue
Anchorage, Alaska 99501

Attention: Mr. Eric P. Yould, Executive Director

Gentlemen:

Re: 1982 Chakachamna Hydroelectric Project Study Plan Review, Interim Report Engineering and Geological Studies (November 1981), Woodward-Clyde Environmental Study Work Plan (December 1981)

The Alaska Department of Fish and Game has reviewed the proposed 1982 Chakachamna Hydro Study Plan and submits the following comments:

1982 Environmental Study Work Plan

We are concerned that the remaining one year of study may prove to be insufficient as very little is currently known about the fish and wildlife resources within the project area. In addition, the study plan does not specify the effort devoted to each task or expected sequence of events and from all appearances the 1982 effort looks to be an overly ambitious undertaking. As we have said in the past, we are willing to provide specific direction towards development of studies if you desire our assistance. Please find comments specific to portions of the 1982 Study Plan enclosed.

In addition, please feel free to contact us if you have any questions or comments.

Sincerely,

for Ronald O. Skoog
Commissioner

Enclosure

cc: C. Yanagawa
R. Andrews
R. Redick
L. Trasky
S. Pennoyer
R. Somerville
R. Logan
A. Kingsbury
S. Eide
D. Daisy
R. Roys
J. Fall

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ALASKA POWER AUTHORITY

10.1 Engineering Studies

Para. 1

Engineering studies should also address development of structures to reduce or eliminate fish entrainment in the power tunnel or turbines. If elevated thermal regimes are anticipated, multilevel intakes for both water diverted for generation and that to provide instream flows should be considered.

10.1.1 Hydrological Studies

Para. 1

In addition to synthesizing Chakachamna Lake outflow data, we believe it necessary to determine the percentage of flow in the Chakachatna system contributed from tributary streams, wetlands, and groundwater with respect to specific stream reaches. This will reveal the significance of lake outflow regulation in reaches where lowered flows may limit habitat. It would be wise to analyze the McArthur system in much the same manner but with respect to augmented flows. Flow augmentation may result in morphological changes, changes in habitat suitability and possible thermal effects.

Para. 2

In addition to making predictions with respect to Chakachamna Lake thermal regimes, it will also be necessary to predict changes in thermal regimes (which would affect salmonid incubation rates) in both McArthur River and Chakachatna River. Both systems have reaches in which spawning occurs that will be affected by lake releases or power diversions. We suggest that recording thermographs be placed in stream reaches where spawning might be impacted. This information along with Chakachamna Lake thermal modeling, meteorological data, and hydrological data can be used in a predictive stream thermal model.

10.1.3 Reservoir and Fish Passage Facilities

Para. 1

In addition to passing fish in and out of Chakachamna Lake, provisions must be developed to allow fish to migrate in and out of tributaries to the lake. It appears that during operation, the lake water surface elevation will never reach currently existing levels and may drop in excess of one hundred feet below existing levels. This will effectively isolate tributaries with respect to fish migrations.

10.1.4 Power Intake and Tunnel

Para. 1

Consideration should be given to design these features to prevent entrainment of fish.

10.1.5 Underground Powerhouse Complex

Para. 1

Since the tailrace discharge will be located in an identified spawning area, it should be designed to prevent habitat degradation. It may even be possible to design this feature to increase the quantity of spawning habitat available and help to offset habitat losses elsewhere.

10.1.6 Transmission Line and Submarine Cable Crossing

Para. 1

Alignment selection and construction logistics should be coordinated with the environmental effort to determine the least detrimental alternative.

10.1.7 Access Roads and Construction Facilities

Para. 1

Campsite selection, road alignments selection, and construction should be coordinated with the environmental effort to determine the least detrimental alternatives.

10.1.8 Cost Estimates and Construction Schedule

Para. 1

Construction scheduling should strive to minimize environmental impacts by avoiding disturbances to fish and wildlife during sensitive periods (spawning, calving, etc.).

1982 Work Plan - Environmental Studies, Woodward-Clyde Consultants, December 8, 1982.

ENVIRONMENTAL HYDROLOGY

Regime Observations

Para. 1

Will these regime observations ultimately result in a detailed prediction of potential morphological and sedimentation changes arrived at through modeling or will predictions be subjective in nature?

Hydrology

Para. 1

What is the rationale for those locations? Have they been chosen with respect to influx of tributary waters, channel configuration, fish habitat, etc.?

Will the gauges be operational for more than one year (1982) or at least one water year?

Will synthetic data be developed for these gages whose period of record equals that used to determine generating capacity, reservoir operation, etc.?

Para. 3

Will any attempt be made to quantitatively assess the significance of the selected wetlands?

In addition to the above questions, we are concerned that hydrological studies of the scope necessary to provide an adequate assessment of hydrologic-hydraulic impacts cannot be completed during the 1982 season. We assume that the gauge network has not been installed at this time nor have transects been located or surveyed. If these tasks are accomplished this spring and summer, the studies will have to be extended till at least summer 1983 to get one water year of data and that is a very minimal amount.

Instream Flow Investigations

Para. 1

Are the five study sites considered representative or critical reaches? It is our understanding that the critical reach approach should be

applied to reaches whose physical or chemical characteristics limit the fishery resource. With the current knowledge we have of these systems, we suspect that the sites should be treated as representative reaches with the possible exception of Chakachatna Canyon which could be a limiting factor with respect to migrations.

Para. 3

With respect to the location of the transects, it is our understanding that two considerations are paramount: 1) a rigid channel; and 2) biological pertinency. Changes in channel shape and whether the location is at a hydraulic control are secondary considerations.

In addition, it would be advantageous to have a resource interagency team review transect selection.

Office Analysis

Will the bed and bank erosion analysis of the McArthur River be a subjective effort or will it involve use of a sediment transport model. The analysis should be applied to Chakachatna River also. Operation of the project will attenuate peak events which probably move great amounts of sediment through the system. Without these events, there may be significant morphological changes.

With respect to the instream flow investigations, although not specified in the study plan, we assume that the IFG-3 model will be

used to determine weighted usable area (WUA) once habitat suitability curves have been developed.

AQUATIC BIOLOGY

Macroinvertebrates

How will impacts to macroinvertebrates be predicted?

Fish

Para. 1

Will this characterization and quantification of habitat effort be coincident with the instream flow effort?

Spawning

Para. 1

If spawning areas have yet conclusively identified, might it not be premature to have already selected IFG methodology study sites which are to be representative of spawning areas?

Pertaining to the statement that hydro-acoustic techniques will be tested to estimate spawning density, if this technique proves

successful, will a full scale program be started? What will the program involve and who will be contracted to conduct it?

Para. 9

We believe that recording thermographs would be installed in selected spawning areas to provide additional data needed to determine if detrimental thermal impacts will result. Temperature probes should be installed to record temperatures of both surface and intragravel flows.

Para. 10 & 11

Are migration pathways addressed through the IFG methodology in a representative or critical reach study site?

With respect to out-migrant monitoring, properly designed, this program could indirectly enumerate smolts and provide one way of quantifying the contribution of the McArthur and Chakachamna systems to the Cook Inlet fisheries to establish levels of mitigation necessary. The Department currently conducts a smolt out-migrant study on the Kasilof River that could serve as a model for the Chakachamna program.

Habitat Utilization

Para. 4

As mentioned earlier, it would be wise to review establishment of proposed habitat transects with an interagency team.

Fish Populations

Para. 1

If it becomes apparent that the project will significantly impact the fisheries resources of these systems, it would be wise to continue fish population studies for several years. Otherwise there will be no data regarding numbers of fish on which to base levels of required mitigation.

Impact Assessment

Para. 2

We suggest that an interagency team be established to propose and review mitigation measures and to identify areas where further study might be indicated.

WILDLIFE BIOLOGY

Wildlife

Para. 2

What is the reason for reevaluating the 1981 species selection? Are there other relevant criteria than the three mentioned here that must be considered. If so, what are they?

Habitat Suitability

Will the existing U.S. Fish and Wildlife Service Alaska models be used to derive HSI or will the consultant develop his own?

Impact Assessment

Rather than departing from the standard HEP analysis because of the uncertainty of future development, we suggest development of three scenarios that describe varying levels of impact to the area and use them to complete the HEP analysis. We believe that there is currently enough information for development of these scenarios.

ALASKA POWER AUTHORITY

334 WEST 5th AVENUE - ANCHORAGE, ALASKA 99501

Phone: (907) 277-7641
(907) 276-0001

RECEIVED
DEC 2 1982
R. I. LODER

November 26, 1982

The Honorable Ronald O. Skoog,
Commissioner
Alaska Department of Fish & Game
Subport Building
Juneau, Alaska 99801

Dear Commissioner Skoog:

Please reference your agency's letter of February 18, 1982, concerning Chakachamna Hydroelectric Project 1982 Work Plan, Environmental Studies: The Alaska Power Authority appreciates the detailed comments your agency has provided, but due to severe budget restraints we have not yet been able to implement most of those. The Power Authority through our consultant, Bechtel/Woodward-Clyde, has collected fishery data during this past summer and fall. Your agency personnel were invited to visit the proposed project area while Woodward-Clyde was actually collecting this data during August 1982.

We would like to invite you and your staff to a meeting at 9:30 A.M. on December 9, 1982, in the new Federal Building, National Weather Service, 5th floor, East Conference Room. The purpose of the meeting will be to present information collected during the summer and fall and answer questions on an informal basis concerning the resource in the area. I have attached an agenda for the meeting.

We have requested additional funding for the FY 84 budget year in order to complete the feasibility study. Once legislative approval has been acquired, a new work plan for environmental studies will be developed taking into account concerns previously expressed by your agency and others. It is our intent to coordinate this plan with the concerned agencies.

Thank you for your continued participation in our planning activities.

Sincerely,

Eric P. Yould
Executive Director

cc: Robert Loder, Bechtel
Wayne Lifton, Woodward-Clyde
Kenneth Plumb, FERC
Carl M. Yanagawa, Alaska Department of Fish & Game
Don McKay, Alaska Department of Fish & Game
Phi Byrna, Alaska Department of Fish & Game

Attachment: Agenda

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
P. O. Box 1668, Juneau, Alaska 99802

February 18, 1982

RECEIVED
FEB 24 1982
ALASKA POWER AUTHORITY

Mr. Eric P. Yould
Executive Director
Alaska Power Authority
333 West 4th Avenue, Suite 31
Anchorage, Alaska 99501

Dear Mr. Yould:

We have received the Chakachamna Hydroelectric Project Interim Report - November 30, 1981, and the 1982 Work Plan for Environmental Studies Associated with this project. We have completed our review of both documents and offer the following comments.

The Interim Report, according to your letter of January 8, 1982, is being distributed in order to provide additional data on which to base comments regarding the 1982 Environmental Studies Work Plan. Accordingly, we have limited our review of this document only to those sections pertinent to the Environmental Studies program, sections 6 and 10. Section 6 provides a summary of those reconnaissance-level surveys conducted during the 1981 season. Although little data are provided, this section identifies areas that appear to be important to fisheries resources and discusses gaps in available knowledge. Section 10 (describing the 1982 studies) and the 1982 Environmental Studies Work Plan both target upon these important areas. However, we feel some caution should be used in basing future studies heavily on the results of the 1981 work. Paragraph 6.3.4 states that these surveys were of "limited duration" and provide only a limited "look" at these river systems. The extent of pink salmon spawning and the location of such spawning within the Chakachatna River are unknown. The same is true for coho within this system. Only limited survey work occurred on rivers tributary to Kenibuna Lake or within Kenibuna Lake itself. The strength of the 1981 salmon runs may not have been representative, as even year runs of pink salmon in upper Cook Inlet are larger than odd year runs. It will be important for 1982 study efforts to remain flexible in order to fully understand the fisheries resources of the project area. The 1982 Work Plans presented to us do not have this flexibility or sufficient scope to adequately assess impacts or identify necessary mitigative measures. We have made some specific comments on both documents, which follow.

Interim Report

10.1.3 Reservoir and Fish Passage Facilities
The report states that studies will be conducted regarding fish passage into and out of the reservoir. The Environmental Studies Work Plan does not identify these studies. What type of research is being discussed here?

10.3 Environmental Studies
This paragraph implies that current minimum flows were based on field research on fisheries. These preliminary releases were developed using a percentage of mean flow (the Montana Method) and do not necessarily meet the needs of the fishery resources within the system.

1982 Work Plan - Environmental Studies

General - We do not believe the proposed studies are of sufficient scope to achieve the stated objectives of providing data to accurately prepare environmental exhibits for the FERC application, assess project impacts, describe existing conditions or develop mitigation measures. At this time we are most concerned with identification of waters within the project area which support habitat utilized by fish, evaluation of altered flow to fishery habitat and the impact of altered temperature regimes. The 1982 fish survey sites should increase our understanding of the relative value of project waters as habitat. We are pleased that instream flow group (IFG) methodologies are being proposed to assess changes in habitat values. However, we believe that a proper application of this system requires considerable effort beyond that which is presented in the work plan. Input from several areas is required in order to apply the IFG methodology. It will be necessary to know the distribution of fish species within the system, to select target species and life stages, and to correlate this information with additional input concerning hydrology and project operations. We realize that much of this description would be too detailed to be included in a general work plan. However, as this study element is critical to impact assessment and mitigation planning, we believe a separate scope of work should be prepared and circulated for comment which deals with the IFG methodology as it applies to the Chakachamna project studies. The work plan does not adequately address the issue of altered temperatures. We suggest that the upcoming studies allow for this important issue. Continuous recording themographs may be valuable at sites which may be impacted by thermal changes. Will a temperature model be prepared?

The Work Plan fails to discuss how mitigative measures will be developed for inclusion into the license application. We suggest early coordination between the contractor and resource agencies on this issue. A mitigation policy similar to that being developed for Susitna would be valuable.

Page 4, paragraph 5. The criteria used in selecting these wetlands for study are not mentioned. Are these areas assumed to be representative of the wetlands within the area of impact or of a special value as habitat?

Page 7, paragraph 2. The instream flow investigations will provide necessary data on the impacts of flow regulation. Based on preliminary information presented by Woodward-Clyde it appears that sloughs or side channels in the upper McArthur and in the Chakachatna River below Straight Creek are important spawning areas. Many of these channels may be impacted by altered flows and should be investigated using in-stream flow methodology. The Work Plan is not clear on whether these sites will receive special attention, but states that new sites will be studied using IFG-2 methodologies. We feel that some new sites (such as side channels utilized by spawners) should receive the IFG-4 methodology to more closely assess project impact.

Page 7, Aquatic Biology: The work plan does not describe what work is planned for further limnological investigation of Lake Chakachatna or Kenibuna. Water quality parameters, depth profiles and plankton tows are some things that should be considered.

Finally, we must express our concern with regard to the project schedule. It is unlikely that any study effort, regardless of its thoroughness, could properly identify the fishery and related impacts within a 10 month period (February to November). The fact that little information currently exists for these systems adds to this concern, as much work will be needed to gather basic reconnaissance-level data. We suggest the timing of the FERC license application and the scope of environmental studies for this project be reconsidered with an aim at insuring a thorough understanding of the resources and a professional assessment of project related impacts and mitigation opportunities.

We appreciate this opportunity to comment at this time.

Sincerely,

Robert W. McVey
Director, Alaska Region

ALASKA POWER AUTHORITY

334 WEST 5th AVENUE - ANCHORAGE, ALASKA 99501
Phone: (907) 277-7641
(907) 276-0001

RECEIVED
DEC 2 1982
R. T. LODER

November 26, 1982

Mr. Robert W. McVey
Director, Alaska Region
National Marine Fisheries Service
P.O. Box 1668
Juneau, Alaska 99802

Dear Mr. McVey:

Please reference your agency's letter of February 18, 1982, concerning Chakachamna Hydroelectric Project 1982 Work Plan, Environmental Studies. The Alaska Power Authority appreciates the detailed comments your agency has provided, but due to severe budget restraints we have not yet been able to implement most of those. The Power Authority through our consultant, Bechtel/Woodward-Clyde, has collected fishery data during this past summer and fall. Your agency personnel visited the proposed project area while Woodward-Clyde was actually collecting this data during August 1982.

We would like to invite you and your staff to a meeting at 9:30 A.M. on December 9, 1982, in the new Federal Building, National Weather Service, 5th floor, East Conference Room. The purpose of the meeting will be to present information collected during the summer and fall and answer questions on an informal basis concerning the resource in the area. I have attached an agenda for the meeting.

We have requested additional funding for the FY 84 budget year in order to complete the feasibility study. Once legislative approval has been acquired, a new work plan for environmental studies will be developed taking into account concerns previously expressed by your agency and others. It is our intent to coordinate this plan with the concerned agencies.

Thank you for your continued participation in our planning activities.

Sincerely,

Eric P. Yould
Executive Director

cc: Robert Loder, Bechtel
Wayne Lifton, Woodward-Clyde
Kenneth Plumb, FERC
Ronald Morris, National Marine Fisheries Service
Brad Smith, National Marine Fisheries Service

Attachment: Agenda

10.3.3 Meeting - December 9, 1982

Representatives of the agencies listed below were invited to attend a meeting in Anchorage, Alaska on December 9, 1982:

- o U.S. Fish and Wildlife Service
- o Alaska Department of Fish and Game
- o National Marine Fisheries Service
- o National Park Service
- o Alaska Department of Natural Resources
- o Northern Alaska Environmental Center

At this meeting, representatives of Alaska Power Authority, Bechtel Civil & Minerals, Inc., and Woodward-Clyde Consultants presented a summary of results of the 1982 engineering and environmental studies performed on the project. A copy of the meeting notes is reproduced on the following pages.

ALASKA POWER AUTHORITY

CHAKACHAMNA HYDROELECTRIC PROJECT

MEETING NOTES

DATE: December 9, 1982

LOCATION: Anchorage, Alaska

SUBJECT: Chakachamna Project Review Meeting

PARTICIPANTS:

Alaska Power Authority
Eric Marchegiani

Bechtel
Bob Loder
Dave Cornman

Woodward-Clyde
Wayne Lifton
Larry Rundquist
Mike Joyce

National Park Service
Larry Wright

Alaska Department of Natural Resources
Karen Oakley

Alaska Department of Fish and Game
Ken Tarbox
Bruce King
Phil Brna
Kevin Delaney
Jim Faro
Gary Liepitz

U.S. Fish and Wildlife Service
Lenny Corin
Gary Stackhouse

National Marine Fisheries Service
Brad Smith

NAEC
Eric Meyers

Representatives from Alaska Power Authority, Bechtel Civil and Minerals, and Woodward-Clyde Consultants (WCC) presented a summary of results of the 1982 engineering and environmental studies performed on the Chakachamna Hydroelectric Project to local, state, and federal agency personnel. The purpose of the meeting was to provide background information to new agency personnel, to inform all present of new project data, and to receive agency inputs regarding study results and future project plans.

Eric Marchegiani, Alaska Power Authority, initiated the meeting by introducing those present. A 61-page handout was distributed containing detailed drawings of conceptual fish passage facilities of 1982 fisheries data and other relevant information. Eric then reviewed principal project events which have occurred since the last project review meeting, December 11, 1981. In addition, Eric reviewed the Power Authority requests for funds and the funds appropriated, by the Legislature, for Chakachamna Project since 1981. The FY 83 budget made it possible to investigate fish passage into and out of the lake, enumeration of the fishery resources, and an evaluation of a reduction in the cost estimate due to utilizing a tunnel boring machine. The Power Authority has requested $2.9 million for FY 1984, to carry the project through out Federal Energy Regulatory Commission (FERC) licensing.

Bob Loder, Bechtel, briefly reviewed the engineering studies performed to evaluate various dam and tunnel alternatives for developing the Chakachamna Lake hydro resource. These studies were reported in the 1981 Interim Report. These engineering and cost studies showed that a Chakachamna Lake tap and tunnel diversion to the adjoining McArthur River was the most attractive alternative for power development. A preliminary capital cost estimate of $1.2 billion was arrived at assuming the use of tunnel boring machines.

Loder then provided a detailed review of the fish passage facility concepts developed in 1982. Facility structures and operation were described on large multi-colored wall drawings. Seasonal passage for downstream and upstream migrant fish is provided at all projected lake operating levels. Fish passage facilities consist of a one mile long divided tunnel from the lake outlet to a point downstream on the Chakachamna River, a multi-level spiraling fish ladder for upstream migrants, and two alternative lake outlet facilities for downstream migrants.

Wayne Lifton (WCC) presented a brief overview of environmental studies performed to date on the project. Larry Rundquist (WCC) then summarized the results of the 1982 hydrologic studies conducted in August and October. Gage locations were illustrated. The data base for recording gages on the Chakachamna and McArthur Rivers was provided in overhead presentation, along with a summary of the staff gage data base. A general description of flow distribution and sediment characteristics was given based on field observations and preliminary data.

Lifton then presented the preliminary results of the 1982 fisheries program with a slide presentation illustrating the 24 sampling stations. Study emphasis was placed on the Chakachamna River. Fish habitat, habitat utilization, and spawning were investigated. Fyke nets and other gear were used in rivers and streams and gill nets, seines, and shocking were used on the lake. The results were summarized in figures (overhead presentation of graphs) representing each sampling station. Preliminary presentation of graphs) representing each sampling station. Preliminary escapement estimates were provided in the handout. It appears that only Sockeye and Dolly Varden are found in streams above Lake Chakachamna.

The major questions and concerns voiced at the meeting are listed below:

General:

* Eric Marchegiani - The total cost estimate is based on the Power Authority's economic parameters. Do not compare these costs with those on the Susitna Project, unless they utilize the same parameters in an economic comparison.

Fish Passage Facilities:

* Would someone be on site to control the gates?

  The system can operated manually or by automatic sensors.

* Has this system been used elsewhere in an automatic mode?

  An existing reservoir in Oregon accommodates similar change in water level. A ladder is conventional, however, the water supply chambers and openings to the reservoir are unconventional.

* Has a gated system been used before?

  Not sure, need to find out. This is not exotic change from what has been used in the past. The most different feature is the one-mile-long tunnel.

* Is there an auxiliary water system to achieve 1,000 cfs?

  That is part of the downstream migration system, and will be discussed later.

* Will a dark tunnel make avoidance probable?

  The tunnel could be lighted if necessary.

* Could this create maintenance problems?

  There will be vehicular access. Someone would check facilities on a regular basis. The powerhouse operator would check water levels and gates.

* Will the water temperature be regulated in the lower outlet?

  No, not as planned. It just takes water from the channel.

* Water taken from the lower depths would be colder. Thermocline may cause fish to pool up.

* Would this be a year-round operation?

  Yes.

* How will ice and debris be handled in the system (i.e., at the grate)?

  We would probably provide means of eliminating ice and debris at the intake.

* After November 1, no fish will be going upstream.

* Ice is an issue that has to be dealt with in the design of the facilities.

* What is the depth of the power tunnel intake?

  Approximately 150 feet below normal lake level and below lake level in the spring.

* Will downstream migrants find the power outlet or lake outlet (attraction)?

  Intake must be designed so they do not fined the power intake.

* What is the possibility of varying temperature in the McArthur?

  Have not addressed this problem yet..

* Explain the dyke. Where does it terminate?

  Protective device for design of fish channel. Channel has to be excavated to allow water entry at daylight level.

* What is cost estimate of tunnel?

  Do not know yet, but there is an advantage of a totally gravity system (pumps are another option). The water level variation was raised to accommodate the gravity system. (1,195 feet to 1,095 feet).

* Will slough habitat be modified downstream?

  This is another aspect which will be addressed later.

Fisheries Studies:

* Explain the graphs.

  Live fish counts were made on weekly basis. Counts were plotted versus consecutive days. Area under curve: fish-days, these are divided by the amount of time the fish were in stream and result in estimated total number of live fish per stream.

Essentially, the same technique was used on Susitna. This information was supplemented with electroshocking, netting, and ground counts. Data gaps did occur during the September storm.

* How many people counted fish?

Two.

* How did you cover the area?

Helicopter was equipped with special bubble windows. Overflights were made as slow and as near to the ground as possible.

* Were there fish at streams you could not monitor?

We counted every stream in which spawning fish were found and some where there were no fish.

* Were you aware of <u>when</u> runs began?

We took the helicopter out once a week for the entire schedule, essentially since mid-July.

* It is hard to understand how two people did all that.

Actually, five or six people were in the field. I am just covering spawning right now.

* Will count data be presented?

Each count will be recorded. The hydroacoustic survey was conducted during the fall to count juvenile distribution in the lake (overhead presentation). We were eventually weathered out.

* What is the distribution at 100 feet? What do the nine and twelve mean?

Number of fish per $m^3 \times 10^3$. Fish were generally found deeper than previously expected, to 100 feet. The numbers are ten foot depths intervals. Fish were shore-oriented.

* Did you find any lake trout?

Yes, quite a few.

* Did you identify any areas where lake trout were concentrated?

We identified large concentrations of lake trout in 1981.

* How many Dolly Varden were there?

  They are residents and primarily caught by gear which gives relative abundance, so can only estimate.

* Are Dolly Varden the most abundant?

  Maybe, hard to say, lots of slimy sculpin, pygmy whitefish, etc. Also, lots of juvenile sockeye in lake.

* Are escape estimates minimum numbers and did you only count clearwater streams?

  Clearwater counts were great. We feel very confident in those areas. When streams clouded up as in September, counts were much less reliable. Many cloudy areas-side channels were countable and counts were corrected by ground truthing.

* Any spawning in mainstream indicated or seen?

  Mainstream areas do not seem to be used. The water was too turbid, substrates were bad for spawning. Only fish we found in mainstream were not ripe or were spawned out (migrants).

* When was fyke netting started?

  August 6.

* What was your recovery on tagged adult fish?

  Not counting Dolly Varden, under 150 Petersen tagged salmon.

* Of all species?

  No, primarily sockeye, coho, and chums, with some pinks.

General Discussions:

Eric Marchegiani, Power Authority, explained the process for future project funding. A discussion ensued on the need to develop a detailed plan of study for full feasibility early in 1983 prior to continuance of planned field studies. A two-step approach to agency review was suggested:

1) Identify program elements and set priorities,

2) Provide detail on agreed upon list of programs and priorities.

Eric Myers (NAEC) expressed concern regarding the FERC licensing process on the Susitna Project and an apparent lack of commitment to adequately study Chakachamna as an alternative to Susitna. Eric Marchegiani assured everyone that the Power Authority is committed to evaluating Chakachamna as an element of an alternative to Susitna as required for FERC licensing. In addition, the Power Authority is pursuing a detailed feasibility study of

Chakachamna as an independent project as indicated by its request for $2.9 million for the Project in FY 84.

Eric Marchegiani, Power Authority, concluded the meeting, indicating that the next report will be out by the end of February. There will be a June Addendum to cover winter and spring work. Please review the fish and bypass system and provide your ideas to us. We will meet to discuss plans for spring and winter.

Distribution of December 9, 1982
Meeting Summary

The Honorable Esther Wunnicke
Commissioner
Department of Natural Resources
Pouch M
Juneau, Alaska 99811
cc: Mr. Robert Loder, Bechtel, San Francisco
Mr. Wayne Lifton, Woodward-Clyde, Anchorage
Ms. Kay Brown, Div. of Minerals & Energy Mgt., DNR, Anchorage
Ms. Karen Oakley, Div. of Minerals & Energy Mgt., DNR, Anchorage
Mr. Roland Shanks, Director, Div. of Research and Development

Mr. Robert W. McVey, Director
Alaska Region
National Marine Fisheries Service
Post Office Box 1668
Juneau, Alaska 99802
cc: Mr. Robert Loder, Bechtel, San Francisco
Mr. Wayne Lifton, Woodward-Clyde, Anchorage
Mr. Brad Smith, Nat'l Marine Fisheries Service, Anchorage
Mr. Ronald Morris, Nat'l Marine Fisheries Service, Anchorage

Mr. Keith Schreiner
Regional Director
1011 East Tudor Road
Anchorage, Alaska 99503
cc: Mr. Robert Loder, Bechtel, San Francisco
Mr. Wayne Lifton, Woodward-Clyde, Anchorage
Mr. Lenny Corin, U.S. Fish & Wildlife Service, Anchorage
Mr. Gary Stackhouse, U.S. Fish & Wildlife Service, Anchorage

Commissioner
Alaska Department of Fish & Game
Subport Building
Juneau, Alaska 99801
cc: Mr. Robert Loder, Bechtel, San Francisco
Mr. Wayne Lifton, Woodward-Clyde, Anchorage
Mr. Carl Yanagawa
Mr. Don McKay

Director
National Park Service
540 West Fifth Avenue, Room 201
Anchorage, Alaska 99501
cc: Mr. Robert Loder, Bechtel, San Francisco
Mr. Wayne Lifton, Woodward-Clyde, Anchorage
Mr. Larry Wright, National Park Service, Anchorage

10.3.3.1 Response

The National Marine Fisheries Service and U.S. Fish and Wildlife Service replied to the Power Authority's invitation to comment on the proposed conceptual designs of the fish passage facilities for the Chakachamna Lake outlet as described at the December 9, 1982 meeting. Copies of the NMFS February 1, 1983 letter and U.S. Fish and Wildlife Service March 9, 1983 letter are reproduced on the following pages. Their suggestions have been taken under advisement but time does not permit action by the Power Authority at this juncture. Present plans provide for an addendum to this March 1983 Interim Feasibility Assessment Report to be issued as rapidly as possible after the spring studies have been completed in June 1983. The Power Authority's response to NMFS and U.S. Fish and Wildlife Service suggestions will be addressed in that addendum.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
P.O. Box 1668
Juneau, Alaska 99802

TO FILES:
Project ☐ General ☐
No. _____ Vol. _____
Files Instr. _____
Date Entered _____

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FEB 07 1983
ALASKA POWER AUTHORITY

February 1, 1983

Mr. Eric Marchegiani
Alaska Power Authority
334 W. 5th Avenue
Anchorage, Alaska 99501

Dear Mr. Marchegiani:

The National Marine Fisheries Service has reviewed the Summary of Fish Passage Facility Design Concepts and Preliminary Results of FY 1982-83 Fish Studies - Chakachamna Hydroelectric Project, Bechtel/Woodward Clyde, December 1982. Our Fish Facilities Division has developed comments specific to the conceptual passage designs, and we are forwarding these for your consideration prior to completion of the February report. We will be able to provide a more complete analysis of fishways design when operational concepts are finalized. The proposed fish passage structures appear feasible, but we believe relatively high mortality will occur with respect to out-migrants.

1. The turn pools at all ladder turns are too short. The interior ladder wall at all turns should extend at least 8 feet upstream and downstream from the adjacent weirs. The exterior wall would of course extend further than 8 feet.

2. All adult fish ladders and channels must be lighted to encourage fish movement. Natural light or artificial light can be used. Access for artificial lighting maintenance is required.

3. The upstream passage facility shows a ladder with 60 pools. For this orifice-overflow type of ladder to function properly the water surface in the pools should be controlled to provide 1.0 ft. of head on the weirs, plus or minus 0.1 foot. The document does not explain how the water level in the ladder will be controlled during periods when the forebay elevation is above or below an even-foot elevation. It is assumed flow would be controlled by throttling the inlet control gate to the appropriate water supply chamber. Proper operation of the ladder will require faultless operation of all 60 gates to the individual ladder pools and all inlet gates to the water supply chambers. This will require good access for frequent gate inspection and O&M. No method of access is indicated.

4. The ladder exits must be sufficiently removed from the downstream migrant facility to prevent adult fish from falling back downstream.

5. Both schemes for juvenile passage appear to have potential for high fish losses. Scheme A might be modified to avoid the turbulent plunge pool which would exist, particularly when either of the top two drum-type gates are operated. The drop of up to 80 feet ± into the basin shown would be very hazardous for fish, since they would be subjected to extreme turbulence with associated pressure fluctuations and shear forces prior to exiting through the tunnel. High injury and mortality rates can be expected. Continuous smooth spillway crests downstream of each gate to a standard spillway stilling basin, and a smooth gradual transition to the tunnel would be an improvement.

   Scheme B has more potential problems than Scheme A. These are: (1) More mechanical equipment is involved, therefore more chance for malfunction. (2) The entire flow is not near the surface where it would aid fish outmigration. (3) Fish may not readily sound to the depth required to exit through the tunnel, after they pass over the flow control plate. (4) Fish passing through the two 7 ft. x 4.75 ft. tunnel discharge control gates can be expected to suffer high mortalities, based on experience at other projects of even lower maximum heads. (5) Some fish can be expected to exit the forebay through the two low level bypasses, particularly if lower forebay elevations exist during outmigration, and flow conditions in the bypass conduits could be damaging to fish.

6. The proposed breakwater in the lake could result in downstream migrants not finding the lake outlet so readily. The location and length of the breakwater and its relationship to shoreline topography should be considered very carefully to avoid anadromous fish passage problems. The approach channel to the lake outlet should be designed with consideration to maintaining adequate velocities to move fish to the outlet structure.

7. The proposed power outlet from the lake to the powerhouse will apparently be located considerable distance from the fish passage facilities. No information is given as to the magnitude of the power discharges. Power discharges can be expected to detract from the limited outmigrant attraction provided by the fish passage facilities, reducing their effectiveness in maintaining fish runs.

Should you have any questions regarding these comments, please contact our Anchorage Field Office at 271-5006.

Sincerely,

for Robert W. McVey
Director, Alaska Region

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1011 E. TUDOR RD.
ANCHORAGE, ALASKA 99503
(907) 276-3800

IN REPLY REFER TO:

WAES

RECEIVED
MAR 11 1983
ALASKA POWER AUTHORITY

09 MAR 1983

Eric P. Yould, Executive Director
Alaska Power Authority
334 West 5th Avenue
Anchorage, Alaska 99501

Dear Mr. Yould:

The Fish and Wildlife Service has reviewed the report prepared for you on the Chakachamna Hydroelectric Project by Bechtel/Woodward-Clyde in December 1982 entitled, A Summary of Fish Passage Facility Design Concepts and Preliminary Results of FY 1982-83 Fish Studies. Our comments below are specific to the conceptual fish passage structures illustrated in the report and do not address the fishing studies. Previous letters, dated 5 March, and 26 March, 1982, provide comments which are still pertinent to the on-going fish and wildlife studies.

The following comments are presented in the order of the sketches contained in the Bechtel/Woodward-Clyde report:

Drawing No. SK-C-001.

1. The proposed reduction in discharge at the lake outlet may accelerate the lakeward movement of Barrier Glacier toward the proposed approach channel and passage facility structure. According to U.S. Geological Survey measurements made during 1961 through 1966, this glacier advanced several feet per year at measuring stations located near the river bank at the lake outlet.

2. Anticipated flows in the vicinity of the rock-fill fish barrier should be determined.

Drawings No. SK-C-002, SK-C-003.

1. Fishway pools numbered 1105, 1125, and 1145 should be at least ten feet long, consistent with the design of the other fishway pools.

2. Provision for an access walkway along the top of the fishway pools and natural or artificial lighting should be provided.

3. The proposed fishway is a weir type (six foot by ten foot pools) with split Ice Harbor type baffles. Each fishway pool would have the standard bottom orifice plus an additional gated opening in the outside wall of each pool to compensate for the anticipated 60 foot fluctuation in lake level. We recommend the following design parameters for the fishway baffles:

Weir crest height	=	6 feet
Weir overflow width	=	3 feet
Orifice size	=	18 inches x 18 inches
Fishway flow	=	27 cubic feet per second (with 12 inch head on baffle)

4. Gate operating mechanisms for the 60 gated openings in the fishways are not shown. We understand gate operation would be automatic, using sensors which open and close designated gates, and would compensate for changes in lake level. Due to the large number of gates, we anticipate operation and maintenance problems. Reducing the extent of lake fluctuations during the upstream migration period would reduce the number of gated openings required.

5. The fishway pool size is dependent upon the design population of fish to be passed. The design population will need to be established and fishway pool size should then be adjusted accordingly.

Drawing No. SK-C-004.

1. The downstream migrant facility should draw flow from the surface of the lake as indicated on this drawing. However, the passage of ice through this system will be a problem during the winter and spring.

2. The drop from the upper gate into the plunge pool can be decreased by utilizing an orifice or gate at the entrance to the discharge tunnel.

Drawing No. SK-C-005.

1. Scheme B may not provide sufficient flow from the surface of the lake to be effective for downstream migrants. The establishment of adequate lake releases is essential to assure that the system maximizes outmigration to the estuary.

Drawing No. SK-C-006.

1. It appears that the adult fish "fall backs" from the lake will be trapped by the horizontal grating proposed at elevation 1072 in the outlet structure. This potential problem could be avoided through use of an angled vertical screen or rack in lieu of the horizontal grating. This angled rack would also serve to guide upstream migrants to the fishway.

We hope that these comments are helpful as Bechtel/Woodward-Clyde continues to refine the initial passage facility concepts. If you have any questions regarding our comments, please contact Leonard P. Corin (907-271-4575) at our Western Alaska Ecological Services field office.

Sincerely,

Acting Regional Director

cc: FWS-WAES
ADF&G, NMFS, EPA, Anchorage

10.4 National Park Service

10.4.1 Lake Clark National Park

The copy of the January 12, 1982 Power Authority letter to Mr. Paul Haertel, Superintendent of Lake Clark National Park is reproduced on the following three pages to illustrate the nature of coordination effected with the National Park Service.

ALASKA POWER AUTHORITY

334 WEST 5th AVENUE · ANCHORAGE, ALASKA 99501

Phone: (907) 277-7641
(907) 276-0001

January 12, 1982

RECEIVED
JAN 15 1982
R. T. LODER

Mr. Paul Haertel
Superintendent of Lake Clark
National Park Service
U. S. Federal Building
Anchorage, Alaska 99501

Dear Mr. Haertel:

We are presently undertaking a feasibility study of the proposed Chakachamna Hydroelectric Project. The study commenced in August 1981 and is scheduled for completion in early 1983.

The project area is located approximately 60 miles west of Anchorage. The water storage reservoir for the proposed hydropower project would be existing Chakachamna Lake, a 23 square-mile lake formed in a steep valley behind a glacial moraine. Current studies have identified several alternative arrangements for the project. The alternative with the greatest power potential involves a lake tap leading through an 11 mile transmountain diversion tunnel to a power plant on the McArthur River. Such a diversion of flow may have significant environmental impacts in the McArthur River and in the Chakachatna River, the outlet stream from Chakachamna Lake. These two rivers are known to have runs of anadromous fish. The planned project construction for any of the alternative layouts presently under consideration does not involve any construction activities within the boundaries of Lake Clark National Park. However, as stated above, the project operation may affect the fish and wildlife in the Chakachatna River basin including part of the National Park by diversion of water from the Chakachatna River and by seasonal lowering of the level of Chakachamna Lake.

The work being performed in the feasibility study includes an assessment of the environmental impact of the project construction and operation. To evaluate the influence of the project on the fish and wildlife populations of the area it is necessary to include in this evaluation those resources within the National Park, specifically Kenibuna Lake since a portion of the anadromous fish run passing through Chakachamna Lake enters Kenibuna Lake.

At this time, the 1981 environmental studies field program (aerial and ground reconnaissance of the general study area) has been completed. The first overview was conducted in August with the objectives being to document the presence of sockeye salmon in the major project waters and to survey the site in preparation for the fall reconnaissance. The second investigation was carried out in mid-September and involved two

weeks of field data collection. The objectives of the effort were to obtain sufficient information and understanding of the project site and its resources to allow for the design of more detailed 1982 studies, and to assess, in a preliminary nature, the overall feasibility of the conceptual designs of the project alternatives. In this 1981 program, no activities were performed within the National Park.

Since part of the 1982 field program will occur within Lake Clark National Park, we are requesting that a special use permit be authorized for the environmental investigations. Specifically, we are requesting that the following nonconsumptive activities be authorized in the National Park:

- fly over and land near the Igitna, Neacola, Another, and Chilligan Rivers using a helicopter;
- use a motorized raft on Kenibuna Lake;
- use standard surveying techniques and depth sounding equipment; and
- conduct vegetation surveys.

In addition, we request that the following consumptive, yet nondestructive, activities be authorized in the National Park:

- the collection of stream and lake substrates to assess stability;
- the use of fyke nets, electroshocking equipment, and seines (adults captured by these techniques will be released);
- the limited use of gill nets along the steep banks of the lake shore. If used, the gill nets will be set for short periods of time to prevent excessive losses.

There will be no camping or similar activities associated with these above activities. A schedule for these activities is attached.

The work described above would be performed for the Authority by Bechtel Civil and Minerals, Inc. and their environmental subcontractor Woodward-Clyde Consultants. Subsequent to these studies, we do not anticipate any further investigations within the Lake Clark National Park.

If you have any questions or if you require additional information on any phase of this program, please contact me.

Sincerely,

for Eric P. Yould
Executive Director

Attachment: Schedule

cc: Robert T. Loder, Bechtel

ALASKA POWER AUTHORITY

Table 1. Tentative Schedule for Activities to be Conducted within Lake Clark National Park

Schedule*	Activity		
	Fish Aerial and Ground Surveys	Wildlife Visual Reconnaissance	Hydrology Habitat Parameter Measurements
31 May-2 June	X	X	X
21-23 June	X		
12-14 July	X		
2-4 August	X		
23-25 August	X		
13-15 September	X		
4-6 October	X		X

*Activities should only require one day during each schedule period.

10.5 Northern Alaska Environmental Center

10.5.1 Correspondence

A copy of a December 13, 1982 letter received from Eric F. Myers of the above referenced agency is reproduced on the following eight pages.

10.5.1.1 Response

A copy of the Power Authority's reply, dated December 30, 1982, is reproduced on the two pages following the reproduction of Mr. Myer's letter.

Northern Alaska Environmental Center
833 Gambell Streeet – Suite B
Anchorage, Alaska 99501
(907) 277-6814

13 December 1982

Mr. Eric Yould
Executive Director
Alaska Power Authority
334 West 5th Avenue
Anchorage, Alaska 99501

RECEIVED
DEC 16 1982
ALASKA POWER AUTHORITY

Dear Mr. Yould:

I am writing to express formally my great concern about the progress and adequacy of the Lake Chakachamna feasibility studies. As you well know, the Chakachamna project is the most significant and likely hydro alternative to Susitna and a comprehensive evaluation of this potential hydro option is central to the on going Railbelt power studies. Without the commitment of the APA to undertake and execute the necessary investigations to assess project feasibility at the level of detail required for preparation of a FERC license application, the APA will preclude meaningful consideration of the Chakachamna option.

As a result of attending the recent December 9, 1982 interagency briefing on the status of the Chakachamna studies, it is apparent that the APA is not honoring its public commitment to continue the Chakachamna investigations in a substantive and timely fashion. It is now evident that the FY 83 funding of $800,000 allocated by the APA Board to the Chakachamna studies is entirely insufficient to address the outstanding questions about project feasibility and that this will have the effect of discounting the viability of the Chakachamna option as part of the FERC Susitna proceedings.

The Northern Alaska Environmental Center has, over the past three years, repeatedly cited the need to move forward with the Chakachamna investigations in an appropriately aggressive fashion so that the Chakachamna and Susitna options can be considered on an equal basis. That is why last June I urged the APA to allocate the full $3.3 million necessary to undertake the full scope of feasibility studies required to assess the Chakachamna site. At that June Board meeting you represented that $800,000 would be sufficient to continue the evaluation of the Chakachamna option. At the December 9 interagency meeting, however, APA project manager Eric Marchegiani made repeated reference to "budgetary constraints" and the fact that he has not "had the level of funding necessary to support" a feasibility level report. The Northern Alaska Environmental Center continues to be deeply concerned that a lack of commitment on the part of the APA to conduct the appropriate engineering,

geotechnical, and environmental studies of the Chakachamna site will result in a prejudiced evaluation of Railbelt electrical options. Precisely the situation we had hoped to avoid is now being realized.

The limited work done by Bechtel and Woodward-Clyde has accomplished little more than confirm the fact that Chakachamna is very attractive economically (relative to Susitna) and that the site supports a significant fishery resource (as does the Susitna). The work by Bechtel/Woodward-Clyde, however, will not yield a level of assessment necessary for preparation of a FERC license application as stated by Mr. Marchegiani, nor will the Bechtel/Woodward-Clyde work provide a sufficient basis for comparing the relative economic and evironmental merit of these projects as required for the FERC/NEPA-EIS process. It seems inescapable that the submission of a Susitna license application in the first quarter of 1983 (as presently planned) would, on its face, be deficient in this regard.

The Northern Alaska Environmental Center shares your oft stated concern for the potential fishery impacts that could attend development of the Chakachamna site, as we are concerned with the myriad impacts that would be associated with development of the Susitna basin. Neither of these projects should enjoy blind support and both must be carefully evaluated as part of a comprehensive Railbelt power planning effort. It is lamentable that some perceive the more modestly scaled 330MW Chakachamna project as a threat to Susitna. Especially at a time when electrical demand projections are dropping dramatically and future load growth is clouded with great uncertainty, such a narrow perspective contributes little to the need for cautious consideration and prudent planning to develop an optimal supply strategy for the Railbelt. As you well appreciate, the questionable need for a massive project like Susitna requires careful evaluation of more flexible capacity supply strategies which could include a combination of short-term benefits from combined cycle combustion turbines using natural gas and long-term benefits from a more modestly scaled hydro project like Chakachamna.

For these reasons we formally ask the APA to defer filing of the Susitna license application in February so that (1) detailed evaluation of the Chakachamna option may be included in the application and (2) the fishery and wildlife impacts that would be associated with either project may be better understood. We ask, moreover, that the APA immediately dedicate the necessary financial and personnel resources to upgrade the Chakachamna study effort to that of a true feasibility study and so that the 1983 field season may be as productive as possible. At a very minimum, this should start with the convening of an interagency steering committee for the Chakachamna project analogous

to the Susitna Hydro Steering Committee.

In the absence of such action on the part of the APA to insure a thorough analysis of Railbelt power alternatives, we feel that you will jeopardize the Susitna license application and subject the entire process to unecessary delay.

The Chakachamna Alternative

The Northern Alaska Environmental Center has not been alone in its effort to draw attention to the need to carefully consider more modestly scaled power options such as Chakachamna as an integral aspect of formulating a responsible plan to meet future Railbelt power requirements. Indeed, the External Review Panel of international experts retained by the APA to provide an independent assessment of the Susitna project, in formal testimony to the APA Board, strongly recommended that your agency identify viable power alternatives in the event that (1) Susitna is delayed or (2) the demand forecasts change. Precisely the latter circumstance has emerged with current Battelle energy projections for the year 2010 as much as 44% lower than the ISER forecasts used by Acres in its development selection analysis which led to the adoption of the Watana/Devil Canyon scenario. See Table 1.

This advice was reflected in the letter sent by the APA to the State legislature (April 26, 1982) which recommended that the Chakachamna and North Slope gas alternatives be thoroughly investigated. The APA Board specifically indicated that FY 83 costs to continue the Chakachamna feasibility studies was on the order of $3.3 million.

The Policy Review Committee, charged with the responsibility of managing the Battelle Alternatives to Susitna study, concurred with these assessments and also supported FY 83 funding to assess the Chakachamna option in detail along with additional investigation of the North Slope gas and Beluga coal options.

More recently, the Division of Budget and Management noted certain deficiencies in the FY 83 studies respecting the APA staff descision not to undertake necessary geotechnical studies. The Division of Budget memo (August 19, 1982), distributed to the full Board by Dr. Ronald Lehr, noted that the limited scope of the FY 83 Chakachamna studies "may result in a (Susitna) FERC license application next spring which is neither complete nor adequate."

Funding

As you know, when the legislture adjourned, it had appropriated $25.6 million for the continuation of the Susitna/ Railbelt power studies. At the June 24, 1982 APA Board meeting consideration

was given to the issue of submitting a FERC license application including the role that the Chakachamna feasibility study played in the overall evaluation of Railbelt power options. I myself took the opportunity at that time to make a statement to the Board and urged that the full $3.3 million necessary for the Chakachamna studies be dedicated to that purpose from the $25.6 million available. To my great disapointment it was your recommendation to the Board that only $800,000 be allocated to the Chakachamna investigations. It was your contention that $800,000 was sufficient to carry the studies forward. As noted in the recently prepared APA FY 84 budget proposal relative to the Chakachamna project, the "FY 83 funds are coming from the Susitna funds since Chakachamna is considered as an alternative to the Susitna Project." The budget document goes on to state that the FY 83 ($800,000) phase of investigation "will see a threshold level of environmental investigation and additional engineering studies to confirm the construction cost estimate and cost of power."

It is not clear to me what a "threshold level" of evaluation means in light of the data that has been gathered by Bechtel/Woodward-Clyde and which was presented at the December 9 interagency meeting. Clearly, the project is still economically attractive, in fact even more so now than when Acres did their feasibility work on Susitna as a result of downward revisions in capital cost estimates by about $0.22 billion due to the ability to use state-of-the-art tunnel boring technology. As for the environmental work — which has focused exclusively on the fishery — there is little to be concluded beyond the fact that the McArthur and Chakachatna drainages support a significant fishery resource on the basis of very limited escapement data. The "threshold" level of data developed by Bechtel and Woodward-Clyde has confirmed the fact that the Chakachamna alternative is as much (if not more) of a Railbelt power alternative due to (1) downward revisions in expected capital costs and (2) downward revisions in expected load growth.

The Need for Additional Investigations

At this point, the Northern Alaska Environmental Center is very concerned that the Chakachamna studies be expanded substantially in scope. We urge that the APA immeadiately commit the financial resources presently at its disposal toward the development of a comprehensive feasibility study of a quality and detail equal to the Susitna studies. The scope of investigations should include a much more detailed examination of the Chakachatna tunnel alternative, especially in light of the recent findings regarding tunnel boring technology. (While the Chakachatna tunnel alternative may not be as attractive as the McArthur tunnel scenario, it offers the distinct advantage of perhaps avoiding altogether impacts to the McArthur drainage.) It is imperative that this effort be initiated immediately and aggressively so that the Chakachamna hydro option can be considered on a parity basis with

Susitna. It was clearly evident from the comments made by the resource agency personnel at the December 9 meeting that there is a great amount of work to be done between now and the point when we could achieve such a level of comparability.

This is particularly disturbing in looking back through the November 1981 Interim Report on the Chakachamna studies which was very explicit about the fact that the consultant was providing services "for performing a feasibility study and for preparing an application for a FERC license to construct" the Chakachamna project. The "1982 Work Plan — Environmental Studies" circulated by the APA to the resource agencies almost exactly one year ago was equally explicit with regard to the overall objective being to prepare the necessary environmental exhibits to accompany an APA license application. Unfortunately, this "paper commitment" has not been supported monetarily.

As currently planned, Bechtel/Woodward-Clyde will issue their findings at the end of February and the study at that point will not be of sufficient quality to make a clear determination about project feasibility. It is perhaps not entirely ironic that the same month is targeted for submission of the Susitna FERC license application. Further work on the Chakachamna feasibility study will then be dependent upon the vagaries of legislative appropriation during a time when increasing political pressure is being orchestrated to "pour concrete."

The Need for a New Plan of Study

I do not mean to imply that even an unlimited budget for the Chakachamna studies as of last June could have yielded a completed feasibility study by "late winter of 1983" as was proposed in the "1982 Work Plan — Environmental Studies" document. The 1982 Work Plan was deficient in many regards, as pointed out in the comments prepared by ADF&G (February 18, 1982), USF&WS (March 5, 1982; March 12, 1982) and NMFS (February 18,1982) much remains to be done to work out a comprehensive Plan of Study to identify and execute essential field studies. However, a larger budget last June and resolve on the part of the APA to initiate the necessary interagency processes would have advanced the studies much further than they are today.

With the limited funding, the 1982 Work Plan and agency comments were "set aside" (to use Mr. Marchegiani's words) and a scope of work negotiated between the APA and Bechtel/Woodward-Clyde without the appropriate involvement of other resource agency personnel. the result is that while we do know somewhat more about the project site, a great deal of money and, more importantly, time has been wasted.

Based on the limited information currently available, the 330MW Chakachamna project still appears to be very attractive economically

with an estimated capital cost of approximately $1.23 billion (Bechtel/October 1982 Progress Report). As you noted in recent remarks to the Alaska Environmental Assembly (November 13, 1982) the Chakachamna project is very competitive with Susitna and quite possibly the more attractive economic choice. This is particularly so because a project the size of Chakachamna would not be vulnerable to the uncertainties of load projections (ie., we can reasonably assume the need to replace 330MW of thermal capacity but cannot necessarily assume the need for all 1600MW's offered by Susitna). While you have acknowledged the economic merit of Chakachamna, you have expressed great concern for the fishery impacts that could attend development of the project. This sentiment is reflected in the Acres feasibility report where Chakachamna was not included in the "base case" plan because "it may have a substantial fishery impact" and because "studies to date have been insufficient to determine expected capital costs with precision" (Acres/Summary Report, March 1982, p. 7). Notwithstanding the substantial expenditures by APA to Acres, the same general observations may be made about the Susitna project.

The Susitna related fishery resource is only dimly understood at this point with only the initial phases of a basic 5-year study program complete. Recent correspondence to your agency by USF&WS (October 5, 1982) and NMFS (October 15, 1982) describes the more important fishery issues that remain entirely unresolved. The fact that the 1982 (second year) field data will not be included in the license application highlights further the severe limitations to our current understanding of the potential impacts to the Susitna basin fishery. More succinctly, at present the Federal and State resource agencies are only now in the process of describing the existing resource and are far from understanding the impacts associated with post-project conditions.

Respecting confidence in the Acres capital cost estimates for Susitna, the fact that an independent cost estimate by Ebasco yielded a $0.36 billion disparity clearly indicates that the "precision" of Acres Susitna cost estimate is somewhat suspect.

Finally, I would note that the minutes of the June 24th APA Board meeting reflect your comment that "Susitna must be the best alternative before the FERC will issue a license." It is our hope that the FERC process will, in fact, insure that the Chakachamna alternative is investigated adequately and the best Railbelt power alternative developed. To that end, we urge the APA to defer its Susitna license application and move forward immediately with expanded Chakachamna studies so that these two major alternatives may be considered on a comparable basis.

Sincerely,

Eric F. Myers

cc: APA Board
USF&WS
NMFS
ADF&G
ADNR
Susitna Hydro Steering Committee
Quentin Edson, FERC
Sierra Club
Alaska Center for the Environment
Trustees for Alaska
Governor Sheffield

Table 1

DECLINING LOAD GROWTH
PROJECTIONS

Year	"Medium" Load Growth Projections/GWh		
	1980 ISER[1]	1982 Battelle[2]	Revised Battelle[3]
1980	2790	2551	2551
1985	3570	3136	3000
1990	4030	4256	3391
1995	5170	4875	3884
2000	6430	5033	4010
2005	7530	5421	4319
2010	8940	6258	4986

Notes:

1. Used by Acres for generation planning studies for development selection; Acres feasibility study Table 5.6.

2. Battelle "base case" ; Battelle Comment Draft Table A.12.

3. Revised Battelle forecast; Prologue Table 3 (Draft).

ALASKA POWER AUTHORITY

334 WEST 5th AVENUE - ANCHORAGE, ALASKA 99501
Phone: (907) 277-7641
(907) 276-0001

RECEIVED
JAN 4 1983
R. T. LODER

December 30, 1982

Mr. Eric F. Meyer
Northern Alaska Environmental Center
833 Gambell Street
Suite B
Anchorage, Alaska 99501

Dear Mr. Meyer:

Please reference your letter of December 13, 1982 in which you suggest the Alaska Power Authority defer the filing of the FERC license on Susitna.

We will not defer the filing of the Susitna FERC license application. The Power Authority believes the studies being done on the Chakachamna project to date are more than sufficient to fulfill all FERC requirements for the study of alternatives for Susitna license application. Furthermore, the Chakachamna project is not itself an alternative to Susitna, but rather an element of a larger alternative scenario that includes coal and natural gas fired generation.

Over $1.8 million has been invested by the Power Authority and the Governor's office in evaluating the Chakachamna hydroelectric potential. Neither the Susitna Feasibility Study nor the Battelle Alternatives Study found the Chakachamna project to be the preferred Railbelt power generation alternative. At the same time, however, the potential for eventual contrary findings was recognized. New information on Chakachamna costs, Susitna costs, or load forecasts could conceivably reverse the findings. Therefore, additional work to explore money saving construction concepts was deemed advisable. The necessary funds were taken from the Susitna appropriation. A FY 82 study plan was drafted which addressed the primary area of concern affecting feasibility: project cost. Fishery impact was also deemed important, as mitigation measures (minimum flows and fish passage) could potentially impact project output and cost.

The current program has three major components: 1) fish passage into and out of the lake, 2) enumeration of the fishery resource, and 3) the applicability of tunnel excavation by means of a tunnel boring machine. (This possibility represents the source of the greatest uncertainty in the cost estimate.)

The fish passage facility analysis has involved the development of a structure which would permit passage of fish at various lake levels with gravity flow. In order to provide gravity flow through the facility, the project would require a small 50 foot rock filled dam at

the outlet of the lake. This structure would probably require continuous maintenance due to the movement of the Barrier Glacier.

The fishery enumeration program has collected data continuously between July and November. In addition, there will be a winter survey and a spring survey. The program will estimate the seasonal distribution, habitat abundance, and numbers of fish. The estimate of fishery impact will be updated based on this additional data. Further work such as an instream flow assessment would be required to fully evaluate project impacts and mitigation measures, but such impact work cannot effectively begin until a year of base line data collection is accomplished.

As you are aware, a representative rock sample has been acquired near the McArthur power house site and has been sent to the Robbins Company Testing Laboratories in Seattle, Washington. The Robbins Company has reported that the rock is similar to the rock found at the Kerckhoff project in California, where a 24 foot diameter tunnel boring operation has been in satisfactory progress during the past year. The test data from the rock analysis has generated information which was utilized to estimate the cost of using a tunnel boring machine rather then the conventional drill and blast method. The estimate has reduced the cost of the project by approximately $200 million.

In summary, the Alaska Power Authority has pursued the Chakachamna Project with the appropriate diligence, given that studies to date have shown it not to be the preferred Railbelt power generation alternative. The current studies are more than adequate to fulfill all FERC requirements for the study of alternatives.

Sincerely,

Eric P. Yould
Executive Director

cc: Robert Loder, Bechtel
Wayne Lifton, Woodward/Clyde
Kenneth Plumb, Secretary, FERC
William Wakefield, FERC
Charles Conway

APPENDIX TO SECTION 4.0

POWER STUDIES

CHAKACHAMNA PROJECT OPERATION STUDY
F/H,H&CE,BECHTEL CIVIL&MINERALS INC.,SF.
ALASKA POWER AUTHORITY

PROJECT 14879001 DATE 110581 PAGE 1

ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/O FISH RELEASES

INSTALLED CAPACITY: 400000. KW

ANNUAL PLANT FACTOR: .5

OVERLOAD FACTOR: 1.00

PLANT EFFICIENCY: .850

FRICTION LOSS COEFFICIENT: .000002370

MONTHLY LOAD FACTORS:

.920 .870 .780 .700 .640 .620 .610 .640 .700 .800 .920 1.000

INITIAL LAKE STORAGE :4033200. AC-FT

MINIMUM LAKE STORAGE : 0. AC-FT

MAXIMUM LAKE STORAGE :4033200. AC-FT

ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/O FISH RELEASES

RESERVOIR STORAGE-ELEVATION-AREA:

AC-FT	FEET	ACRE
0.	760.	0.
2025.	765.	810.
7300.	770.	1300.
27200.	780.	2690.
111000.	800.	5670.
241000.	820.	7320.
397000.	840.	8270.
572000.	860.	9280.
769000.	880.	10400.
988000.	900.	11590.
1224000.	920.	11960.
1467000.	940.	12320.
1717000.	960.	12650.
1973000.	980.	12980.
2236000.	1000.	13280.
2504000.	1020.	13520.
2776000.	1040.	13740.
3053000.	1060.	13960.
3335000.	1080.	14170.
3620000.	1100.	14390.
3910000.	1120.	14620.
4033200.	1128.	15212.

TAILWATER-FLOW RELATIONSHIP:

FEET	CFS
210.	0.
210.	100000.

MONTHLY MINIMUM INSTREAM FLOWS IN CFS:

0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.

MONTHLY DIVERSION REQUIREMENTS IN CFS:

0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.

MONTHLY RESERVOIR EVAPORATION IN INCHES:

0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.

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ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/O FISH RELEASES

INFLOWS TO THE LAKE IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	400.	307.	267.	393.	3637.	6837.	11209.	9337.	3145.	1439.	799.	870.	3220.	1960
2	877.	589.	470.	346.	1881.	7983.	12808.	10899.	6225.	1586.	843.	696.	3767.	1961
3	633.	541.	471.	470.	1265.	7925.	13149.	10411.	5542.	1197.	863.	613.	3590.	1962
4	458.	357.	315.	337.	1801.	4735.	13249.	12208.	5847.	2056.	930.	710.	3587.	1963
5	364.	435.	332.	477.	1830.	8093.	10700.	11798.	4246.	1245.	909.	662.	3424.	1964
6	419.	219.	337.	398.	1286.	3490.	13046.	10516.	10802.	2114.	597.	466.	3641.	1965
7	388.	336.	350.	410.	1893.	8072.	10303.	9974.	6608.	1953.	910.	313.	3459.	1966
8	531.	449.	384.	880.	2030.	8761.	14931.	15695.	6191.	2040.	1215.	571.	4473.	1967
9	534.	510.	467.	630.	2996.	7808.	13117.	11257.	2793.	976.	689.	612.	3532.	1968
10	485.	486.	500.	652.	1948.	9271.	12510.	7297.	2793.	3057.	1215.	541.	3396.	1969
11	497.	504.	550.	899.	2265.	6789.	10360.	7986.	2734.	1359.	742.	460.	2929.	1970
MEAN	511.	430.	404.	536.	2076.	7251.	12307.	10671.	5175.	1729.	883.	592.	3547.	
MAX	877.	589.	550.	899.	3637.	9271.	14931.	15695.	10802.	3057.	1215.	870.	4473.	
MIN	364.	219.	267.	337.	1265.	3490.	10303.	7297.	2734.	976.	597.	313.	2929.	

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ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/O FISH RELEASES

POWER RELEASE IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	3813.	3680.	3356.	2992.	2793.	2635.	2530.	2597.	3079.	3282.	3910.	4288.	3246.	1960
2	4014.	3877.	3443.	3149.	2941.	2771.	2591.	2597.	2851.	3282.	3910.	4288.	3310.	1961
3	4014.	3877.	3536.	3149.	2941.	2771.	2656.	2659.	2851.	3282.	3911.	4403.	3338.	1962
4	4014.	3877.	3536.	3149.	2941.	2845.	2656.	2659.	2851.	3282.	3910.	4288.	3334.	1963
5	4014.	3876.	3536.	3149.	2941.	2771.	2656.	2659.	2851.	3282.	3911.	4403.	3338.	1964
6	4014.	3877.	3536.	3149.	2941.	2845.	2724.	2724.	2851.	3282.	3910.	4288.	3345.	1965
7	4014.	3877.	3536.	3149.	2941.	2771.	2656.	2659.	2851.	3282.	3910.	4288.	3328.	1966
8	4014.	3877.	3536.	3149.	2941.	2771.	2591.	2597.	2851.	3282.	3910.	4288.	3317.	1967
9	4014.	3876.	3444.	3149.	2865.	2771.	2591.	2597.	2851.	3282.	3911.	4403.	3313.	1968
10	4014.	3877.	3536.	3149.	2941.	2771.	2591.	2659.	2851.	3282.	3910.	4288.	3323.	1969
11	4014.	3877.	3536.	3149.	2865.	2771.	2656.	2659.	2920.	3363.	4013.	4405.	3352.	1970
MEAN	3996.	3859.	3503.	3135.	2914.	2772.	2627.	2643.	2878.	3289.	3920.	4330.	3322.	
MAX	4014.	3877.	3536.	3149.	2941.	2845.	2724.	2724.	3079.	3363.	4013.	4405.	3352.	
MIN	3813.	3680.	3356.	2992.	2793.	2635.	2530.	2597.	2851.	3282.	3910.	4288.	3246.	

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ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/C FISH RELEASES

SPILL IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	1417.	6740.	66.	0.	0.	0.	685.	1960
2	0.	0.	0.	0.	0.	0.	0.	2437.	3374.	0.	0.	0.	484.	1961
3	0.	0.	0.	0.	0.	0.	0.	1248.	2691.	0.	0.	0.	328.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	2342.	0.	0.	0.	195.	1963
5	0.	0.	0.	0.	0.	0.	0.	874.	1395.	0.	0.	0.	189.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	3444.	0.	0.	0.	287.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	1882.	0.	0.	0.	157.	1966
8	0.	0.	0.	0.	0.	0.	0.	10188.	3340.	0.	0.	0.	1127.	1967
9	0.	0.	0.	0.	0.	0.	0.	4580.	0.	0.	0.	0.	382.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	129.	2370.	1685.	0.	0.	0.	349.	
MAX	0.	0.	0.	0.	0.	0.	1417.	10188.	3444.	0.	0.	0.	1127.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

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ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/O FISH RELEASES

FISH RELEASE IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

CHAKACHAMNA PROJECT OPERATION STUDY
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ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/C FISH RELEASES

NET EVAPORATION IN AC-FT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/O FISH RELEASES

E.O.P. STORAGE IN ACRE-FT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	3823331.	3629312.	3439385.	3284714.	3336637.	3586651.	4033200.	4033200.	4033200.	3919884.	3734772.	3524610.	3698241.	1960
2	3331718.	3149100.	2966291.	2795474.	2734289.	3044413.	3672605.	4033200.	4033200.	3928923.	3746429.	3525568.	3413767.	1961
3	3317673.	3132385.	2943921.	2784482.	2681421.	2988093.	3633277.	4033200.	4033200.	3905004.	3723654.	3490595.	3388909.	1962
4	3274399.	3078097.	2880837.	2713484.	2643365.	2755850.	3407174.	3994312.	4033200.	3957822.	3780505.	3560504.	3340029.	1963
5	3336069.	3138121.	2941106.	2782084.	2713763.	3030432.	3525033.	4033200.	4033200.	3907956.	3729343.	3499297.	3389134.	1964
6	3278243.	3075077.	2878370.	2714647.	2612861.	2651264.	3285913.	3765014.	4033200.	3961388.	3764256.	3529253.	3295790.	1965
7	3306294.	3109625.	2913717.	2750708.	2686245.	3001665.	3471855.	3921630.	4033200.	3951489.	3772981.	3528571.	3370665.	1966
8	3314404.	3124011.	2930194.	2795151.	2739128.	3095546.	3854284.	4033200.	4033200.	3956838.	3796480.	3567933.	3436697.	1967
9	3353950.	3160316.	2977276.	2827358.	2835420.	3135142.	3782341.	4033200.	4029735.	3887950.	3696247.	3463126.	3431838.	1968
10	3246131.	3057753.	2871108.	2722499.	2661418.	3048183.	3658052.	3943232.	3939767.	3925938.	3765579.	3535188.	3364574.	1969
11	3318930.	3131592.	2947982.	2814070.	2777185.	3016272.	3489967.	3817504.	3806440.	3883224.	3488577.	3246018.	3294813.	1970
MEAN	3354649.	3162385.	2971835.	2817152.	2765612.	3032137.	3619427.	3967354.	4003776.	3907856.	3727166.	3497333.	3402223.	
MAX	3823331.	3629312.	3439385.	3284714.	3336637.	3586651.	4033200.	4033200.	4033200.	3961388.	3796480.	3567933.	3698241.	
MIN	3246131.	3057753.	2871108.	2713484.	2612861.	2651264.	3285913.	3765014.	3806440.	3883224.	3488577.	3246018.	3294813.	

ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/O FISH RELEASES

WATER BALANCE

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

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ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/O FISH RELEASES

POWER IN MW

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	1960
2	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	1961
3	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	1962
4	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	1963
5	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	1964
6	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	1965
7	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	1966
8	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	1967
9	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	1968
10	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	1969
11	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	1970
MEAN	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	
MAX	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	
MIN	240.	227.	203.	183.	167.	162.	159.	167.	183.	209.	240.	261.	200.	

ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/O FISH RELEASES

ENERGY IN MWH

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTYR	CALYR
1	178560.	157962.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1756299.	1960
2	178560.	152515.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1750852.	1961
3	178560.	152515.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1750852.	1962
4	178560.	152515.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1750852.	1963
5	178560.	157962.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1756299.	1964
6	178560.	152515.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1750852.	1965
7	178560.	152515.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1750852.	1966
8	178560.	152515.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1750852.	1967
9	178560.	157962.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1756299.	1968
10	178560.	152515.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1750852.	1969
11	178560.	152515.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1750852.	1970
MEAN	178560.	154000.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1752338.	
MAX	178560.	157962.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1756299.	
MIN	178560.	152515.	151388.	131478.	124216.	116452.	118393.	124216.	131478.	155270.	172800.	194087.	1750852.	

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ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/O FISH RELEASES

REMAINING SPILLS IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	3170.	0.	0.	0.	0.	264.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	38.	0.	0.	0.	3.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	108.	0.	0.	0.	9.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	6619.	4.	0.	0.	0.	552.	1967
9	0.	0.	0.	0.	0.	0.	0.	1011.	0.	0.	0.	0.	84.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	982.	14.	0.	0.	0.	83.	
MAX	0.	0.	0.	0.	0.	0.	0.	6619.	108.	0.	0.	0.	552.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

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ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/O FISH RELEASES

AVERAGE GENERATION IN MW DURING SPILLS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	256.	400.	188.	0.	0.	0.	70.	1960
2	0.	0.	0.	0.	0.	0.	0.	327.	400.	0.	0.	0.	61.	1961
3	0.	0.	0.	0.	0.	0.	0.	253.	358.	0.	0.	0.	51.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	336.	0.	0.	0.	28.	1963
5	0.	0.	0.	0.	0.	0.	0.	229.	275.	0.	0.	0.	42.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	400.	0.	0.	0.	33.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	306.	0.	0.	0.	25.	1966
8	0.	0.	0.	0.	0.	0.	0.	400.	400.	0.	0.	0.	67.	1967
9	0.	0.	0.	0.	0.	0.	0.	400.	0.	0.	0.	0.	33.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	23.	183.	242.	0.	0.	0.	37.	
MAX	0.	0.	0.	0.	0.	0.	256.	400.	400.	0.	0.	0.	70.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

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ALTERNATIVE A: MCARTHUR SHORT TUNNEL, W/O FISH RELEASES

SURPLUS ENERGY IN MWH

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTYR	CALYR
1	0.	0.	0.	0.	0.	0.	72279.	173384.	4167.	0.	0.	0.	249830.	1960
2	0.	0.	0.	0.	0.	0.	0.	118747.	156522.	0.	0.	0.	275269.	1961
3	0.	0.	0.	0.	0.	0.	0.	64330.	126489.	0.	0.	0.	190819.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	110265.	0.	0.	0.	110265.	1963
5	0.	0.	0.	0.	0.	0.	0.	46308.	66163.	0.	0.	0.	112471.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	156522.	0.	0.	0.	156522.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	88832.	0.	0.	0.	88832.	1966
8	0.	0.	0.	0.	0.	0.	0.	173384.	156522.	0.	0.	0.	329906.	1967
9	0.	0.	0.	0.	0.	0.	0.	173384.	0.	0.	0.	0.	173384.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	6571.	68140.	78680.	0.	0.	0.	153391.	
MAX	0.	0.	0.	0.	0.	0.	72279.	173384.	156522.	0.	0.	0.	329906.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

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ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

INSTALLED CAPACITY: 333000. KW

ANNUAL PLANT FACTOR: .5

OVERLOAD FACTOR: 1.00

PLANT EFFICIENCY: .850

FRICTION LOSS COEFFICIENT: .000002370

MONTHLY LOAD FACTORS:

.920 .870 .780 .700 .640 .620 .610 .640 .700 .800 .920 1.000

INITIAL LAKE STORAGE :4033200. AC-FT

MINIMUM LAKE STORAGE : 0. AC-FT

MAXIMUM LAKE STORAGE :4033200. AC-FT

ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

RESERVOIR STORAGE-ELEVATION-AREA:

AC-FT	FEET	ACRE
0.	760.	0.
2025.	765.	810.
7300.	770.	1300.
27200.	780.	2690.
111000.	800.	5670.
241000.	820.	7320.
397000.	840.	8270.
572000.	860.	9280.
769000.	880.	10400.
988000.	900.	11590.
1224000.	920.	11960.
1467000.	940.	12320.
1717000.	960.	12650.
1973000.	980.	12980.
2236000.	1000.	13280.
2504000.	1020.	13520.
2776000.	1040.	13740.
3053000.	1060.	13960.
3335000.	1080.	14170.
3620000.	1100.	14390.
3910000.	1120.	14620.
4033200.	1128.	15212.

TAILWATER-FLOW RELATIONSHIP:

FEET	CFS
210.	0.
210.	100000.

MONTHLY MINIMUM INSTREAM FLOWS IN CFS:

365. 365. 365. 1094. 1094. 1094. 1094. 1094. 1094. 365. 365. 365.

MONTHLY DIVERSION REQUIREMENTS IN CFS:

0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.

MONTHLY RESERVOIR EVAPORATION IN INCHES:

0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.

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ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

INFLOWS TO THE LAKE IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	400.	307.	267.	393.	3637.	6837.	11209.	9337.	3145.	1439.	799.	870.	3220.	1960
2	877.	589.	470.	346.	1881.	7983.	12808.	10899.	6225.	1586.	843.	696.	3767.	1961
3	633.	541.	471.	470.	1265.	7925.	13149.	10411.	5542.	1197.	863.	613.	3590.	1962
4	498.	357.	315.	337.	1801.	4735.	13249.	12208.	5847.	2056.	930.	710.	3587.	1963
5	364.	435.	332.	477.	1830.	8093.	10700.	11798.	4246.	1245.	909.	662.	3424.	1964
6	419.	219.	337.	398.	1266.	3490.	13046.	10516.	10802.	2114.	597.	466.	3641.	1965
7	388.	336.	350.	410.	1893.	8072.	10303.	9974.	6608.	1953.	910.	313.	3459.	1966
8	531.	445.	384.	880.	2030.	8761.	14931.	15695.	6191.	2040.	1215.	571.	4473.	1967
9	534.	510.	467.	630.	2996.	7808.	13117.	11257.	2793.	976.	689.	612.	3532.	1968
10	465.	486.	500.	652.	1948.	9271.	12510.	7297.	2793.	3057.	1215.	541.	3396.	1969
11	497.	504.	550.	899.	2265.	6789.	10360.	7986.	2734.	1359.	742.	460.	2929.	1970
MEAN	511.	430.	404.	536.	2076.	7251.	12307.	10671.	5175.	1729.	883.	592.	3547.	
MAX	877.	589.	550.	899.	3637.	9271.	14931.	15695.	10802.	3057.	1215.	870.	4473.	
MIN	364.	219.	267.	337.	1265.	3490.	10303.	7297.	2734.	976.	597.	313.	2929.	

CHAKACHAMNA PROJECT OPERATION STUDY
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ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

POWER RELEASE IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	3104.	2998.	2739.	2448.	2232.	2160.	2075.	2130.	2335.	2682.	3180.	3475.	2630.	1960
2	3260.	3151.	2809.	2573.	2345.	2269.	2125.	2130.	2335.	2682.	3180.	3475.	2694.	1961
3	3260.	3151.	2809.	2573.	2345.	2269.	2125.	2180.	2335.	2682.	3180.	3475.	2699.	1962
4	3260.	3151.	2809.	2573.	2345.	2269.	2177.	2180.	2335.	2682.	3180.	3475.	2703.	1963
5	3260.	3151.	2809.	2573.	2345.	2269.	2177.	2180.	2335.	2682.	3180.	3475.	2703.	1964
6	3260.	3151.	2809.	2573.	2345.	2328.	2231.	2232.	2336.	2682.	3180.	3475.	2717.	1965
7	3260.	3151.	2809.	2573.	2345.	2269.	2177.	2180.	2335.	2682.	3180.	3475.	2703.	1966
8	3260.	3151.	2809.	2573.	2345.	2269.	2125.	2130.	2335.	2682.	3180.	3475.	2694.	1967
9	3260.	3072.	2809.	2573.	2345.	2213.	2125.	2130.	2335.	2682.	3180.	3564.	2691.	1968
10	3260.	3151.	2881.	2573.	2406.	2269.	2125.	2180.	2390.	2746.	3180.	3564.	2727.	1969
11	3260.	3151.	2881.	2573.	2345.	2269.	2177.	2232.	2390.	2813.	3260.	3658.	2751.	1970
MEAN	3246.	3130.	2815.	2562.	2340.	2260.	2149.	2171.	2345.	2699.	3187.	3508.	2701.	
MAX	3260.	3151.	2881.	2573.	2406.	2328.	2231.	2232.	2390.	2813.	3260.	3658.	2751.	
MIN	3104.	2998.	2739.	2448.	2232.	2160.	2075.	2130.	2335.	2682.	3180.	3475.	2630.	

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ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

SPILL IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	836.	6113.	0.	0.	0.	0.	579.	1960
2	0.	0.	0.	0.	0.	0.	0.	2082.	2796.	0.	0.	0.	406.	1961
3	0.	0.	0.	0.	0.	0.	0.	1218.	2113.	0.	0.	0.	278.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	2065.	0.	0.	0.	172.	1963
5	0.	0.	0.	0.	0.	0.	0.	831.	817.	0.	0.	0.	137.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	3180.	0.	0.	0.	265.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	1321.	0.	0.	0.	110.	1966
8	0.	0.	0.	0.	0.	0.	0.	9736.	2762.	0.	0.	0.	1041.	1967
9	0.	0.	0.	0.	0.	0.	0.	4288.	0.	0.	0.	0.	357.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	76.	2206.	1368.	0.	0.	0.	304.	
MAX	0.	0.	0.	0.	0.	0.	836.	9736.	3180.	0.	0.	0.	1041.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

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ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

FISH RELEASE IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	365.	307.	267.	393.	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	658.	1960
2	365.	365.	365.	346.	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	667.	1961
3	365.	365.	365.	470.	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	677.	1962
4	365.	357.	315.	337.	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	662.	1963
5	364.	365.	332.	477.	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	675.	1964
6	365.	219.	337.	398.	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	657.	1965
7	365.	336.	350.	410.	1094.	1094.	1094.	1094.	1094.	365.	365.	313.	664.	1966
8	365.	365.	365.	880.	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	712.	1967
9	365.	365.	365.	630.	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	691.	1968
10	365.	365.	365.	652.	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	693.	1969
11	365.	365.	365.	899.	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	713.	1970
MEAN	365.	343.	345.	536.	1094.	1094.	1094.	1094.	1094.	365.	365.	360.	679.	
MAX	365.	365.	365.	899.	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	713.	
MIN	364.	219.	267.	337.	1094.	1094.	1094.	1094.	1094.	365.	365.	313.	657.	

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ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

NET EVAPORATION IN AC-FT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

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ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

E.O.P. STORAGE IN ACRE-FT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	3844486.	3672051.	3503609.	3357932.	3377054.	3590235.	4033200.	4033200.	4016273.	3517430.	3754049.	3571403.	3722577.	1960
2	3402437.	3239885.	3073650.	2920553.	2824773.	3099675.	3689300.	4033200.	4033200.	3943396.	3782633.	3589288.	3469332.	1961
3	3405319.	3240101.	3073928.	2920830.	2787174.	3058625.	3669218.	4033200.	4033200.	3919477.	3759904.	3561456.	3455203.	1962
4	3369186.	3194193.	3021502.	2868398.	2767700.	2849328.	3462870.	4012209.	4033200.	3972295.	3816709.	3624225.	3415984.	1963
5	3423797.	3246581.	3073891.	2920793.	2821878.	3103326.	3560138.	4033200.	4033200.	3922428.	3765593.	3570158.	3456249.	1964
6	3373030.	3198037.	3025346.	2872242.	2739877.	2743929.	3341621.	3783716.	4033200.	3975861.	3800460.	3592974.	3373358.	1965
7	3393940.	3218947.	3046256.	2893152.	2798110.	3078308.	3510710.	3922686.	4033200.	3965961.	3809186.	3595489.	3438829.	1966
8	3405247.	3234920.	3063397.	2910300.	2823682.	3144879.	3865042.	4033200.	4033200.	3971311.	3832684.	3631653.	3495793.	1967
9	3441617.	3273230.	3106810.	2953713.	2926492.	3194307.	3802931.	4033200.	3995328.	3868016.	3698073.	3494118.	3482320.	1968
10	3301049.	3132759.	2963905.	2810801.	2715398.	3066938.	3638240.	3885616.	3844473.	3841176.	3702533.	3494213.	3366425.	1969
11	3301881.	3134551.	2968811.	2815707.	2743549.	2947400.	3383303.	3669834.	3625181.	3513341.	3341792.	3122697.	3214007.	1970
MEAN	3423817.	3253208.	3083737.	2931311.	2847790.	3079723.	3632416.	3952114.	3973968.	3851881.	3733056.	3531607.	3444552.	
MAX	3844486.	3672051.	3503609.	3357932.	3377054.	3590235.	4033200.	4033200.	4033200.	3975861.	3832684.	3631653.	3722577.	
MIN	3301049.	3132759.	2963905.	2810801.	2715398.	2743929.	3341621.	3669834.	3625181.	3513341.	3341792.	3122697.	3214007.	

ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

WATER BALANCE

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

POWER IN MW

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	1960
2	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	1961
3	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	1962
4	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	1963
5	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	1964
6	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	1965
7	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	1966
8	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	1967
9	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	1968
10	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	1969
11	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	1970
MEAN	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	
MAX	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	
MIN	198.	187.	168.	151.	138.	133.	131.	138.	151.	172.	198.	215.	165.	

ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

ENERGY IN MWH

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTYR	CALYR
1	147312.	130318.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1448947.	1960
2	147312.	125825.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1444453.	1961
3	147312.	125825.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1444453.	1962
4	147312.	125825.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1444453.	1963
5	147312.	130318.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1448947.	1964
6	147312.	125825.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1444453.	1965
7	147312.	125825.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1444453.	1966
8	147312.	125825.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1444453.	1967
9	147312.	130318.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1448947.	1968
10	147312.	125825.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1444453.	1969
11	147312.	125825.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1444453.	1970
MEAN	147312.	127050.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1445679.	
MAX	147312.	130318.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1448947.	
MIN	147312.	125825.	124895.	108470.	102478.	96073.	97674.	102478.	108470.	128097.	142560.	160122.	1444453.	

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ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

REMAINING SPILLS IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	3189.	0.	0.	0.	0.	266.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	66.	0.	0.	0.	5.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	445.	0.	0.	0.	37.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	6812.	32.	0.	0.	0.	570.	1967
9	0.	0.	0.	0.	0.	0.	0.	1364.	0.	0.	0.	0.	114.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	1033.	49.	0.	0.	0.	90.	
MAX	0.	0.	0.	0.	0.	0.	0.	6812.	445.	0.	0.	0.	570.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

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ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

AVERAGE GENERATION IN MW DURING SPILLS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	190.	330.	0.	0.	0.	0.	43.	1960
2	0.	0.	0.	0.	0.	0.	0.	275.	330.	0.	0.	0.	50.	1961
3	0.	0.	0.	0.	0.	0.	0.	222.	290.	0.	0.	0.	43.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	287.	0.	0.	0.	24.	1963
5	0.	0.	0.	0.	0.	0.	0.	196.	205.	0.	0.	0.	33.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	330.	0.	0.	0.	27.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	238.	0.	0.	0.	20.	1966
8	0.	0.	0.	0.	0.	0.	0.	330.	330.	0.	0.	0.	55.	1967
9	0.	0.	0.	0.	0.	0.	0.	330.	0.	0.	0.	0.	27.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	17.	153.	183.	0.	0.	0.	29.	
MAX	0.	0.	0.	0.	0.	0.	190.	330.	330.	0.	0.	0.	55.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE B: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

SURPLUS ENERGY IN MWH

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTYR	CALYR
1	0.	0.	0.	0.	0.	0.	43738.	143042.	0.	0.	0.	0.	186780.	1960
2	0.	0.	0.	0.	0.	0.	0.	102145.	129130.	0.	0.	0.	231275.	1961
3	0.	0.	0.	0.	0.	0.	0.	62388.	100187.	0.	0.	0.	162575.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	97946.	0.	0.	0.	97946.	1963
5	0.	0.	0.	0.	0.	0.	0.	43608.	39391.	0.	0.	0.	82999.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	129130.	0.	0.	0.	129130.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	63069.	0.	0.	0.	63069.	1966
8	0.	0.	0.	0.	0.	0.	0.	143042.	129130.	0.	0.	0.	272173.	1967
9	0.	0.	0.	0.	0.	0.	0.	143042.	0.	0.	0.	0.	143042.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	3976.	57933.	62544.	0.	0.	0.	124454.	
MAX	0.	0.	0.	0.	0.	0.	43738.	143042.	129130.	0.	0.	0.	272173.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

INSTALLED CAPACITY: 300000. KW

ANNUAL PLANT FACTOR: .5

OVERLOAD FACTOR: 1.00

PLANT EFFICIENCY: .850

FRICTION LOSS COEFFICIENT: .000002800

MONTHLY LOAD FACTORS:

.920 .870 .780 .700 .640 .620 .610 .640 .700 .800 .920 1.000

INITIAL LAKE STORAGE :4033200. AC-FT

MINIMUM LAKE STORAGE :2423600. AC-FT

MAXIMUM LAKE STORAGE :4033200. AC-FT

ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

RESERVOIR STORAGE-ELEVATION-AREA:

AC-FT	FEET	ACRE
0.	760.	0.
2025.	765.	810.
7300.	770.	1300.
27200.	780.	2690.
111000.	800.	5670.
241000.	820.	7320.
397000.	840.	8270.
572000.	860.	9280.
769000.	880.	10400.
988000.	900.	11590.
1224000.	920.	11960.
1467000.	940.	12320.
1717000.	960.	12650.
1973000.	980.	12980.
2236000.	1000.	13280.
2504000.	1020.	13520.
2776000.	1040.	13740.
3053000.	1060.	13960.
3335000.	1080.	14170.
3620000.	1100.	14390.
3910000.	1120.	14620.
4033200.	1128.	15212.

TAILWATER-FLOW RELATIONSHIP:

FEET	CFS
400.	0.
400.	100000.

MONTHLY MINIMUM INSTREAM FLOWS IN CFS:

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

MONTHLY DIVERSION REQUIREMENTS IN CFS:

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

MONTHLY RESERVOIR EVAPORATION IN INCHES:

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

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ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

INFLOWS TO THE LAKE IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	400.	307.	267.	393.	3637.	6837.	11209.	9337.	3145.	1439.	799.	870.	3220.	1960
2	877.	589.	470.	346.	1881.	7983.	12808.	10899.	6225.	1586.	843.	696.	3767.	1961
3	633.	541.	471.	470.	1265.	7925.	13149.	10411.	5542.	1197.	863.	613.	3590.	1962
4	498.	357.	315.	337.	1801.	4735.	13249.	12208.	5847.	2056.	930.	710.	3587.	1963
5	364.	435.	332.	477.	1830.	8093.	10700.	11798.	4246.	1245.	909.	662.	3424.	1964
6	419.	219.	337.	398.	1286.	3490.	13046.	10516.	10802.	2114.	597.	466.	3641.	1965
7	388.	336.	350.	410.	1893.	8072.	10303.	9974.	6608.	1953.	910.	313.	3459.	1966
8	531.	449.	384.	880.	2030.	8761.	14931.	15695.	6191.	2040.	1215.	571.	4473.	1967
9	534.	510.	467.	630.	2996.	7808.	13117.	11257.	2793.	976.	689.	612.	3532.	1968
10	485.	486.	500.	652.	1948.	9271.	12510.	7297.	2793.	3057.	1215.	541.	3396.	1969
11	497.	504.	550.	899.	2265.	6789.	10360.	7986.	2734.	1359.	742.	460.	2929.	1970
MEAN	511.	430.	404.	536.	2076.	7251.	12307.	10671.	5175.	1729.	883.	592.	3547.	
MAX	877.	589.	550.	899.	3637.	9271.	14931.	15695.	10802.	3057.	1215.	870.	4473.	
MIN	364.	219.	267.	337.	1265.	3490.	10303.	7297.	2734.	976.	597.	313.	2929.	

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ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

POWER RELEASE IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	3673.	3567.	3266.	2903.	2636.	2550.	2429.	2478.	2725.	3146.	3798.	4187.	3113.	1960
2	3939.	3828.	3384.	3111.	2821.	2726.	2507.	2479.	2725.	3146.	3798.	4187.	3221.	1961
3	3939.	3828.	3384.	3111.	2923.	2727.	2507.	2479.	2725.	3146.	3798.	4183.	3229.	1962
4	3939.	3831.	3508.	3111.	2924.	2825.	2590.	2556.	2725.	3146.	3798.	4187.	3262.	1963
5	3939.	3828.	3384.	3111.	2821.	2727.	2590.	2556.	2725.	3146.	3798.	4187.	3234.	1964
6	3939.	3831.	3508.	3111.	2924.	2825.	2680.	2638.	2725.	3146.	3798.	4187.	3276.	1965
7	3939.	3831.	3508.	3111.	2923.	2727.	2590.	2556.	2725.	3146.	3798.	4187.	3253.	1966
8	3939.	3828.	3381.	3111.	2821.	2726.	2507.	2479.	2725.	3146.	3798.	4187.	3221.	1967
9	3939.	3828.	3384.	3111.	2821.	2726.	2507.	2479.	2725.	3146.	3800.	4343.	3234.	1968
10	3939.	3831.	3508.	3111.	2924.	2727.	2507.	2555.	2725.	3146.	3670.	4187.	3236.	1969
11	3936.	3828.	3384.	3111.	2821.	2726.	2507.	2556.	2725.	3248.	3800.	4343.	3249.	1970
MEAN	3914.	3806.	3418.	3092.	2851.	2728.	2538.	2528.	2725.	3156.	3787.	4215.	3230.	
MAX	3939.	3831.	3508.	3111.	2924.	2825.	2680.	2638.	2725.	3248.	3800.	4343.	3276.	
MIN	3673.	3567.	3266.	2903.	2636.	2550.	2429.	2478.	2725.	3146.	3670.	4183.	3113.	

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ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

SPILL IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	2177.	6859.	420.	0.	0.	0.	788.	1960
2	0.	0.	0.	0.	0.	0.	0.	3365.	3500.	0.	0.	0.	572.	1961
3	0.	0.	0.	0.	0.	0.	0.	2292.	2817.	0.	0.	0.	426.	1962
4	0.	0.	0.	0.	0.	0.	0.	221.	3122.	0.	0.	0.	279.	1963
5	0.	0.	0.	0.	0.	0.	0.	1862.	1521.	0.	0.	0.	282.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	4407.	0.	0.	0.	367.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	2791.	0.	0.	0.	233.	1966
8	0.	0.	0.	0.	0.	0.	0.	11212.	3466.	0.	0.	0.	1223.	1967
9	0.	0.	0.	0.	0.	0.	0.	5433.	68.	0.	0.	0.	458.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	198.	2840.	2010.	0.	0.	0.	421.	
MAX	0.	0.	0.	0.	0.	0.	2177.	11212.	4407.	0.	0.	0.	1223.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

FISH RELEASE IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

,NET EVAPORATION IN AC-FT

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

E.O.P. STORAGE IN ACRE-FT

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	3831933.	3644415.	3459987.	3310606.	3372125.	3627219.	4033200.	4033200.	4033200.	3928218.	3749757.	3545788.	3714137.	1960
2	3357525.	3177621.	2998464.	2833961.	2776163.	3088971.	3722366.	4033200.	4033200.	3937256.	3761414.	3546746.	3438907.	1961
3	3343480.	3160911.	2981815.	2824690.	2722736.	3032053.	3686391.	4033200.	4033200.	3913338.	3738685.	3519172.	3415806.	1962
4	3307604.	3114656.	2918324.	2753285.	2684231.	2797895.	3453292.	4033200.	4033200.	3966156.	3795490.	3581683.	3369918.	1963
5	3361876.	3166690.	2979048.	2822339.	2761406.	3080719.	3579412.	4033200.	4033200.	3916289.	3744374.	3527616.	3417181.	1964
6	3311191.	3110578.	2915599.	2754189.	2653470.	2693051.	3330460.	3814864.	4033200.	3969722.	3779241.	3550432.	3326333.	1965
7	3332100.	3137986.	2943806.	2783110.	2719771.	3037835.	3512089.	3968230.	4033200.	3959822.	3787967.	3549749.	3397139.	1966
8	3340211.	3152532.	2968270.	2835542.	2786906.	3146007.	3909940.	4033200.	4033200.	3965172.	3811465.	3589111.	3464296.	1967
9	3379757.	3188885.	3009543.	2861939.	2872700.	3175094.	3827489.	4033200.	4033200.	3899749.	3714608.	3485208.	3456781.	1968
10	3272841.	3087057.	2902100.	2755805.	2695790.	3085199.	3700270.	3991830.	3995875.	3990379.	3844274.	3620075.	3411791.	1969
11	3408630.	3224007.	3049768.	2918171.	2883985.	3125744.	3608617.	3942521.	3943055.	3826882.	3644895.	3406148.	3415202.	1970
MEAN	3386104.	3196849.	3011520.	2859421.	2811753.	3080890.	3669411.	3995440.	4021612.	3933907.	3761106.	3538339.	3438863.	
MAX	3831933.	3644415.	3459987.	3310606.	3372125.	3627219.	4033200.	4033200.	4033200.	3990379.	3844274.	3620075.	3714137.	
MIN	3272841.	3087057.	2902100.	2753285.	2653470.	2693051.	3330460.	3814864.	3943055.	3826882.	3644895.	3406148.	3326333.	

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ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

E.O.P. LAKE LEVEL IN FEET

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	1100.	1100.	1080.	1060.	1080.	1100.	1120.	1120.	1120.	1120.	1100.	1080.	1098.	1960
2	1080.	1060.	1040.	1040.	1040.	1060.	1100.	1120.	1120.	1120.	1100.	1080.	1080.	1961
3	1080.	1060.	1040.	1040.	1020.	1040.	1100.	1120.	1120.	1120.	1100.	1080.	1077.	1962
4	1060.	1060.	1040.	1020.	1020.	1040.	1080.	1120.	1120.	1120.	1100.	1080.	1072.	1963
5	1080.	1060.	1040.	1040.	1020.	1060.	1080.	1120.	1120.	1120.	1100.	1080.	1077.	1964
6	1060.	1060.	1040.	1020.	1020.	1020.	1060.	1100.	1120.	1120.	1100.	1080.	1067.	1965
7	1060.	1060.	1040.	1040.	1020.	1040.	1080.	1120.	1120.	1120.	1100.	1080.	1073.	1966
8	1080.	1060.	1040.	1040.	1040.	1060.	1100.	1120.	1120.	1120.	1100.	1080.	1080.	1967
9	1080.	1060.	1040.	1040.	1040.	1060.	1100.	1120.	1120.	1100.	1100.	1080.	1078.	1968
10	1060.	1060.	1040.	1020.	1020.	1060.	1100.	1120.	1120.	1120.	1100.	1100.	1077.	1969
11	1080.	1060.	1040.	1040.	1040.	1060.	1080.	1120.	1120.	1100.	1100.	1080.	1077.	1970
MEAN	1075.	1064.	1044.	1036.	1033.	1055.	1091.	1118.	1120.	1116.	1100.	1082.	1078.	
MAX	1100.	1100.	1080.	1060.	1080.	1100.	1120.	1120.	1120.	1120.	1100.	1100.	1098.	
MIN	1060.	1060.	1040.	1020.	1020.	1020.	1060.	1100.	1120.	1100.	1100.	1080.	1067.	

ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

WATER BALANCE

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

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ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

POWER IN MW

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1960
2	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1961
3	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1962
4	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1963
5	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1964
6	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1965
7	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1966
8	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1967
9	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1968
10	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1969
11	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1970
MEAN	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	
MAX	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	
MIN	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	

ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

ENERGY IN MWH

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTYR	CALYR
1	133920.	118471.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1317224.	1960
2	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1961
3	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1962
4	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1963
5	133920.	118471.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1317224.	1964
6	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1965
7	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1966
8	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1967
9	133920.	118471.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1317224.	1968
10	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1969
11	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1970
MEAN	133920.	115500.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1314253.	
MAX	133920.	118471.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1317224.	
MIN	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	

ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

ENERGY DEFICIT IN MWH

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

AVERAGE GENERATION IN MW IN MONTHS OF SPILLS

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	236.	300.	160.	0.	0.	0.	58.	1960
2	0.	0.	0.	0.	0.	0.	0.	299.	300.	0.	0.	0.	50.	1961
3	0.	0.	0.	0.	0.	0.	0.	244.	282.	0.	0.	0.	44.	1962
4	0.	0.	0.	0.	0.	0.	0.	142.	297.	0.	0.	0.	37.	1963
5	0.	0.	0.	0.	0.	0.	0.	226.	216.	0.	0.	0.	37.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	300.	0.	0.	0.	25.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	280.	0.	0.	0.	23.	1966
8	0.	0.	0.	0.	0.	0.	0.	300.	300.	0.	0.	0.	50.	1967
9	0.	0.	0.	0.	0.	0.	0.	300.	142.	0.	0.	0.	37.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	21.	165.	207.	0.	0.	0.	33.	
MAX	0.	0.	0.	0.	0.	0.	236.	300.	300.	0.	0.	0.	58.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

SURPLUS ENERGY IN MWH

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTYR	CALYR
1	0.	0.	0.	0.	0.	0.	86681.	130038.	16519.	0.	0.	0.	233238.	1960
2	0.	0.	0.	0.	0.	0.	0.	129139.	117391.	0.	0.	0.	246530.	1961
3	0.	0.	0.	0.	0.	0.	0.	88319.	104264.	0.	0.	0.	192583.	1962
4	0.	0.	0.	0.	0.	0.	0.	12317.	115429.	0.	0.	0.	127746.	1963
5	0.	0.	0.	0.	0.	0.	0.	74660.	56822.	0.	0.	0.	131482.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	117391.	0.	0.	0.	117391.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	103318.	0.	0.	0.	103318.	1966
8	0.	0.	0.	0.	0.	0.	0.	130038.	117391.	0.	0.	0.	247430.	1967
9	0.	0.	0.	0.	0.	0.	0.	130038.	3633.	0.	0.	0.	133671.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	7880.	63141.	68378.	0.	0.	0.	139399.	
MAX	0.	0.	0.	0.	0.	0.	86681.	130038.	117391.	0.	0.	0.	247430.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE C: CHAKACHATNA TUNNEL, WITHOUT FISH RELEASES

REMAINING SPILLS IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	3470.	0.	0.	0.	0.	289.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	324.	0.	0.	0.	27.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	1232.	0.	0.	0.	103.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	7823.	290.	0.	0.	0.	676.	1967
9	0.	0.	0.	0.	0.	0.	0.	2044.	0.	0.	0.	0.	170.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	1212.	168.	0.	0.	0.	115.	
MAX	0.	0.	0.	0.	0.	0.	0.	7823.	1232.	0.	0.	0.	676.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE D: CHAKACHATNA TUNNEL, WITH FISH RELEASES-

INSTALLED CAPACITY: 300000. KW

ANNUAL PLANT FACTOR: .5

OVERLOAD FACTOR: 1.00

PLANT EFFICIENCY: .850

FRICTION LOSS COEFFICIENT: .000002800

MONTHLY LOAD FACTORS:

.920 .870 .780 .700 .640 .620 .610 .640 .700 .800 .920 1.000

INITIAL LAKE STORAGE :4033200. AC-FT

MINIMUM LAKE STORAGE :2423600. AC-FT

MAXIMUM LAKE STORAGE :4033200. AC-FT

ALTERNATIVE D: CHAKACHATNA TUNNEL, WITH FISH RELEASES

RESERVOIR STORAGE-ELEVATION-AREA:

AC-FT	FEET	ACRE
0.	760.	0.
2025.	765.	810.
7300.	770.	1300.
27200.	780.	2690.
111000.	800.	5670.
241000.	820.	7320.
397000.	840.	8270.
572000.	860.	9280.
769000.	880.	10400.
988000.	900.	11590.
1224000.	920.	11960.
1467000.	940.	12320.
1717000.	960.	12650.
1973000.	980.	12980.
2236000.	1000.	13280.
2504000.	1020.	13520.
2776000.	1040.	13740.
3053000.	1060.	13960.
3335000.	1080.	14170.
3620000.	1100.	14390.
3910000.	1120.	14620.
4033200.	1128.	15212.

TAILWATER-FLOW RELATIONSHIP:

FEET	CFS
400.	0.
400.	100000.

MONTHLY MINIMUM INSTREAM FLOWS IN CFS:

30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.

MONTHLY DIVERSION REQUIREMENTS IN CFS:

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

MONTHLY RESERVOIR EVAPORATION IN INCHES:

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

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ALTERNATIVE D: CHAKACHATNA TUNNEL, WITH FISH RELEASES

INFLOWS TO THE LAKE IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	400.	307.	267.	393.	3637.	6837.	11209.	9337.	3145.	1439.	799.	870.	3220.	1960
2	877.	589.	470.	346.	1881.	7983.	12808.	10899.	6225.	1586.	843.	696.	3767.	1961
3	633.	541.	471.	470.	1265.	7925.	13149.	10411.	5542.	1197.	863.	613.	3590.	1962
4	498.	357.	315.	337.	1801.	4735.	13249.	12208.	5847.	2056.	930.	710.	3587.	1963
5	364.	435.	332.	477.	1830.	8093.	10700.	11798.	4246.	1245.	909.	662.	3424.	1964
6	419.	219.	337.	398.	1286.	3490.	13046.	10516.	10802.	2114.	597.	466.	3641.	1965
7	388.	336.	350.	410.	1893.	8072.	10303.	9974.	6608.	1953.	910.	313.	3459.	1966
8	531.	449.	384.	880.	2030.	8761.	14931.	15695.	6191.	2040.	1215.	571.	4473.	1967
9	534.	510.	467.	630.	2996.	7808.	13117.	11257.	2793.	976.	689.	612.	3532.	1968
10	485.	486.	500.	652.	1948.	9271.	12510.	7297.	2793.	3057.	1215.	541.	3396.	1969
11	497.	504.	550.	899.	2265.	6789.	10360.	7986.	2734.	1359.	742.	460.	2929.	1970
MEAN	511.	430.	404.	536.	2076.	7251.	12307.	10671.	5175.	1729.	883.	592.	3547.	
MAX	877.	589.	550.	899.	3637.	9271.	14931.	15695.	10802.	3057.	1215.	870.	4473.	
MIN	364.	219.	267.	337.	1265.	3490.	10303.	7297.	2734.	976.	597.	313.	2929.	

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ALTERNATIVE D1 CHAKACHATNA TUNNEL, WITH FISH RELEASES

POWER RELEASE IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	3673.	3567.	3266.	2903.	2726.	2550.	2429.	2478.	3076.	3146.	3798.	4187.	3150.	1960
2	3939.	3828.	3384.	3111.	2821.	2727.	2507.	2479.	2725.	3146.	3798.	4187.	3221.	1961
3	3939.	3828.	3381.	3111.	2923.	2727.	2506.	2555.	2725.	3146.	3798.	4343.	3248.	1962
4	3939.	3831.	3508.	3111.	2924.	2825.	2591.	2556.	2725.	3146.	3798.	4187.	3262.	1963
5	3939.	3828.	3381.	3111.	2923.	2727.	2590.	2556.	2725.	3146.	3798.	4187.	3243.	1964
6	3939.	3831.	3508.	3111.	2924.	2825.	2680.	2638.	2725.	3146.	3798.	4187.	3276.	1965
7	3939.	3831.	3508.	3111.	2924.	2727.	2590.	2556.	2725.	3146.	3798.	4187.	3253.	1966
8	3939.	3831.	3508.	3111.	2821.	2727.	2507.	2479.	2725.	3146.	3798.	4187.	3232.	1967
9	3939.	3828.	3384.	3111.	2821.	2726.	2507.	2479.	2725.	3146.	3800.	4343.	3234.	1968
10	3939.	3831.	3508.	3111.	2924.	2727.	2507.	2555.	2725.	3146.	3798.	4187.	3247.	1969
11	3939.	3828.	3384.	3111.	2821.	2726.	2590.	2556.	2811.	3249.	3800.	4348.	3264.	1970
MEAN	3915.	3806.	3429.	3092.	2868.	2728.	2546.	2535.	2765.	3156.	3799.	4230.	3239.	
MAX	3939.	3831.	3508.	3111.	2924.	2825.	2680.	2638.	3076.	3249.	3800.	4348.	3276.	
MIN	3673.	3567.	3266.	2903.	2726.	2550.	2429.	2478.	2725.	3146.	3798.	4187.	3150.	

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ALTERNATIVE D: CHAKACHATNA TUNNEL, WITH FISH RELEASES

SPILL IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	1882.	6829.	39.	0.	0.	0.	729.	1960
2	0.	0.	0.	0.	0.	0.	0.	3040.	3470.	0.	0.	0.	543.	1961
3	0.	0.	0.	0.	0.	0.	0.	1896.	2787.	0.	0.	0.	390.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	2820.	0.	0.	0.	235.	1963
5	0.	0.	0.	0.	0.	0.	0.	1438.	1491.	0.	0.	0.	244.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	4042.	0.	0.	0.	337.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	2425.	0.	0.	0.	202.	1966
8	0.	0.	0.	0.	0.	0.	0.	10757.	3436.	0.	0.	0.	1183.	1967
9	0.	0.	0.	0.	0.	0.	0.	5108.	38.	0.	0.	0.	429.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	171.	2642.	1868.	0.	0.	0.	390.	
MAX	0.	0.	0.	0.	0.	0.	1882.	10757.	4042.	0.	0.	0.	1183.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE D: CHAKACHATNA TUNNEL, WITH FISH RELEASES

FISH RELEASE IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	1960
2	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	1961
3	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	1962
4	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	1963
5	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	1964
6	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	1965
7	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	1966
8	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	1967
9	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	1968
10	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	1969
11	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	1970
MEAN	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	
MAX	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	
MIN	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	

ALTERNATIVE D1 CHAKACHATNA TUNNEL, WITH FISH RELEASES

,NET EVAPORATION IN AC-FT

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE D: CHAKACHATNA TUNNEL, WITH FISH RELEASES

E.O.P. STORAGE IN ACRE-FT

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	3830088.	3640844.	3454572.	3303406.	3357590.	3610899.	4033200.	4033200.	4033200.	3926373.	3746127.	3540314.	3709151.	1960
2	3350206.	3168636.	2987635.	2821346.	2761704.	3072687.	3704237.	4033200.	4033200.	3935412.	3757784.	3541272.	3430610.	1961
3	3336161.	3151926.	2971168.	2812258.	2708459.	3015991.	3668577.	4033200.	4033200.	3911493.	3735056.	3503872.	3406780.	1962
4	3290460.	3095845.	2897668.	2730844.	2659946.	2771825.	3425345.	4017005.	4033200.	3964311.	3791860.	3576209.	3354543.	1963
5	3354557.	3157645.	2968341.	2809847.	2740789.	3058318.	3555166.	4033200.	4033200.	3914444.	3740744.	3522141.	3407366.	1964
6	3303872.	3101593.	2904769.	2741575.	2639010.	2676807.	3312371.	3794930.	4033200.	3967877.	3775612.	3544957.	3316381.	1965
7	3324781.	3129000.	2932976.	2770495.	2705254.	3021533.	3493942.	3948239.	4033200.	3957978.	3784337.	3544275.	3387167.	1966
8	3332892.	3143387.	2949452.	2814939.	2764459.	3121736.	3883824.	4033200.	4033200.	3963327.	3807835.	3583637.	3452657.	1967
9	3372438.	3179840.	2998654.	2849265.	2858181.	3158790.	3809340.	4033200.	4033200.	3897904.	3710979.	3479733.	3448460.	1968
10	3265522.	3078072.	2891270.	2743190.	2681330.	3068954.	3682181.	3971897.	3974156.	3966816.	3811324.	3585281.	3393333.	1969
11	3371807.	3185517.	3009435.	2876052.	2840021.	3079996.	3555938.	3887997.	3881626.	3763544.	3579772.	3338880.	3364215.	1970
MEAN	3375707.	3184755.	2996903.	2843020.	2792431.	3059776.	3647647.	3983570.	4014053.	3924498.	3749221.	3523688.	3424606.	
MAX	3830088.	3640844.	3454572.	3303406.	3357590.	3610899.	4033200.	4033200.	4033200.	3967877.	3811324.	3585281.	3709151.	
MIN	3265522.	3078072.	2891270.	2730844.	2639010.	2676807.	3312371.	3794930.	3881626.	3763544.	3579772.	3338880.	3316381.	

ALTERNATIVE D: CHAKACHATNA TUNNEL, WITH FISH RELEASES

E.O.P. LAKE LEVEL IN FEET

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	1100.	1100.	1080.	1060.	1080.	1080.	1120.	1120.	1120.	1120.	1100.	1080.	1097.	1960
2	1080.	1060.	1040.	1040.	1020.	1060.	1100.	1120.	1120.	1120.	1100.	1080.	1078.	1961
3	1080.	1060.	1040.	1040.	1020.	1040.	1100.	1120.	1120.	1120.	1100.	1080.	1077.	1962
4	1060.	1060.	1040.	1020.	1020.	1020.	1080.	1120.	1120.	1120.	1100.	1080.	1070.	1963
5	1080.	1060.	1040.	1040.	1020.	1060.	1080.	1120.	1120.	1120.	1100.	1080.	1077.	1964
6	1060.	1060.	1040.	1020.	1020.	1020.	1060.	1100.	1120.	1120.	1100.	1080.	1067.	1965
7	1060.	1060.	1040.	1020.	1020.	1040.	1080.	1120.	1120.	1120.	1100.	1080.	1072.	1966
8	1060.	1060.	1040.	1040.	1020.	1060.	1100.	1120.	1120.	1120.	1100.	1060.	1077.	1967
9	1080.	1060.	1040.	1040.	1040.	1060.	1100.	1120.	1120.	1100.	1100.	1080.	1078.	1968
10	1060.	1060.	1040.	1020.	1020.	1060.	1100.	1120.	1120.	1120.	1100.	1080.	1075.	1969
11	1080.	1060.	1040.	1040.	1040.	1060.	1080.	1100.	1100.	1100.	1080.	1080.	1072.	1970
MEAN	1073.	1064.	1044.	1035.	1029.	1051.	1091.	1116.	1118.	1116.	1098.	1080.	1076.	
MAX	1100.	1100.	1080.	1060.	1080.	1080.	1120.	1120.	1120.	1120.	1100.	1080.	1097.	
MIN	1060.	1060.	1040.	1020.	1020.	1020.	1060.	1100.	1100.	1100.	1080.	1080.	1067.	

ALTERNATIVE D: CHAKACHATNA TUNNEL, WITH FISH RELEASES

WATER BALANCE

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

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ALTERNATIVE D: CHAKACHATNA TUNNEL, WITH FISH RELEASES

POWER IN MW

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1960
2	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1961
3	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1962
4	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1963
5	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1964
6	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1965
7	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1966
8	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1967
9	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1968
10	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1969
11	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	1970
MEAN	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	
MAX	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	
MIN	180.	170.	153.	137.	125.	121.	119.	125.	137.	157.	180.	196.	150.	

ALTERNATIVE D: CHAKACHATNA TUNNEL, WITH FISH RELEASES

ENERGY IN MWH

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTYR	CALYR
1	133920.	118471.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1317224.	1960
2	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1961
3	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1962
4	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1963
5	133920.	118471.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1317224.	1964
6	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1965
7	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1966
8	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1967
9	133920.	118471.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1317224.	1968
10	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1969
11	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	1970
MEAN	133920.	115500.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1314253.	
MAX	133920.	118471.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1317224.	
MIN	133920.	114386.	113541.	98609.	93162.	87339.	88795.	93162.	98609.	116452.	129600.	145565.	1313139.	

ALTERNATIVE D: CHAKACHATNA TUNNEL, WITH FISH RELEASES

ENERGY DEFICIT IN MWH

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE D1 CHAKACHATNA TUNNEL, WITH FISH RELEASES

AVERAGE GENERATION IN MW IN MONTHS OF SPILLS

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	221.	300.	141.	0.	0.	0.	55.	1960
2	0.	0.	0.	0.	0.	0.	0.	282.	300.	0.	0.	0.	49.	1961
3	0.	0.	0.	0.	0.	0.	0.	227.	280.	0.	0.	0.	42.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	282.	0.	0.	0.	23.	1963
5	0.	0.	0.	0.	0.	0.	0.	204.	214.	0.	0.	0.	35.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	300.	0.	0.	0.	25.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	262.	0.	0.	0.	22.	1966
8	0.	0.	0.	0.	0.	0.	0.	300.	300.	0.	0.	0.	50.	1967
9	0.	0.	0.	0.	0.	0.	0.	300.	140.	0.	0.	0.	37.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	20.	147.	202.	0.	0.	0.	31.	
MAX	0.	0.	0.	0.	0.	0.	221.	300.	300.	0.	0.	0.	55.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE D: CHAKACHATNA TUNNEL, WITH FISH RELEASES

SURPLUS ENERGY IN MWH

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTYR	CALYR
1	0.	0.	0.	0.	0.	0.	75427.	130038.	2679.	0.	0.	0.	208144.	1960
2	0.	0.	0.	0.	0.	0.	0.	116782.	117391.	0.	0.	0.	234174.	1961
3	0.	0.	0.	0.	0.	0.	0.	75918.	103166.	0.	0.	0.	179084.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	104368.	0.	0.	0.	104368.	1963
5	0.	0.	0.	0.	0.	0.	0.	58541.	55724.	0.	0.	0.	114265.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	117391.	0.	0.	0.	117391.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	89921.	0.	0.	0.	89921.	1966
8	0.	0.	0.	0.	0.	0.	0.	130038.	117391.	0.	0.	0.	247430.	1967
9	0.	0.	0.	0.	0.	0.	0.	130038.	2535.	0.	0.	0.	132573.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	6857.	58305.	64597.	0.	0.	0.	129759.	
MAX	0.	0.	0.	0.	0.	0.	75427.	130038.	117391.	0.	0.	0.	247430.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE D: CHAKACHATNA TUNNEL, WITH FISH RELEASES

REMAINING SPILLS IN CFS

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	3440.	0.	0.	0.	0.	287.	1960
2	0.	0.	0.	0.	0.	0.	0.	0.	294.	0.	0.	0.	25.	1961
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
6	0.	0.	0.	0.	0.	0.	0.	0.	867.	0.	0.	0.	72.	1965
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
8	0.	0.	0.	0.	0.	0.	0.	7368.	260.	0.	0.	0.	636.	1967
9	0.	0.	0.	0.	0.	0.	0.	1719.	0.	0.	0.	0.	143.	1968
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
MEAN	0.	0.	0.	0.	0.	0.	0.	1139.	129.	0.	0.	0.	106.	
MAX	0.	0.	0.	0.	0.	0.	0.	7368.	867.	0.	0.	0.	636.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

INSTALLED CAPACITY: 330000. KW

ANNUAL PLANT FACTOR: .45

OVERLOAE FACTOR: 1.00

PLANT EFFICIENCY: .850

FRICTION LOSS COEFFICIENT: .000002370

STARTER CAPACITY: 5000. CFS

TOLERANCE: .010 PERCENT

MONTHLY LOAD FACTORS:

.640	.620	.610	.640	.700	.800	.920	1.000	.920	.870	.780	.700

INITIAL LAKE STORAGE :4477500. AC-FT

MINIMUM LAKE STORAGE :3377750. AC-FT

MAXIMUM LAKE STORAGE :4477500. AC-FT

ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

RESERVOIR STORAGE-ELEVATION-AREA:

AC-FT	FEET	ACRE
0.	760.	0.
2025.	765.	810.
7300.	770.	1300.
27200.	780.	2690.
111000.	800.	5670.
241000.	820.	7320.
397000.	840.	8270.
572000.	860.	9280.
769000.	880.	10400.
988000.	900.	11590.
1224000.	920.	11960.
1467000.	940.	12320.
1717000.	960.	12650.
1973000.	980.	12980.
2236000.	1000.	13280.
2504000.	1020.	13520.
2776000.	1040.	13740.
3053000.	1060.	13960.
3335000.	1080.	14170.
3620000.	1100.	14390.
3910000.	1120.	14620.
4218000.	1140.	16100.
4250000.	1142.	16780.
4477500.	1155.	17842.

TAILWATER-FLOW RELATIONSHIP:

FEET	CFS
210.	0.
210.	100000.

MONTHLY MINIMUM INSTREAM FLOWS IN CFS:

1094. 1094. 1094. 1094. 1094. 365. 365. 365. 365. 365. 365. 1094.

MONTHLY DIVERSION REQUIREMENTS IN CFS:

0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.

MONTHLY RESERVOIR EVAPORATION IN INCHES:

0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.

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ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

INFLOWS TO THE LAKE IN CFS

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	AVEYR	CALYR
1	4513.	10728.	15220.	11615.	6305.	2689.	802.	636.	542.	488.	493.	541.	4548.	1950
2	2055.	8572.	13194.	10548.	4521.	1761.	569.	532.	495.	472.	450.	631.	3650.	1951
3	3801.	10719.	13095.	8831.	8635.	3216.	842.	699.	630.	495.	467.	510.	4328.	1952
4	2027.	8204.	12575.	9431.	3562.	2712.	865.	642.	523.	477.	477.	641.	3511.	1953
5	3992.	13247.	13355.	10808.	4505.	2002.	629.	550.	527.	472.	458.	541.	4257.	1954
6	3434.	9002.	12091.	12046.	6075.	2787.	755.	619.	578.	507.	466.	487.	4071.	1955
7	2193.	6826.	12996.	9983.	5068.	1988.	595.	532.	504.	475.	449.	496.	3509.	1956
8	2936.	7475.	14601.	10235.	5940.	2053.	583.	565.	569.	536.	505.	598.	3883.	1957
9	4393.	14817.	13149.	10405.	6910.	2707.	793.	562.	569.	510.	489.	675.	4665.	1958
10	2496.	9930.	10163.	8691.	3452.	1896.	526.	483.	426.	468.	449.	526.	3292.	1959
11	3120.	9459.	10388.	11731.	3662.	1370.	654.	508.	400.	307.	267.	393.	3522.	1960
12	3637.	6837.	11209.	9337.	3145.	1439.	799.	870.	877.	589.	470.	346.	3296.	1961
13	1881.	7983.	12808.	10899.	6225.	1586.	843.	696.	633.	541.	471.	470.	3753.	1962
14	1265.	7925.	13149.	10411.	5542.	1197.	863.	613.	498.	357.	315.	337.	3539.	1963
15	1801.	4735.	13249.	12208.	5847.	2086.	930.	710.	364.	435.	332.	477.	3598.	1964
16	1830.	8093.	10700.	11798.	4246.	1245.	909.	662.	419.	219.	337.	398.	3405.	1965
17	1286.	3490.	11633.	11929.	10802.	2114.	597.	466.	388.	336.	350.	410.	3659.	1966
18	1893.	8072.	10303.	9974.	6608.	1953.	910.	313.	531.	449.	384.	880.	3523.	1967
19	2030.	8761.	14931.	15695.	6191.	2040.	1215.	571.	534.	510.	467.	630.	4465.	1968
20	2996.	7808.	13117.	11257.	2793.	976.	689.	612.	485.	486.	500.	652.	3531.	1969
21	1948.	9271.	12478.	7297.	2793.	3057.	1215.	601.	497.	504.	550.	899.	3426.	1970
22	2265.	6789.	10360.	7986.	2734.	1359.	742.	460.	394.	441.	513.	1275.	2943.	1971
23	4063.	12672.	13695.	16680.	5075.	3181.	1090.	736.	581.	531.	492.	479.	4940.	1972
24	3468.	8228.	13490.	9263.	5012.	2396.	679.	514.	495.	492.	480.	586.	3759.	1973
25	2131.	7457.	8859.	7809.	2794.	2527.	740.	623.	558.	526.	501.	554.	2923.	1974
26	4215.	6248.	6781.	6159.	6850.	3059.	909.	530.	498.	485.	485.	489.	3059.	1975
27	4784.	10649.	10889.	6802.	5107.	3136.	814.	622.	544.	524.	498.	625.	3750.	1976
28	5283.	8587.	8304.	6494.	4947.	3917.	1058.	1055.	1044.	773.	606.	606.	3556.	1977
29	5335.	19864.	13898.	11224.	6059.	3709.	922.	700.	609.	537.	509.	558.	5327.	1978
30	5387.	7917.	10146.	7865.	4513.	3258.	706.	701.	597.	562.	547.	713.	3576.	1979
31	6776.	8514.	8958.	9157.	4572.	4471.	1412.	882.	762.	718.	647.	810.	3973.	1980
MEAN	3201.	8996.	11928.	10147.	5177.	2383.	828.	621.	551.	491.	465.	588.	3781.	
MAX	6776.	19864.	15220.	16680.	10802.	4471.	1412.	1055.	1044.	773.	647.	1275.	5327.	
MIN	1265.	3490.	6781.	6159.	2734.	976.	526.	313.	364.	219.	267.	337.	2923.	

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ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

POWER RELEASE IN CFS

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	AVEYR	CALYR
1	1834.	1756.	1712.	1810.	2004.	2311.	2682.	2954.	2740.	2614.	2360.	2134.	2243.	1950
2	1962.	1879.	1782.	1813.	2010.	2315.	2693.	2970.	2756.	2631.	2376.	2149.	2278.	1951
3	1968.	1867.	1766.	1819.	1995.	2309.	2681.	2953.	2738.	2612.	2359.	2133.	2267.	1952
4	1961.	1880.	1787.	1818.	2014.	2311.	2681.	2953.	2739.	2613.	2360.	2134.	2271.	1953
5	1952.	1842.	1737.	1813.	2011.	2314.	2690.	2965.	2752.	2626.	2372.	2145.	2268.	1954
6	1966.	1874.	1781.	1808.	2005.	2311.	2682.	2954.	2740.	2614.	2360.	2135.	2269.	1955
7	1962.	1886.	1796.	1822.	2008.	2314.	2690.	2966.	2753.	2628.	2374.	2147.	2279.	1956
8	1970.	1887.	1788.	1814.	2005.	2314.	2689.	2965.	2751.	2625.	2370.	2143.	2277.	1957
9	1959.	1840.	1731.	1814.	2002.	2311.	2682.	2954.	2741.	2614.	2361.	2135.	2262.	1958
10	1960.	1869.	1781.	1823.	2014.	2315.	2691.	2969.	2756.	2631.	2377.	2150.	2278.	1959
11	1971.	1879.	1790.	1820.	2014.	2317.	2696.	2974.	2761.	2638.	2384.	2157.	2284.	1960
12	1976.	1892.	1809.	1842.	2016.	2317.	2695.	2969.	2751.	2622.	2368.	2141.	2283.	1961
13	1970.	1889.	1795.	1819.	2004.	2316.	2693.	2967.	2752.	2625.	2371.	2144.	2279.	1962
14	1975.	1898.	1802.	1826.	2007.	2318.	2697.	2973.	2759.	2634.	2381.	2154.	2285.	1963
15	1962.	1917.	1830.	1843.	2006.	2314.	2687.	2959.	2746.	2622.	2369.	2143.	2285.	1964
16	1972.	1891.	1805.	1832.	2012.	2318.	2696.	2972.	2758.	2633.	2380.	2153.	2285.	1965
17	1984.	1927.	1852.	1868.	1987.	2314.	2689.	2965.	2753.	2629.	2376.	2149.	2291.	1966
18	1977.	1896.	1811.	1845.	2003.	2315.	2689.	2964.	2751.	2626.	2372.	2146.	2283.	1967
19	1973.	1889.	1783.	1796.	2004.	2314.	2686.	2957.	2744.	2618.	2365.	2139.	2272.	1968
20	1962.	1878.	1785.	1811.	2017.	2322.	2704.	2983.	2768.	2643.	2387.	2159.	2285.	1969
21	1986.	1899.	1800.	1837.	2017.	2312.	2679.	2949.	2735.	2610.	2356.	2130.	2276.	1970
22	1957.	1881.	1803.	1844.	2017.	2321.	2700.	2979.	2766.	2642.	2386.	2157.	2288.	1971
23	1973.	1862.	1754.	1793.	2008.	2309.	2680.	2950.	2735.	2609.	2356.	2130.	2263.	1972
24	1951.	1864.	1771.	1818.	2009.	2313.	2685.	2960.	2747.	2621.	2367.	2141.	2270.	1973
25	1968.	1889.	1813.	1860.	2020.	2318.	2691.	2966.	2752.	2625.	2371.	2144.	2285.	1974
26	1961.	1878.	1816.	1878.	2029.	2310.	2681.	2953.	2740.	2614.	2361.	2135.	2280.	1975
27	1949.	1846.	1758.	1826.	2008.	2309.	2682.	2954.	2740.	2614.	2361.	2135.	2265.	1976
28	1947.	1850.	1776.	1833.	2009.	2306.	2680.	2948.	2728.	2598.	2343.	2117.	2251.	1977
29	1931.	1794.	1716.	1811.	2005.	2307.	2681.	2952.	2737.	2611.	2357.	2131.	2253.	1978
30	1943.	1849.	1771.	1823.	2011.	2309.	2682.	2954.	2740.	2613.	2359.	2133.	2265.	1979
31	1938.	1836.	1763.	1818.	2010.	2303.	2678.	2945.	2728.	2600.	2345.	2119.	2257.	1980
MEAN	1959.	1870.	1783.	1826.	2009.	2313.	2688.	2961.	2747.	2621.	2367.	2141.	2274.	
MAX	1986.	1927.	1852.	1878.	2029.	2322.	2704.	2983.	2768.	2643.	2387.	2159.	2291.	
MIN	1834.	1756.	1712.	1793.	1987.	2303.	2678.	2945.	2728.	2598.	2343.	2117.	2243.	

ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

SPILL IN CFS

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	AVEYR	CALYR
1	1585.	7878.	12414.	8711.	3207.	13.	0.	0.	0.	0.	0.	0.	2817.	1950
2	0.	0.	770.	7641.	1417.	0.	0.	0.	0.	0.	0.	0.	819.	1951
3	0.	0.	3074.	5918.	5546.	542.	0.	0.	0.	0.	0.	0.	1257.	1952
4	0.	0.	0.	6378.	454.	36.	0.	0.	0.	0.	0.	0.	572.	1953
5	0.	0.	7508.	7901.	1400.	0.	0.	0.	0.	0.	0.	0.	1401.	1954
6	0.	0.	404.	9144.	2976.	111.	0.	0.	0.	0.	0.	0.	1053.	1955
7	0.	0.	0.	6028.	1966.	0.	0.	0.	0.	0.	0.	0.	666.	1956
8	0.	0.	731.	7327.	2841.	0.	0.	0.	0.	0.	0.	0.	908.	1957
9	0.	0.	8312.	7497.	3814.	31.	0.	0.	0.	0.	0.	0.	1638.	1958
10	0.	0.	0.	5238.	344.	0.	0.	0.	0.	0.	0.	0.	465.	1959
11	0.	0.	0.	7217.	554.	0.	0.	0.	0.	0.	0.	0.	648.	1960
12	0.	0.	0.	2861.	35.	0.	0.	0.	0.	0.	0.	0.	241.	1961
13	0.	0.	0.	6926.	3127.	0.	0.	0.	0.	0.	0.	0.	838.	1962
14	0.	0.	0.	5803.	2441.	0.	0.	0.	0.	0.	0.	0.	687.	1963
15	0.	0.	0.	4180.	2747.	0.	0.	0.	0.	0.	0.	0.	577.	1964
16	0.	0.	0.	5542.	1140.	0.	0.	0.	0.	0.	0.	0.	557.	1965
17	0.	0.	0.	575.	7721.	0.	0.	0.	0.	0.	0.	0.	691.	1966
18	0.	0.	0.	2809.	3511.	0.	0.	0.	0.	0.	0.	0.	527.	1967
19	0.	0.	1533.	12805.	3093.	0.	0.	0.	0.	0.	0.	0.	1453.	1968
20	0.	0.	471.	8352.	0.	0.	0.	0.	0.	0.	0.	0.	735.	1969
21	0.	0.	0.	2567.	0.	72.	0.	0.	0.	0.	0.	0.	220.	1970
22	0.	0.	0.	1866.	0.	0.	0.	0.	0.	0.	0.	0.	155.	1971
23	0.	0.	5219.	13793.	1973.	507.	0.	0.	0.	0.	0.	0.	1791.	1972
24	0.	0.	2584.	6351.	1909.	0.	0.	0.	0.	0.	0.	0.	904.	1973
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1974
26	0.	0.	0.	0.	197.	384.	0.	0.	0.	0.	0.	0.	41.	1975
27	0.	0.	3215.	3882.	2005.	462.	0.	0.	0.	0.	0.	0.	797.	1976
28	0.	0.	0.	2695.	1844.	1246.	0.	0.	0.	0.	0.	0.	482.	1977
29	0.	6592.	11088.	8319.	2960.	1037.	0.	0.	0.	0.	0.	0.	2500.	1978
30	0.	0.	802.	4948.	1408.	584.	0.	0.	0.	0.	0.	0.	645.	1979
31	0.	0.	1436.	6245.	1468.	1803.	0.	0.	0.	0.	0.	0.	913.	1980
MEAN	51.	467.	1921.	5791.	2000.	220.	0.	0.	0.	0.	0.	0.	871.	
MAX	1585.	7878.	12414.	13793.	7721.	1803.	0.	0.	0.	0.	0.	0.	2817.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

FISH RELEASE IN CFS

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	AVEYR	CALYR
1	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	541.	683.	1950
2	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	631.	691.	1951
3	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	510.	681.	1952
4	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	641.	692.	1953
5	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	541.	683.	1954
6	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	487.	679.	1955
7	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	496.	680.	1956
8	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	598.	688.	1957
9	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	675.	695.	1958
10	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	526.	682.	1959
11	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	307.	267.	393.	658.	1960
12	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	346.	667.	1961
13	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	470.	678.	1962
14	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	357.	315.	337.	662.	1963
15	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	364.	365.	332.	477.	675.	1964
16	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	219.	337.	398.	657.	1965
17	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	336.	350.	410.	669.	1966
18	1094.	1094.	1094.	1094.	1094.	365.	365.	313.	365.	365.	365.	880.	707.	1967
19	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	630.	691.	1968
20	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	652.	693.	1969
21	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	899.	713.	1970
22	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	1094.	730.	1971
23	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	479.	678.	1972
24	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	586.	687.	1973
25	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	554.	685.	1974
26	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	489.	679.	1975
27	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	625.	690.	1976
28	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	606.	689.	1977
29	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	558.	685.	1978
30	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	713.	698.	1979
31	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	810.	706.	1980
MEAN	1094.	1094.	1094.	1094.	1094.	365.	365.	363.	365.	357.	358.	582.	685.	
MAX	1094.	1094.	1094.	1094.	1094.	365.	365.	365.	365.	365.	365.	1094.	730.	
MIN	1094.	1094.	1094.	1094.	1094.	365.	365.	313.	364.	219.	267.	337.	657.	

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ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

,NET EVAPORATION IN AC-FT

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1950
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1951
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1952
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1953
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1954
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1955
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1956
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1957
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1958
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1959
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
12	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
14	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
15	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
16	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
17	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
18	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1971
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1972
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1973
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1974
26	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1975
27	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1976
28	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1977
29	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1978
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1979
31	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1980
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

E.O.P. STORAGE IN ACRE-FT

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	AVEYR	CALYR
1	4477500.	4477500.	4477500.	4477500.	4477500.	4477500.	4343937.	4178982.	4021409.	3883070.	3745820.	3618830.	4221420.	1950
2	3557280.	3890445.	4477500.	4477500.	4477500.	4420969.	4272884.	4100551.	3939069.	3798899.	3658001.	3530102.	4050058.	1951
3	3575561.	4037206.	4477500.	4477500.	4477500.	4477500.	4346329.	4185300.	4033252.	3890484.	3751712.	3624782.	4112885.	1952
4	3561561.	3872769.	4468818.	4477500.	4477500.	4477500.	4347705.	4183166.	4024470.	3885551.	3747340.	3620366.	4095354.	1953
5	3678513.	4292086.	4477500.	4477500.	4477500.	4435854.	4291513.	4120550.	3961305.	3821397.	3681259.	3553606.	4105715.	1954
6	3576621.	3935657.	4477500.	4477500.	4477500.	4477500.	4341126.	4175085.	4019690.	3882394.	3743466.	3616452.	4100041.	1955
7	3563406.	3792268.	4413665.	4477500.	4477500.	4434989.	4288605.	4116489.	3955768.	3810939.	3670121.	3542351.	4045300.	1956
8	3534480.	3801875.	4477500.	4477500.	4477500.	4439004.	4291944.	4121916.	3965287.	3829002.	3691860.	3564316.	4056015.	1957
9	3646696.	4353809.	4477500.	4477500.	4477500.	4477500.	4343398.	4173860.	4017892.	3880744.	3743219.	3616202.	4140485.	1958
10	3581877.	3996422.	4444553.	4477500.	4477500.	4429307.	4278737.	4103451.	3937736.	3797327.	3656348.	3528432.	4059099.	1959
11	3531794.	3917746.	4379145.	4477500.	4477500.	4396818.	4253567.	4079480.	3911849.	3760115.	3613499.	3485129.	4023679.	1960
12	3520005.	3749135.	4259863.	4477500.	4477500.	4401080.	4266546.	4115051.	3977393.	3844210.	3705083.	3577675.	4030920.	1961
13	3504965.	3802458.	4412330.	4477500.	4477500.	4410160.	4278352.	4116247.	3963506.	3827479.	3688216.	3560635.	4043279.	1962
14	3449689.	3743212.	4373660.	4477500.	4477500.	4386133.	4255271.	4087709.	3926248.	3779949.	3633568.	3505411.	4007987.	1963
15	3427032.	3529642.	4164483.	4477500.	4477500.	4441042.	4314758.	4154012.	3985169.	3838383.	3692693.	3565157.	4005614.	1964
16	3489171.	3793096.	4272757.	4477500.	4477500.	4389098.	4261018.	4096569.	3930333.	3784082.	3637751.	3509638.	4009876.	1965
17	3399476.	3427392.	3961509.	4477500.	4477500.	4442771.	4296588.	4120495.	3952648.	3806661.	3660597.	3532726.	3962988.	1966
18	3460307.	3762715.	4217620.	4477500.	4477500.	4432827.	4305262.	4123035.	3964069.	3822909.	3678212.	3550527.	4022707.	1967
19	3486753.	3830584.	4477500.	4477500.	4477500.	4438201.	4328934.	4159771.	4001459.	3859198.	3720060.	3592806.	4070655.	1968
20	3589145.	3876930.	4477500.	4477500.	4458580.	4353391.	4211779.	4043551.	3880715.	3740634.	3602136.	3473645.	4015459.	1969
21	3404028.	3777592.	4366893.	4477500.	4458580.	4477500.	4368638.	4201814.	4041746.	3904523.	3771048.	3644315.	4074515.	1970
22	3595992.	3822934.	4281846.	4477500.	4455056.	4373491.	4235260.	4057948.	3889667.	3747179.	3609563.	3491978.	4003201.	1971
23	3553247.	4131416.	4477500.	4477500.	4477500.	4477500.	4361162.	4202599.	4047738.	3907217.	3770185.	3643444.	4127251.	1972
24	3669439.	3983032.	4477500.	4477500.	4477500.	4460189.	4319090.	4146270.	3985373.	3846862.	3708384.	3581010.	4094346.	1973
25	3523781.	3790034.	4155425.	4453961.	4434923.	4425319.	4287507.	4121009.	3963688.	3826825.	3689411.	3561842.	4019474.	1974
26	3633198.	3828135.	4066131.	4262118.	4477500.	4477500.	4350336.	4178901.	4018605.	3880068.	3742288.	3615262.	4044170.	1975
27	3722292.	4181004.	4477500.	4477500.	4477500.	4477500.	4344654.	4178842.	4021391.	3880166.	3743191.	3616174.	4133143.	1976
28	3754042.	4089818.	4423913.	4477500.	4477500.	4477500.	4359248.	4220394.	4094404.	3972776.	3843551.	3717551.	4159016.	1977
29	3859593.	4477500.	4477500.	4477500.	4477500.	4477500.	4351114.	4190204.	4036918.	3901486.	3765440.	3638650.	4177575.	1978
30	3783157.	4079140.	4477500.	4477500.	4477500.	4477500.	4338314.	4177313.	4023122.	3888934.	3755092.	3628197.	4131939.	1979
31	3858416.	4190670.	4477500.	4477500.	4477500.	4477500.	4380421.	4231118.	4087815.	3958563.	3831711.	3705592.	4179525.	1980
MEAN	3611904.	3943038.	4381455.	4469793.	4474182.	4442521.	4310129.	4143925.	3986443.	3847033.	3708091.	3581058.	4074964.	
MAX	4477500.	4477500.	4477500.	4477500.	4477500.	4477500.	4380421.	4231118.	4094404.	3972776.	3843551.	3717551.	4221420.	
MIN	3399476.	3427392.	3961509.	4262118.	4434923.	4353391.	4211779.	4043551.	3880715.	3740634.	3602136.	3473645.	3962988.	

ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

E.O.P. LAKE LEVEL IN FEET

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	AVEYR	CALYR
1	1155.	1155.	1155.	1155.	1155.	1155.	1147.	1137.	1127.	1118.	1109.	1100.	1139.	1950
2	1096.	1119.	1155.	1155.	1155.	1152.	1143.	1132.	1122.	1112.	1103.	1094.	1128.	1951
3	1097.	1128.	1155.	1155.	1155.	1155.	1148.	1138.	1128.	1119.	1109.	1100.	1132.	1952
4	1096.	1117.	1155.	1155.	1155.	1155.	1148.	1138.	1127.	1118.	1109.	1100.	1131.	1953
5	1104.	1144.	1155.	1155.	1155.	1153.	1144.	1134.	1123.	1114.	1104.	1095.	1132.	1954
6	1097.	1122.	1155.	1155.	1155.	1155.	1147.	1137.	1127.	1118.	1109.	1100.	1131.	1955
7	1096.	1112.	1151.	1155.	1155.	1153.	1144.	1133.	1123.	1113.	1103.	1095.	1128.	1956
8	1094.	1113.	1155.	1155.	1155.	1153.	1144.	1134.	1124.	1114.	1105.	1096.	1128.	1957
9	1102.	1148.	1155.	1155.	1155.	1155.	1147.	1137.	1127.	1118.	1108.	1100.	1134.	1958
10	1097.	1126.	1153.	1155.	1155.	1152.	1144.	1133.	1122.	1112.	1103.	1094.	1129.	1959
11	1094.	1121.	1149.	1155.	1155.	1150.	1142.	1131.	1120.	1110.	1100.	1091.	1126.	1960
12	1093.	1109.	1143.	1155.	1155.	1151.	1143.	1133.	1124.	1115.	1106.	1097.	1127.	1961
13	1092.	1113.	1151.	1155.	1155.	1151.	1144.	1133.	1123.	1114.	1105.	1096.	1128.	1962
14	1088.	1108.	1149.	1155.	1155.	1150.	1142.	1132.	1121.	1111.	1101.	1092.	1125.	1963
15	1086.	1094.	1137.	1155.	1155.	1153.	1146.	1136.	1125.	1115.	1105.	1096.	1125.	1964
16	1091.	1112.	1143.	1155.	1155.	1150.	1143.	1132.	1121.	1111.	1101.	1092.	1126.	1965
17	1085.	1086.	1123.	1155.	1155.	1153.	1145.	1134.	1123.	1113.	1103.	1094.	1122.	1966
18	1089.	1110.	1140.	1155.	1155.	1152.	1145.	1134.	1124.	1114.	1104.	1095.	1126.	1967
19	1091.	1115.	1155.	1155.	1155.	1153.	1147.	1136.	1126.	1116.	1107.	1098.	1129.	1968
20	1098.	1118.	1155.	1155.	1154.	1148.	1140.	1129.	1118.	1108.	1099.	1090.	1126.	1969
21	1085.	1111.	1149.	1155.	1154.	1155.	1149.	1139.	1129.	1120.	1110.	1102.	1130.	1970
22	1098.	1114.	1144.	1155.	1154.	1149.	1141.	1130.	1119.	1109.	1099.	1091.	1125.	1971
23	1095.	1134.	1155.	1155.	1155.	1155.	1148.	1139.	1129.	1120.	1110.	1102.	1133.	1972
24	1103.	1125.	1155.	1155.	1155.	1154.	1146.	1135.	1125.	1116.	1106.	1097.	1131.	1973
25	1093.	1112.	1136.	1154.	1153.	1152.	1144.	1134.	1123.	1114.	1105.	1096.	1126.	1974
26	1101.	1114.	1130.	1143.	1155.	1155.	1148.	1137.	1127.	1118.	1108.	1100.	1128.	1975
27	1107.	1138.	1155.	1155.	1155.	1155.	1147.	1137.	1127.	1118.	1108.	1100.	1134.	1976
28	1109.	1132.	1152.	1155.	1155.	1155.	1148.	1140.	1132.	1124.	1115.	1107.	1135.	1977
29	1117.	1155.	1155.	1155.	1155.	1155.	1148.	1138.	1128.	1119.	1110.	1101.	1136.	1978
30	1111.	1131.	1155.	1155.	1155.	1155.	1147.	1137.	1127.	1119.	1109.	1101.	1134.	1979
31	1116.	1138.	1155.	1155.	1155.	1155.	1149.	1141.	1132.	1123.	1115.	1106.	1137.	1980
MEAN	1099.	1122.	1149.	1155.	1155.	1153.	1145.	1135.	1125.	1116.	1106.	1097.	1130.	
MAX	1155.	1155.	1155.	1155.	1155.	1155.	1149.	1141.	1132.	1124.	1115.	1107.	1139.	
MIN	1085.	1086.	1123.	1143.	1153.	1148.	1140.	1129.	1118.	1108.	1099.	1090.	1122.	

ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

WATER BALANCE

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	AVEYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1950
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1951
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1952
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1953
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1954
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1955
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1956
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1957
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1958
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1959
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
12	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
14	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
15	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
16	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
17	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
18	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1971
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1972
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1973
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1974
26	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1975
27	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1976
28	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1977
29	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1978
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1979
31	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1980
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

POWER IN MW

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	AVEYR	CALYR
1	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1950
2	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1951
3	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1952
4	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1953
5	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1954
6	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1955
7	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1956
8	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1957
9	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1958
10	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1959
11	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1960
12	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1961
13	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1962
14	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1963
15	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1964
16	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1965
17	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1966
18	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1967
19	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1968
20	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1969
21	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1970
22	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1971
23	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1972
24	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1973
25	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1974
26	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1975
27	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1976
28	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1977
29	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1978
30	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1979
31	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	1980
MEAN	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	
MAX	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	
MIN	124.	120.	118.	124.	136.	155.	178.	194.	178.	169.	151.	136.	149.	

CHAKACHAMNA PROJECT OPERATION STUDY
H/H,H&CF,BECHTEL CIVIL&MINERALS INC.,SF.
ALASKA POWER AUTHORITY

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ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

ENERGY IN MWH

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	TOTYR	CALYR
1	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1950
2	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1951
3	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	117287.	112405.	97623.	1304052.	1952
4	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1953
5	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1954
6	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1955
7	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	117287.	112405.	97623.	1304052.	1956
8	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1957
9	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1958
10	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1959
11	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	117287.	112405.	97623.	1304052.	1960
12	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1961
13	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1962
14	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1963
15	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	117287.	112405.	97623.	1304052.	1964
16	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1965
17	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1966
18	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1967
19	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	117287.	112405.	97623.	1304052.	1968
20	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1969
21	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1970
22	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1971
23	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	117287.	112405.	97623.	1304052.	1972
24	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1973
25	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1974
26	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1975
27	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	117287.	112405.	97623.	1304052.	1976
28	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1977
29	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1978
30	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	1979
31	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	117287.	112405.	97623.	1304052.	1980
MEAN	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	114286.	112405.	97623.	1301051.	
MAX	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	117287.	112405.	97623.	1304052.	
MIN	92230.	86466.	87907.	92230.	97623.	115288.	128304.	144110.	132581.	113242.	112405.	97623.	1300008.	

ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

ENERGY DEFICIT IN MWH

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	TOTYR	CALYR
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1950
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1951
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1952
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1953
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1954
6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1955
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1956
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1957
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1958
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1959
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1960
12	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1962
14	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1963
15	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1964
16	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1965
17	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1966
18	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1967
19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1968
20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1969
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1971
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1972
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1973
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1974
26	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1975
27	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1976
28	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1977
29	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1978
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1979
31	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1980
MEAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MAX	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

AVERAGE GENERATION IN MW IN MONTHS OF SPILLS

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	AVEYR	CALYR
1	231.	330.	330.	330.	330.	156.	0.	0.	0.	0.	0.	0.	142.	1950
2	0.	0.	172.	330.	231.	0.	0.	0.	0.	0.	0.	0.	61.	1951
3	0.	0.	326.	330.	330.	191.	0.	0.	0.	0.	0.	0.	98.	1952
4	0.	0.	0.	330.	166.	157.	0.	0.	0.	0.	0.	0.	54.	1953
5	0.	0.	330.	330.	230.	0.	0.	0.	0.	0.	0.	0.	74.	1954
6	0.	0.	147.	330.	330.	163.	0.	0.	0.	0.	0.	0.	81.	1955
7	0.	0.	0.	330.	267.	0.	0.	0.	0.	0.	0.	0.	50.	1956
8	0.	0.	170.	330.	326.	0.	0.	0.	0.	0.	0.	0.	69.	1957
9	0.	0.	330.	330.	330.	157.	0.	0.	0.	0.	0.	0.	96.	1958
10	0.	0.	0.	330.	159.	0.	0.	0.	0.	0.	0.	0.	41.	1959
11	0.	0.	0.	330.	173.	0.	0.	0.	0.	0.	0.	0.	42.	1960
12	0.	0.	0.	317.	138.	0.	0.	0.	0.	0.	0.	0.	38.	1961
13	0.	0.	0.	330.	330.	0.	0.	0.	0.	0.	0.	0.	55.	1962
14	0.	0.	0.	330.	299.	0.	0.	0.	0.	0.	0.	0.	52.	1963
15	0.	0.	0.	330.	320.	0.	0.	0.	0.	0.	0.	0.	54.	1964
16	0.	0.	0.	330.	212.	0.	0.	0.	0.	0.	0.	0.	45.	1965
17	0.	0.	0.	165.	330.	0.	0.	0.	0.	0.	0.	0.	41.	1966
18	0.	0.	0.	314.	330.	0.	0.	0.	0.	0.	0.	0.	54.	1967
19	0.	0.	224.	330.	330.	0.	0.	0.	0.	0.	0.	0.	74.	1968
20	0.	0.	152.	330.	0.	0.	0.	0.	0.	0.	0.	0.	40.	1969
21	0.	0.	0.	297.	0.	160.	0.	0.	0.	0.	0.	0.	38.	1970
22	0.	0.	0.	250.	0.	0.	0.	0.	0.	0.	0.	0.	21.	1971
23	0.	0.	330.	330.	268.	189.	0.	0.	0.	0.	0.	0.	93.	1972
24	0.	0.	294.	330.	264.	0.	0.	0.	0.	0.	0.	0.	74.	1973
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1974
26	0.	0.	0.	0.	144.	181.	0.	0.	0.	0.	0.	0.	27.	1975
27	0.	0.	330.	330.	270.	186.	0.	0.	0.	0.	0.	0.	93.	1976
28	0.	0.	0.	305.	259.	238.	0.	0.	0.	0.	0.	0.	67.	1977
29	0.	330.	330.	330.	330.	224.	0.	0.	0.	0.	0.	0.	129.	1978
30	0.	0.	174.	330.	230.	194.	0.	0.	0.	0.	0.	0.	77.	1979
31	0.	0.	216.	330.	234.	275.	0.	0.	0.	0.	0.	0.	88.	1980
MEAN	7.	21.	124.	298.	231.	80.	0.	0.	0.	0.	0.	0.	63.	
MAX	231.	330.	330.	330.	330.	275.	0.	0.	0.	0.	0.	0.	142.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

SURPLUS ENERGY IN MWH

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	TOTYR	CALYR
1	79356.	151134.	157613.	153290.	139977.	723.	0.	0.	0.	0.	0.	0.	682093.	1950
2	0.	0.	40191.	153290.	68462.	0.	0.	0.	0.	0.	0.	0.	261942.	1951
3	0.	0.	155008.	153290.	139977.	27030.	0.	0.	0.	0.	0.	0.	475305.	1952
4	0.	0.	0.	153290.	21985.	1871.	0.	0.	0.	0.	0.	0.	177146.	1953
5	0.	0.	157613.	153290.	67686.	0.	0.	0.	0.	0.	0.	0.	378589.	1954
6	0.	0.	21737.	153290.	139977.	5615.	0.	0.	0.	0.	0.	0.	320619.	1955
7	0.	0.	0.	153290.	94971.	0.	0.	0.	0.	0.	0.	0.	248261.	1956
8	0.	0.	38512.	153290.	137231.	0.	0.	0.	0.	0.	0.	0.	329033.	1957
9	0.	0.	157613.	153290.	139977.	1621.	0.	0.	0.	0.	0.	0.	452502.	1958
10	0.	0.	0.	153290.	16654.	0.	0.	0.	0.	0.	0.	0.	169944.	1959
11	0.	0.	0.	153290.	26832.	0.	0.	0.	0.	0.	0.	0.	180121.	1960
12	0.	0.	0.	143566.	1776.	0.	0.	0.	0.	0.	0.	0.	145342.	1961
13	0.	0.	0.	153290.	139977.	0.	0.	0.	0.	0.	0.	0.	293267.	1962
14	0.	0.	0.	153290.	117943.	0.	0.	0.	0.	0.	0.	0.	271233.	1963
15	0.	0.	0.	153290.	132724.	0.	0.	0.	0.	0.	0.	0.	286014.	1964
16	0.	0.	0.	153290.	55134.	0.	0.	0.	0.	0.	0.	0.	208424.	1965
17	0.	0.	0.	30253.	139977.	0.	0.	0.	0.	0.	0.	0.	170231.	1966
18	0.	0.	0.	141059.	139977.	0.	0.	0.	0.	0.	0.	0.	281036.	1967
19	0.	0.	78505.	153290.	139977.	0.	0.	0.	0.	0.	0.	0.	371773.	1968
20	0.	0.	25295.	153290.	0.	0.	0.	0.	0.	0.	0.	0.	178585.	1969
21	0.	0.	0.	128560.	0.	3732.	0.	0.	0.	0.	0.	0.	132293.	1970
22	0.	0.	0.	93760.	0.	0.	0.	0.	0.	0.	0.	0.	93760.	1971
23	0.	0.	157613.	153290.	95310.	25283.	0.	0.	0.	0.	0.	0.	431496.	1972
24	0.	0.	130615.	153290.	92257.	0.	0.	0.	0.	0.	0.	0.	376162.	1973
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1974
26	0.	0.	0.	0.	5914.	19192.	0.	0.	0.	0.	0.	0.	25107.	1975
27	0.	0.	157613.	153290.	96861.	23036.	0.	0.	0.	0.	0.	0.	430801.	1976
28	0.	0.	0.	135036.	89107.	62023.	0.	0.	0.	0.	0.	0.	286166.	1977
29	0.	151134.	157613.	153290.	139977.	51639.	0.	0.	0.	0.	0.	0.	653654.	1978
30	0.	0.	41236.	153290.	68074.	29126.	0.	0.	0.	0.	0.	0.	291726.	1979
31	0.	0.	72645.	153290.	70933.	89677.	0.	0.	0.	0.	0.	0.	386546.	1980
MEAN	2560.	9751.	49981.	135416.	81279.	10986.	0.	0.	0.	0.	0.	0.	289973.	
MAX	79356.	151134.	157613.	153290.	139977.	89677.	0.	0.	0.	0.	0.	0.	682093.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

ALTERNATIVE E: MCARTHUR SHORT TUNNEL, WITH FISH RELEASES

REMAINING SPILLS IN CFS

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	AVEYR	CALYR
1	0.	4742.	9239.	5629.	308.	0.	0.	0.	0.	0.	0.	0.	1660.	1950
2	0.	0.	0.	4562.	0.	0.	0.	0.	0.	0.	0.	0.	380.	1951
3	0.	0.	0.	2845.	2638.	0.	0.	0.	0.	0.	0.	0.	457.	1952
4	0.	0.	0.	3304.	0.	0.	0.	0.	0.	0.	0.	0.	275.	1953
5	0.	0.	4353.	4822.	0.	0.	0.	0.	0.	0.	0.	0.	765.	1954
6	0.	0.	0.	6060.	78.	0.	0.	0.	0.	0.	0.	0.	512.	1955
7	0.	0.	0.	2959.	0.	0.	0.	0.	0.	0.	0.	0.	247.	1956
8	0.	0.	0.	4249.	0.	0.	0.	0.	0.	0.	0.	0.	354.	1957
9	0.	0.	5151.	4419.	913.	0.	0.	0.	0.	0.	0.	0.	874.	1958
10	0.	0.	0.	2169.	0.	0.	0.	0.	0.	0.	0.	0.	181.	1959
11	0.	0.	0.	4145.	0.	0.	0.	0.	0.	0.	0.	0.	345.	1960
12	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1961
13	0.	0.	0.	3853.	228.	0.	0.	0.	0.	0.	0.	0.	340.	1962
14	0.	0.	0.	2736.	0.	0.	0.	0.	0.	0.	0.	0.	228.	1963
15	0.	0.	0.	1126.	0.	0.	0.	0.	0.	0.	0.	0.	94.	1964
16	0.	0.	0.	2482.	0.	0.	0.	0.	0.	0.	0.	0.	207.	1965
17	0.	0.	0.	0.	4805.	0.	0.	0.	0.	0.	0.	0.	400.	1966
18	0.	0.	0.	0.	611.	0.	0.	0.	0.	0.	0.	0.	51.	1967
19	0.	0.	0.	9709.	194.	0.	0.	0.	0.	0.	0.	0.	825.	1968
20	0.	0.	0.	5271.	0.	0.	0.	0.	0.	0.	0.	0.	439.	1969
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1970
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1971
23	0.	0.	2080.	10694.	0.	0.	0.	0.	0.	0.	0.	0.	1065.	1972
24	0.	0.	0.	3277.	0.	0.	0.	0.	0.	0.	0.	0.	273.	1973
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1974
26	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1975
27	0.	0.	81.	816.	0.	0.	0.	0.	0.	0.	0.	0.	75.	1976
28	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1977
29	0.	3494.	7917.	5238.	62.	0.	0.	0.	0.	0.	0.	0.	1393.	1978
30	0.	0.	0.	1879.	0.	0.	0.	0.	0.	0.	0.	0.	157.	1979
31	0.	0.	0.	3171.	0.	0.	0.	0.	0.	0.	0.	0.	264.	1980
MEAN	0.	266.	930.	3078.	317.	0.	0.	0.	0.	0.	0.	0.	383.	
MAX	0.	4742.	9239.	10694.	4805.	0.	0.	0.	0.	0.	0.	0.	1660.	
MIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	

APPENDIX TO SECTION 8.0

ESTIMATE SUMMARIES

CHAKACHAMNA HYDROELECTRIC PROJECT
CONCEPTUAL ESTIMATE SUMMARIES – SHEET 1 OF 2

ALTERNATIVES	ESTIMATED COSTS IN THOUSANDS OF DOLLARS									
	A		B		C		D		E	
LAND AND LAND RIGHTS	Not included	0	Not included	0	Not included	0	Not included	0	Not included	
POWER PLANT STRUCTURE AND IMPROVEMENTS										
Valve Chamber	5,600		5,500		5,600		5,600		5,500	
Underground Power House	26,200		25,200		26,200		26,200		25,200	
Bus Galleries	200		200		200		200		200	
Transformer Gallery	4,600		4,300		4,300		4,300		4,300	
Valve Chamber and Transformer Gallery – Access Tunnel	400		400		400		400		400	
P. H. Access Tunnel	13,500		13,500		13,500		13,500		13,500	
Cable Way	800		800		800		800		800	
		51,300		49,900		51,000		51,000		49,900
RESERVOIR, DAM AND WATERWAYS										
Reservoir	100		100		100		100		100	
Intake Structure	10,400		9,300		10,400		10,400		9,300	
Intake Gate Shaft	13,200		12,400		13,200		13,200		17,600	
Fish Facilities	–		–		–		–		85,400	
Dike & Spillway	–		–		–		–		9,100	
Access Tunnel										
– At Intake	21,600		19,100		21,600		21,600		0	
– At Surge Chamber, No. 3	6,600		5,900		8,900		8,900		5,900	
– At Mile 3, 5, No. 1	0		0		20,800		20,800		0	
– At Mile 7, 5, No. 2	0		0		14,500		14,500		0	
Power Tunnel	626,800		580,400		712,500		712,500		447,800	
Surge Chamber – Upper	12,900		11,000		12,900		12,900		18,900	
Penstock – Inclined Section	18,000		16,500		15,400		15,400		0	
– Horizontal Section and Elbow	6,700		6,000		6,700		6,700		6,000	
– Wye Branches to Valve Chamber	13,200		11,900		12,100		12,100		11,900	
– Between Valve Chamber & Power House	800		600		800		800		600	
Draft Tube Tunnels	1,900		1,700		1,900		1,900		1,700	
Surge Chamber – Tailrace	2,400		2,400		2,400		2,400		2,400	
Tailrace Tunnel and Structure	10,300		9,600		10,300		10,300		9,600	
Tailrace Channel	900		700		900		900		700	
River Training Works	500		500		500		500		500	
Miscellaneous Mechanical and Electrical	7,100		6,100		5,700		5,700		6,100	
		753,400		694,200		871,600		871,600		633,600

A, B – McArthur development, high level tunnel excavated by drilling and blasting
C, D – Chacackatna valley development excavated by drilling and blasting
E – Mc Arthur development, low level tunnel excavated by boring machine

CHAKACHAMNA HYDROELECTRIC PROJECT
CONCEPTUAL ESTIMATE SUMMARIES – SHEET 2 OF 2

ALTERNATIVES	ESTIMATED COSTS IN THOUSANDS OF DOLLARS				
	A	B	C	D	E
TURBINES AND GENERATORS	67,900	57,900	54,500	54,500	57,900
ACCESSORY ELECTRICAL EQUIPMENT	11,200	9,500	9,000	9,000	9,500
MISCELLANEOUS POWER PLANT EQUIPMENT	8,600	7,300	6,900	6,900	7,300
SWITCHYARD STRUCTURES	3,600	3,600	3,600	3,600	3,600
SWITCHYARD EQUIPMENT	13,800	12,500	12,100	12,100	12,500
COMM. SUPV. CONTROL EQUIPMENT	1,600	1,600	1,600	1,600	1,600
TRANSPORTATION FACILITIES					
Port	4,600	4,600	4,600	4,600	4,600
Airport	2,000	2,000	2,000	2,000	2,000
Access and Construction Roads	59,600	59,600	44,100	44,100	59,600
	66,200	66,200	50,700	50,700	66,200
TRANSMISSION LINE & CABLE CROSSING	63,200	63,200	56,500	56,500	63,200
TOTAL SPECIFIC CONSTRUCTION COST AT JANUARY 1982 PRICE LEVELS	1,040,800	965,900	1,117,500	1,117,500	905,300
ENGINEERING & CONSTRUCTION MANAGEMENT	124,900	115,900	134,100	134,100	108,700
SUBTOTAL	1,165,700	1,081,800	1,251,600	1,251,600	1,014,000
CONTINGENCY @ 20%	233,100	216,400	250,300	250,300	203,000
ESCALATION	Not Incl.	Not Incl.	Not Incl.	Not Incl.	Not Incl.
INTEREST DURING CONST. @ 3% PER ANNUM	111,900	104,100	101,400	101,400	97,400
OWNER'S COSTS	Not Incl.	Not Incl.	Not Incl.	Not Incl.	Not Incl.
ALLOWANCE FOR FISH PASSAGE FACILITIES	–	50,000	–	50,000	Under Reservoir Item
TOTAL PROJECT COST AT JANUARY, 1982 PRICE LEVELS	1,510,700	1,452,300	1,603,300	1,653,300	1,314,400
USE	1,500,000	1,450,000	1,600,000	1,650,000	1,314,000

A, B – McArthur development, high level tunnel excavated by drilling and blasting
C, D – Chacackatna valley development excavated by drilling and blasting
E – Mc Arthur development, low level tunnel excavated by boring machine

ALTERNATIVE A
ESTIMATED COST

ESTIMATE SUMMARY

HAJ/APD
PREPARED BY

MF
CHECKED BY

CONCEPTUAL
TYPE OF ESTIMATE

ALTERNATIVE A

14879-001
JOB NO.

NOV. 1981
DATE

CHAKACHAMNA HYDROELECTRIC PROJECT
PROJECT

ALASKA POWER AUTHORITY
PREPARED FOR

NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	POWER PLANT STRUCTURE & IMPROVEMENTS						
	Valve Chamber						
	Excavation & Supports	10,500	CY	270	2,835,000		
	Concrete & Reinf Steel	6,520	CY	410	2,673,200		
	Struc. Steel & Misc.Metals	52	TON	1,800	93,600		
	Round-Off				(1,800)	5,600,000	
	Underground Powerhouse						
	Dewatering		LS		4,100,000		Entire Underground Complex
	Excavation & Supports	64,000	CY	155	9,920,000		
	Drilling-Percus.& Rotary	15,000	LF	30	450,000		2" - 3"ϕ
	Concrete & Reinf.Steel	14,200	CY	630	8,946,000		
	Struc.Steel & Misc Metals	330	TON	5,300	1,749,000		
	Architectural		LS		1,000,000		
	Round-Off				35,000		
						26,200,000	
	Bus Galleries Between Power-house & Transformer Vaults						
	Excavation & Supports	200	CY	825	165,000		
	Concrete	120	CY	290	34,800		
	Round Off				200		
						200,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Transformer Gallery & Tunnels						
	Excavation & Supports	13,000	CY	280	3,640,000		
	Concrete & Reinf Steel	900	CY	460	414,000		
	Struc Steel & Misc.Metals	130	TON	3,800	494,000		
	Round Off				52,000		
						4,600,000	
	Valve Chamber & Transformer						
	Gallery-Access Tunnels						
	Excavation & Supports	1,500	CY	250	375,000		
	Concrete	60	CY	290	17,400		
	Round-Off				7,600		
						400,000	
	Powerhouse Access Tunnel						
	Portal Excav.& Protection	56,000	CY	10	560,000		
	Portal Conc.& Reinf.Steel	1,000	CY	570	570,000		
	Tunnel Excav.& Supports	24,000	CY	300	7,200,000		
	Tunnel Concrete	900	CY	290	261,000		
	Tunnel Misc. Metals	30	TON	11,000	330,000		
	Subsurface Exploration						
	Mobilization		LS		1,500,000		
	Exploratory Adit	1,000	LF	1,800	1,800,000		
	Core drilling	5,000	LF	140	700,000		
	Helicopter Service		LS		600,000		
	Round-Off				(21,000)		
						13,500,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Cable Way						
	Concrete & Reinf. Steel	1,000	CY	700	700,000		
	Misc. Metals & Cable Sup.	26	TON	5,100	132,600		
	Port Panels						
	Round-Off				(32,600)		
						800,000	
	TOTAL POWER PLANT STRUCTURE & IMPROVEMENTS					51,300,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	RESERVOIR, DAM & WATERWAYS						
	Reservoir						
	Water Level Recording		LS			100,000	
	Intake Structure						
	Site Exploration						
	Mobilization		LS		150,000		
	Core Drilling	5,000	LF	80	400,000		
	Helicopter Service		LS		150,000		
	Tunnel Excav.& Supports	12,000	CY	470	5,640,000		
	Tunnel Conc.& Reinf.Steel	100	CY	350	35,000		
	Lake-Tap (Final Round)		LS		3,000,000		L = 26'
	Place & Remove Temp.Conc	600	CY	700	420,000		
	Diving Crew	60	DAYS	10,000	600,000		
	Round-Off				5,000		
						10,400,000	
	Intake Gate Shaft						
	Shaft Excav.& Supports	10,000	CY	360	3,600,000		
	Mass Surface Excav.	50,000	CY	30	1,500,000		
	Concrete & Reinf. Steel	5,700	CY	890	5,073,000		
	Misc. Metals,Gates & Hoist	244	TON	12,500	3,050,000		
	Round-Off				(23,000)		
						13,200,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access Tunnel at Intake						
	Portal Excav. & Protection	6,000	CY	50	300,000		
	Tunnel Excav.& Supports	72,000	CY	295	21,240,000		
	Tunnel Conc. & Reinf.Steel	200	CY	500	100,000		
	Round-Off				(40,000)		
						21,600,000	
	Access Tunnel at Surge Chamber						
	Portal Excav. & Protection	6,000	CY	35	210,000		
	Tunnel Excav.& Supports	17,000	CY	295	5,015,000		
	Tunnel Conc. & Reinf.Steel	2,000	CY	420	840,000		
	Grouting Contact & Pressure	2,500	CF	58	145,000		
	Waterright Bulkhead & Frame	27	TON	13,800	372,600		
	Round-Off				17,400	6,600,000	
	Power Tunnel						
	Excavation & Supports	53,400	LF	8,800	469,920,000		
	Concrete	410,000	CY	334	136,940,000		
	Grouting Contact & Pressure	370,000	CF	54	19,980,000		
	Round-Off				(40,000)		
						626,800,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Surge Chamber - Upper						
	Excavation & Supports	35,500	CY	200	7,100,000		
	Concrete & Reinf.Steel	6,100	CY	880	5,368,000		
	Earthworks & Fencing	15,000	CY	27	405,000		Heliport, Storage, Work Area
	Round-Off				27,000		
						12,900,000	
	Penstock-Inclined Section						
	Excavation & Supports	27,000	CY	280	7,560,000		
	Concrete & Reinf. Steel	12,000	CY	845	10,140,000		
	Grouting Contact & Pressure	6,200	CF	52	322,400		
	Round-Off				(22,400)		
						18,000,000	
	Penstock-Horizontal Section & Elbow						
	Excavation & Supports	14,000	CY	310	4,340,000		
	Concrete $ Reinf. Steel	6,000	CY	365	2,190,000		
	Grouting - Contact	3,000	CF	50	150,000		
	Round-Off				20,000		
						6,700,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Penstock-Wye Branches to Valve Chamber						
	Excavation & Supports	10,000	CY	440	4,400,000		
	Concrete & Reinf. Steel	7,200	CY	608	4,377,600		
	Steel Liner	850	TON	5,000	4,250,000		
	Grouting-Contact	3,000	CY	50	150,000		
	Round-Off				22,400		
						13,200,000	
	Penstock Between Valve Chamber & Powerhouse						
	Excavation & Supports	1,000	CY	440	440,000		
	Concrete & Backfill	600	CY	550	330,000		
	Round-Off				30,000		
						800,000	
	Draft Tube Tunnels						
	Rock Bolts & Grout	19,000	LF	27	513,000		
	Concrete & Reinf. Steel	3,300	CY	425	1,402,500		
	Round-Off				(15,500)		
						1,900,000	
	Surge Chamber - Tailrace						
	Excavation & Supports	5,000	CY	480		2,400,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Tailrace Tunnel & Structures						
	Cofferdam & Dewatering		LS		2,000,000		
	Portal Excav. & Protection	2,000	CY	65	130,000		
	Concrete & Reinf. Steel	1,200	CY	600	720,000		
	Walkway Bridge		LS		65,000		
	Stoplogs & Hoists	81	TON	8,500	688,500		
	Tunnel Excav. & Supports	25,000	CY	260	6,500,000		
	Plug Excavation	4,000	CY	50	200,000		
	Round-Off				(3,500)		
						10,300,000	
	Tailrace Channel						
	Channel Excavation	100,000	CY	9		900,000	
	River Training Works						
	River Bed Deepening	50,000	CY	10		500,000	
	Mech & Elec.		LS			7,100,000	
	TOTAL RESERVOIR, DAM AND WATERWAYS					753,400,000	

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	Turbines & Generators						
	Turbines	4	EA	9,930,000	39,720,000		
	Generators	4	EA	7,050,000	28,200,000		
	Round-Off				(20,000)		
						67,900,000	
	Accessory Electrical Equipment						
	Equipment		LS			11,200,000	
	Misc. Power Plant Equipment						
	Crane Bridge	1	EA		1,100,000		
	Other Power Plant Equip.		LS		7,500,000		
						8,600,000	
	Switchyard Structures						
	Earthworks	15,000	CY	25	375,000		
	Concrete & Reinf. Steel	3,800	CY	640	2,432,000		
	Struc. Steel & Misc.Metals	225	TON	3,500	787,500		
	Round-Off				5,500		
						3,600,000	

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	Switchyard Equipment						
	Transformers 105 MVA	5	EA	1,152,000	5,760,000		
	Unit & Line Breakers	7	EA	206,000	1,442,000		
	Switches & Lightn.Arrestors	30	EA	37,000	1,110,000		
	230 KV Cables	18,000	LF	140	2,520,000		
	Controls & Metr'g Equip.		LS		3,000,000		
	Round Off				(32,000)		
						13,800,000	
	Communication and Supv. Control Equip.		LS			1,600,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	TRANSPORTATION FACILITIES						
	Port Facilities						
	Causeway	19,600	CY	80	1,568,000		
	Trestle Piles	50	TON	11,300	565,000		L = 150 LF, ϕ12", t = ½"
	Trestle Struct. Steel	110	TON	3,500	385,000		
	Trestle Reinf. Conc.	150	CY	700	105,000		
	Facilities - Allowance		LS		2,000,000		
	Round-Off				(23,000)		
						4,600,000	
	Airport						
	Earthwork	54,500	CY	16	872,000		
	Culverts	1,000	LF	65	65,000		
	Subbase & Base	55,000	CY	14	770,000		
	Building - Allowance		LS		300,000		
	Round-Off				(7,000)		
						2,000,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access & Construction Roads						
	Mile 0+00 to 18+00						
	Earthwork	175,000	CY	6.60	1,155,000		
	Culverts	1,500	LF	65	97,500		36"ϕ CMP
	Bridges	1,400	SF	150	210,000		
	Subbase & Base	85,400	CY	15	1,281,000		
	Guard Rail	1,200	LF	25	30,000		
	Repair Existing Road	95,000	LF	10	950,000		
	Snow Fences	5,000	LF	35	175,000		
	Round-Off				1,500		
						3,900,000	
	Mile 18+00 to 35+00						
	Earthworks	1,465,000	CY	6.60	9,669,000		
	Culverts	3,600	LF	80	288,000		48"ϕ CMP
	Subbase & Base	165,000	CY	15	2,475,000		
	Guard Rail	13,000	LF	25	325,000		
	Repair Existing Road	16,000	LF	10	160,000		
	Snow Fences	1,000	LF	35	35,000		
	Round-Off				48,000		
						13,000,000	
	Mile 35+00 to 39+00						
	Earthwork	445,000	CY	8.30	3,693,500		
	Culverts	1,000	LF	80	80,000		48"ϕ CMP
	Bridge	9,000	SF	150	1,350,000		
	Subbase & Base	38,000	CY	15	570,000		
	Guard Rail	10,000	LF	27	270,000		
	Snow Fences	2,000	LF	35	70,000		
	Round-Off				(33,500)		
						6,000,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Walkway To Gate Shaft						
	Earthwork	1,200	CY	20	24,000		
	Guard Rail	1,000	LF	25	25,000		
	Bridge	200	SF	150	30,000		
	Riprap	100	CY	35	3,500		
	Round-Off				17,500		
						100,000	
	Access Road to MacArthur Valley						
	Earthwork	545,000	CY	7	3,815,000		
	Culverts	2,400	LF	75	180,000		36"ø and 48"ø CMP
	Bridge Improvements	9,000	SF	70	630,000		
	Subbase & Base	105,000	CY	15	1,575,000		
	Guard Rail	6,000	LF	25	150,000		
	Snow Fences	3,000	LF	35	105,000		
	Round-Off				45,000		
						6,500,000	
	Access Road to Tailrace Tunnel						
	Earthwork	56,000	CY	8	448,000		
	Culverts	100	LF	80	8,000		48"ø CMP
	Subbase & Base	2,500	CY	20	50,000		
	Guard Rail	600	LF	25	15,000		
	Round-Off				(21,000)		
						500,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access Road to Downstream Power Tunnel						
	Earthwork	215,000	CY	9.80	2,107,000		
	Culverts	800	LF	80	64,000		48"ϕ CMP
	Bridge	3,000	SF	150	450,000		
	Subbase & Base	10,000	CY	21	210,000		
	Guardrail	9,000	LF	32	288,000		
	Snowshed & Slide Fall	1,000	LF	800	800,000		
	Round-Off				(19,000)		
						3,900,000	
	Temporary Construction Roads						
	Earthwork	61,000	CY	6	366,000		
	Culverts	600	LF	80	48,000		48"ϕ CMP
	Bridge	3,000	SF	150	450,000		
	Guardrail	2,000	LF	25	50,000		
	Round-Off				(14,000)		
						900,000	
	Road Maintenance						
	Summer Season	45	MO	150,000	6,750,000		
	Winter Season	30	MO	600,000	18,000,000		
	Round-Off				50,000		
						24,800,000	
	TOTAL ACCESS & CONSTRUCTION ROADS					59,600,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Transmission Line						
	Clear & Grub	82	MI	225,000	18,450,000		
	Transmission Line	82	MI	343,000	28,126,000		
	Submarine Cable	21	MI	792,000	16,632,000		
	Round-Off				(8,000)		
						63,200,000	
	TOTAL SPECIFIC CONSTRUCTION COST						
	AT JANUARY 1982 PRICE LEVELS					1,040,800,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	POWER PLANT STRUCTURE & IMPROVEMENTS						
	Valve Chamber						
	Excavation & Supports	10,000	CY	275	2,750,000		
	Concrete & Reinf Steel	6,520	CY	410	2,673,200		
	Struc. Steel & Misc.Metals	52	TON	1,800	93,600		
	Round-Off				(16,800)		
						5,500,000	
	Underground Powerhouse						
	Dewatering		LS		4,100,000		Entire Underground Complex
	Excavation & Supports	58,900	CY	168	9,895,200		
	Drilling-Percus.& Rotary	12,700	LF	27	342,900		2" - 3"ϕ
	Concrete & Reinf.Steel	13,100	CY	630	8,253,000		
	Struc.Steel & Misc Metals	300	TON	5,300	1,590,000		
	Architectural		LS		1,000,000		
	Round-Off				18,900		
						25,200,000	
	Bus Galleries Between Power-house & Transformer Vaults						
	Excavation & Supports	200	CY	825	165,000		
	Concrete	120	CY	290	34,800		
	Round Off				200		
						200,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Transformer Gallery & Tunnels						
	Excavation & Supports	11,960	CY	290	3,468,400		
	Concrete & Reinf Steel	830	CY	460	381,800		
	Struc Steel & Misc.Metals	120	TON	3,800	456,000		
	Round Off				(6,200)		
						4,300,000	
	Valve Chamber & Transformer						
	Gallery-Access Tunnels						
	Excavation & Supports	1,500	CY	250	375,000		
	Concrete	60	CY	290	17,400		
	Round-Off				7,600		
						400,000	
	Powerhouse Access Tunnel						
	Portal Excav.& Protection	56,000	CY	10	560,000		
	Portal Conc.& Reinf.Steel	1,000	CY	570	570,000		
	Tunnel Excav.& Supports	24,000	CY	300	7,200,000		
	Tunnel Concrete	900	CY	290	261,000		
	Tunnel Misc. Metals	30	TON	11,000	330,000		
	Subsurface Exploration						
	Mobilization		LS		1,500,000		
	Exploratory Adit	1,000	LF	1,800	1,800,000		
	Core drilling	5,000	LF	140	700,000		
	Helicopter Service		LS		600,000		
	Round-Off				(21,000)		
						13,500,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Cable Way						
	Concrete & Reinf. Steel	1,000	CY	700	700,000		
	Misc. Metals & Cable Sup.	26	TON	5,100	132,600		
	Port Panels						
	Round-Off				(32,600)		
						800,000	
	TOTAL POWER PLANT STRUCTURE & IMPROVEMENTS					49,900,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	RESERVOIR, DAM & WATERWAYS						
	Reservoir						
	Water Level Recording		LS			100,000	
	Intake Structure						
	Site Exploration						
	Mobilization		LS		150,000		
	Core Drilling	5,000	LF	80	400,000		
	Helicopter Service		LS		150,000		
	Tunnel Excav.& Supports	10,000	CY	510	5,100,000		
	Tunnel Conc.& Reinf.Steel	90	CY	350	31,500		
	Lake-Tap (Final Round)		LS		2,500,000		L = 26'
	Place & Remove Temp.Conc	550	CY	700	385,000		
	Diving Crew	60	DAYS	10,000	600,000		
	Round-Off				(16,500)		
						9,300,000	
	Intake Gate Shaft						
	Shaft Excav.& Supports	10,000	CY	360	3,600,000		
	Mass Surface Excav.	50,000	CY	30	1,500,000		
	Concrete & Reinf. Steel	5,200	CY	890	4,628,000		
	Misc. Metals,Gates & Hoist	220	TON	12,200	2,684,000		
	Round-Off				(12,000)		
						12,400,000	

ESTIMATE SUMMARY

HAJ/APD
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MF
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CONCEPTUAL
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ALTERNATIVE B

CHAKACHAMNA HYDROELECTRIC PROJECT
PROJECT

ALASKA POWER AUTHORITY
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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access Tunnel at Intake						
	Portal Excav. & Protection	6,000	CY	50	300,000		
	Tunnel Excav.& Supports	60,000	CY	312	18,720,000		
	Tunnel Conc. & Reinf.Steel	170	CY	500	85,000		
	Round-Off				(5,000)		
						19,100,000	
	Access Tunnel at Surge Chamber						
	Portal Excav. & Protection	6,000	CY	35	210,000		
	Tunnel Excav.& Supports	14,000	CY	317	4,438,000		
	Tunnel Conc. & Reinf.Steel	1,700	CY	420	714,000		
	Grouting Contact & Pressure	2,260	CF	58	131,080		
	Wateright Bulkhead & Frame	27	TON	13,800	372,600		
	Round-Off				34,320		
						5,900,000	
	Power Tunnel						
	Excavation & Supports	53,400	LF	8,372	447,064,800		
	Concrete	348,000	CY	334	116,232,000		
	Grouting Contact & Pressure	317,000	CF	54	17,118,000		
	Round-Off				(14,800)		
						580,400,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Surge Chamber - Upper						
	Excavation & Supports	25,500	CY	227	5,788,500		
	Concrete & Reinf.Steel	5,500	CY	880	4,840,000		
	Earthworks & Fencing	15,000	CY	27	405,000		Heilport, Storage, Work Area
	Round-Off				(33,500)		
						11,000,000	
	Penstock-Inclined Section						
	Excavation & Supports	24,000	CY	306	7,344,000		
	Concrete & Reinf. Steel	10,500	CY	845	8,872,500		
	Grouting Contact & Pressure	5,500	CF	52	286,000		
	Round-Off				(2,500)		
						16,500,000	
	Penstock-Horizontal Section & Elbow						
	Excavation & Supports	12,000	CY	334	4,008,000		
	Concrete $ Reinf. Steel	5,100	CY	365	1,861,500		
	Grouting - Contact	2,600	CF	50	130,000		
	Round-Off				500		
						6,000,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Penstock-Wye Branches to Valve Chamber						
	Excavation & Supports	9,000	CY	480	4,320,000		
	Concrete & Reinf. Steel	6,100	CY	608	3,708,800		
	Steel Liner	700	TON	5,000	3,500,000		
	Grouting-Contact	7,000	CY	56	392,000		
	Round-Off				(20,800)		
						11,900,000	
	Penstock Between Valve Chamber & Powerhouse						
	Excavation & Supports	850	CY	440	374,000		
	Concrete & Backfill	500	CY	550	275,000		
	Round-Off				(49,000)		
						600,000	
	Draft Tube Tunnels						
	Rock Bolts & Grout	15,000	LF	29	435,000		
	Concrete & Reinf. Steel	2,975	CY	425	1,264,375		
	Round-Off				625		
						1,700,000	
	Surge Chamber - Tailrace						
	Excavation & Supports	5,000	CY	480		2,400,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Tailrace Tunnel & Structures						
	Cofferdam & Dewatering		LS		2,000,000		
	Portal Excav. & Protection	2,000	CY	65	130,000		
	Concrete & Reinf. Steel	1,200	CY	600	720,000		
	Walkway Bridge		LS		65,000		
	Stoplogs & Hoists	81	TON	8,500	688,500		
	Tunnel Excav. & Supports	20,000	CY	290	5,800,000		
	Plug Excavation	4,000	CY	50	200,000		
	Round-Off				(3,500)		
						9,600,000	
	Tailrace Channel						
	Channel Excavation	80,000	CY	9	720,000		
					(20,000)		
						700,000	
	River Training Works						
	River Bed Deepening	50,000	CY	10		500,000	
	Mech & Elec.		LS			6,100,000	
	TOTAL RESERVOIR, DAM AND WATERWAYS					694,200,000	

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CHAKACHAMNA HYDROELECTRIC PROJECT — PROJECT

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Turbines & Generators						330 MW
	Turbines	4	EA	8,480,000	33,920,000		
	Generators	4	EA	6,000,000	24,000,000		
	Round-Off				(20,000)		
						57,900,000	
	Accessory Electrical Equipment						
	Equipment		LS			9,500,000	
	Misc. Power Plant Equipment						
	Crane Bridge	1	EA		930,000		
	Other Power Plant Equip.		LS		6,370,000	7,300,000	
	Switchyard Structures						
	Earthworks	15,000	CY	25	375,000		
	Concrete & Reinf. Steel	3,800	CY	640	2,432,000		
	Struc. Steel & Misc.Metals	225	TON	3,500	787,500		
	Round-Off				5,500		
						3,600,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Switchyard Equipment						
	Transformers 105 MVA	5	EA	1,030,000	5,150,000		
	Unit & Line Breakers	7	EA	185,000	1,295,000		
	Switches & Lightn.Arrestors	30	EA	34,000	1,020,000		
	230 KV Cables	18,000	LF	130	2,340,000		
	Controls & Metr'g Equip.		LS		2,700,000		
	Round Off				(5,000)		
						12,500,000	
	Communication and Supv						
	Control Equip.		LS			1,600,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	TRANSPORTATION FACILITIES						
	Port Facilities						
	Causeway	19,600	CY	80	1,568,000		
	Trestle Piles	50	TON	11,300	565,000		L = 150 LF, ϕ12", t = ½"
	Trestle Struct. Steel	110	TON	3,500	385,000		
	Trestle Reinf. Conc.	150	CY	700	105,000		
	Facilities - Allowance		LS		2,000,000		
	Round-Off				(23,000)		
						4,600,00	
	Airport						
	Earthwork	54,500	CY	16	872,000		
	Culverts	1,000	LF	65	65,000		
	Subbase & Base	55,000	CY	14	770,000		
	Building - Allowance		LS		300,000		
	Round-Off				(7,000)		
						2,000,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access & Construction Roads						
	Mile 0+00 to 18+00						
	Earthwork	175,000	CY	6.60	1,155,000		
	Culverts	1,500	LF	65	97,500		36"ϕ CMP
	Bridges	1,400	SF	150	210,000		
	Subbase & Base	85,400	CY	15	1,281,000		
	Guard Rail	1,200	LF	25	30,000		
	Repair Existing Road	95,000	LF	10	950,000		
	Snow Fences	5,000	LF	35	175,000		
	Round-Off				1,500		
						3,900,000	
	Mile 18+00 to 35+00						
	Earthworks	1,465,000	CY	6.60	9,669,000		
	Culverts	3,600	LF	80	288,000		48"ϕ CMP
	Subbase & Base	165,000	CY	15	2,475,000		
	Guard Rail	13,000	LF	25	325,000		
	Repair Existing Road	16,000	LF	10	160,000		
	Snow Fences	1,000	LF	35	35,000		
	Round-Off				48,000		
						13,000,000	
	Mile 35+00 to 39+00						
	Earthwork	445,000	CY	8.30	3,693,500		
	Culverts	1,000	LF	80	80,000		48"ϕ CMP
	Bridge	9,000	SF	150	1,350,000		
	Subbase & Base	38,000	CY	15	570,000		
	Guard Rail	10,000	LF	27	270,000		
	Snow Fences	2,000	LF	35	70,000		
	Round-Off				(33,500)		
						6,000,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Walkway To Gate Shaft						
	Earthwork	1,200	CY	20	24,000		
	Guard Rail	1,000	LF	25	25,000		
	Bridge	200	SF	150	30,000		
	Riprap	100	CY	35	3,500		
	Round-Off				17,500		
						100,000	
	Access Road to MacArthur Valley						
	Earthwork	545,000	CY	7	3,815,000		
	Culverts	2,400	LF	75	180,000		36"ϕ and 48"ϕ CMP
	Bridge Improvements	9,000	SF	70	630,000		
	Subbase & Base	105,000	CY	15	1,575,000		
	Guard Rail	6,000	LF	25	150,000		
	Snow Fences	3,000	LF	35	105,000		
	Round-Off				45,000		
						6,500,000	
	Access Road to Tailrace Tunnel						
	Earthwork	56,000	CY	8	448,000		
	Culverts	100	LF	80	8,000		48"ϕ CMP
	Subbase & Base	2,500	CY	20	50,000		
	Guard Rail	600	LF	25	15,000		
	Round-Off				(21,000)		
						500,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access Road to Downstream Power Tunnel						
	Earthwork	215,000	CY	9.80	2,107,000		
	Culverts	800	LF	80	64,000		48"ϕ CMP
	Bridge	3,000	SF	150	450,000		
	Subbase & Base	10,000	CY	21	210,000		
	Guardrail	9,000	LF	32	288,000		
	Snowshed & Slide Fall	1,000	LF	800	800,000		
	Round-Off				(19,000)		
						3,900,000	
	Temporary Construction Roads						
	Earthwork	61,000	CY	6	366,000		
	Culverts	600	LF	80	48,000		48"ϕ CMP
	Bridge	3,000	SF	150	450,000		
	Guardrail	2,000	LF	25	50,000		
	Round-Off				(14,000)		
						900,000	
	Road Maintenance						
	Summer Season	45	MO	150,000	6,750,000		
	Winter Season	30	MO	600,000	18,000,000		
	Round-Off				50,000		
						24,800,000	
	TOTAL ACCESS & CONSTRUCTION ROADS					59,600,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Transmission Line						
	Clear & Grub	82	MI	225,000	18,450,000		
	Transmission Line	82	MI	343,000	28,126,000		
	Submarine Cable	21	MI	792,000	16,632,000		
	Round-Off				(8,000)		
						63,200,000	
	TOTAL SPECIFIC CONSTRUCTION						
	COST AT JANUARY 1982 PRICE						
	LEVELS					965,900,000	

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ESTIMATED COST

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	POWER PLANT STRUCTURE & IMPROVEMENTS						
	Valve Chamber						
	Excavation & Supports	10,500	CY	270	2,835,000		
	Concrete & Reinf Steel	6,520	CY	410	2,673,200		
	Struc. Steel & Misc.Metals	52	TON	1,800	93,600		
	Round-Off				(1,800)		
						5,600,000	
	Underground Powerhouse						
	Dewatering		LS		4,100,000		Entire Underground Complex
	Excavation & Supports	64,000	CY	155	9,920,000		
	Drilling-Percus.& Rotary	15,000	LF	30	450,000		2" - 3"ϕ
	Concrete & Reinf.Steel	14,200	CY	630	8,946,000		
	Struc.Steel & Misc Metals	330	TON	5,300	1,749,000		
	Architectural		LS		1,000,000		
	Round-Off				35,000		
						26,200,000	
	Bus Galleries Between Power-house & Transformer Vaults						
	Excavation & Supports	200	CY	825	165,000		
	Concrete	120	CY	290	34,800		
	Round Off				200		
						200,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Transformer Gallery & Tunnels						
	Excavation & Supports	11,960	CY	290	3,468,400		
	Concrete & Reinf Steel	830	CY	460	381,800		
	Struc Steel & Misc.Metals	120	TON	3,800	456,000		
	Round Off				(6,200)		
						4,300,000	
	Valve Chamber & Transformer Gallery-Access Tunnels						
	Excavation & Supports	1,500	CY	250	375,000		
	Concrete	60	CY	290	17,400		
	Round-Off				7,600		
						400,000	
	Powerhouse Access Tunnel						
	Portal Excav.& Protection	56,000	CY	10	560,000		
	Portal Conc.& Reinf.Steel	1,000	CY	570	570,000		
	Tunnel Excav.& Supports	24,000	CY	300	7,200,000		
	Tunnel Concrete	900	CY	290	261,000		
	Tunnel Misc. Metals	30	TON	11,000	330,000		
	Subsurface Exploration						
	Mobilization		LS		1,500,000		
	Exploratory Adit	1,000	LF	1,800	1,800,000		
	Core drilling	5,000	LF	140	700,000		
	Helicopter Service		LS		600,000		
	Round-Off				(21,000)		
						13,500,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Cable Way						
	Concrete & Reinf. Steel	1,000	CY	700	700,000		
	Misc. Metals & Cable Sup.	26	TON	5,100	132,600		
	Port Panels						
	Round-Off				(32,600)		
						800,000	
	TOTAL POWER PLANT STRUCTURE & IMPROVEMENTS					51,000,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	RESERVOIR, DAM & WATERWAYS						
	Reservoir						
	Water Level Recording		LS			100,000	
	Intake Structure						
	Site Exploration						
	Mobilization		LS		150,000		
	Core Drilling	5,000	LF	80	400,000		
	Helicopter Service		LS		150,000		
	Tunnel Excav.& Supports	12,000	CY	470	5,640,000		
	Tunnel Conc.& Reinf.Steel	100	CY	350	35,000		
	Lake-Tap (Final Round)		LS		3,000,000		L = 26'
	Place & Remove Temp.Conc	600	CY	700	420,000		
	Diving Crew	60	DAYS	10,000	600,000		
	Round-Off				5,000		
						10,400,000	
	Intake Gate Shaft						
	Shaft Excav.& Supports	10,000	CY	360	3,600,000		
	Mass Surface Excav.	50,000	CY	30	1,500,000		
	Concrete & Reinf. Steel	5,700	CY	890	5,073,000		
	Misc. Metals,Gates & Hoist	244	TON	12,500	3,050,000		
	Round-Off				(23,000)		
						13,200,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access Tunnel at Intake						
	Portal Excav. & Protection	6,000	CY	50	300,000		
	Tunnel Excav.& Supports	72,000	CY	295	21,240,000		
	Tunnel Conc. & Reinf.Steel	200	CY	500	100,000		
	Round-Off				(40,000)		
						21,600,000	
	Access Tunnel at Surge Chamber						
	Portal Excav. & Protection	6,000	CY	55	330,000		
	Tunnel Excav.& Supports	23,000	CY	323	7,429,000		
	Tunnel Conc. & Reinf.Steel	2,300	CY	420	966,000		
	Grouting Contact & Pressure	3,400	CF	58	197,200		
	Round-Off				(22,200)		
						8,900,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access Tunnel at Mile 3.5 No.1						
	Portal Excav & Protection	6,000	CY	53	318,000		
	Tunnel Excav & Supports	68,000	CY	297	20,196,000		
	Tunnel Conc & Reinf Steel	500	CY	430	215,000		
	Grouting-Contact & Pressure	1,125	CF	58	65,250		
	Round-Off				5,750		
						20,800,000	
	Access Tunnel at Mile 7.5 No.2						
	Portal Excav & Protection	6,000	CY	54	324,000		
	Tunnel Excav & Supports	45,000	CY	298	13,410,000		
	Tunnel Conc & Reinf Steel	1,600	CY	420	672,000		
	Grouting-Contact & Pressure	2,300	CF	58	133,400		
	Round-Off				(39,400)		
						14,500,000	
	Power Tunnel						
	Excavation & Supports	67,000	LF	7,698	515,766,000		
	Concrete	514,000	CY	334	171,676,000		
	Grouting-Contact & Pressure	464,000	CF	54	25,056,000		
	Round-Off				2,000		
						712,500,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Surge Chamber - Upper						
	Excavation & Supports	35,500	CY	200	7,100,000		
	Concrete & Reinf.Steel	6,100	CY	880	5,368,000		
	Earthworks & Fencing	15,000	CY	27	405,000		Heliport, Storage, Work Area
	Round-Off				27,000		
						12,900,000	
	Penstock-Inclined Section						
	Excavation & Supports	23,400	CY	271	6,341,400		
	Concrete & Reinf. Steel	10,500	CY	837	8,788,500		
	Grouting Contact & Pressure	5,000	CF	52	260,000		
	Round-Off				10,100		
						15,400,000	
	Penstock-Horizontal Section & Elbow						
	Excavation & Supports	14,000	CY	310	4,340,000		
	Concrete $ Reinf. Steel	6,000	CY	365	2,190,000		
	Grouting - Contact	3,000	CF	50	150,000		
	Round-Off				20,000		
						6,700,000	

ESTIMATE SUMMARY

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ALASKA POWER AUTHORITY
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SHEET 8 OF 16

NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Penstock-Wye Branches to Valve Chamber						
	Excavation & Supports	10,000	CY	432	4,320,000		
	Concrete & Reinf. Steel	7,200	CY	608	4,377,600		
	Steel Liner	650	TON	5,000	3,250,000		
	Grouting-Contact	3,000	CY	50	150,000		
	Round-Off				2,400		
						12,100,000	
	Penstock Between Valve Chamber & Powerhouse						
	Excavation & Supports	1,000	CY	440	440,000		
	Concrete & Backfill	600	CY	550	330,000		
	Round-Off				30,000		
						800,000	
	Draft Tube Tunnels						
	Rock Bolts & Grout	19,000	LF	27	513,000		
	Concrete & Reinf. Steel	3,300	CY	425	1,402,500		
	Round-Off				(15,500)		
						1,900,000	
	Surge Chamber - Tailrace						
	Excavation & Supports	5,000	CY	480		2,400,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Tailrace Tunnel & Structures						
	Cofferdam & Dewatering		LS		2,000,000		
	Portal Excav. & Protection	2,000	CY	65	130,000		
	Concrete & Reinf. Steel	1,200	CY	600	720,000		
	Walkway Bridge		LS		65,000		
	Stoplogs & Hoists	81	TON	8,500	688,500		
	Tunnel Excav. & Supports	25,000	CY	260	6,500,000		
	Plug Excavation	4,000	CY	50	200,000		
	Round-Off				(3,500)		
						10,300,000	
	Tailrace Channel						
	Channel Excavation	100,000	CY	9		900,000	
	River Training Works						
	River Bed Deepening	50,000	CY	10		500,000	
	Mech & Elec.		LS			5,700,000	
	TOTAL RESERVOIR, DAM AND WATERWAYS					871,600,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Turbines & Generators						300 MW
	Turbines	4	EA	7,970,000	31,880,000		
	Generators	4	EA	5,660,000	22,640,000		
	Round-Off				(20,000)		
						54,500,000	
	Accessory Electrical Equipment						
	Equipment		LS			9,000,000	
	Misc. Power Plant Equipment						
	Crane Bridge	1	EA		900,000		
	Other Power Plant Equip.		LS		6,000,000		
						6,900,000	
	Switchyard Structures						
	Earthworks	15,000	CY	25	375,000		
	Concrete & Reinf. Steel	3,800	CY	640	2,432,000		
	Struc. Steel & Misc.Metals	225	TON	3,500	787,500		
	Round-Off				5,500		
						3,600,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Switchyard Equipment						
	Transformers 105 MVA	5	EA	1,010,000	5,050,000		
	Unit & Line Breakers	7	EA	180,000	1,260,000		
	Switches & Lightn.Arrestors	30	EA	33,000	990,000		
	230 KV Cables	18,000	LF	120	2,160,000		
	Controls & Metr'g Equip.		LS		2,630,000		
	Round Off				10,000		
						12,100,000	
	Comm. Supv. Control Equip.		LS			1,600,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	TRANSPORTATION FACILITIES						
	Port Facilities						
	Causeway	19,600	CY	80	1,568,000		
	Trestle Piles	50	TON	11,300	565,000		L = 150 LF, ø12", t = ½"
	Trestle Struct. Steel	110	TON	3,500	385,000		
	Trestle Reinf. Conc.	150	CY	700	105,000		
	Facilities - Allowance		LS		2,000,000		
	Round-Off				(23,000)		
						4,600,000	
	Airport						
	Earthwork	54,500	CY	16	872,000		
	Culverts	1,000	LF	65	65,000		
	Subbase & Base	55,000	CY	14	770,000		
	Building - Allowance		LS		300,000		
	Round-Off				(7,000)		
						2,000,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access & Construction Roads						
	Mile 0+00 to 18+00						
	Earthwork	175,000	CY	6.60	1,155,000		
	Culverts	1,500	LF	65	97,500		
	Bridges	1,400	SF	150	210,000		
	Subbase & Base	85,400	CY	15	1,281,000		
	Guard Rail	1,200	LF	25	30,000		
	Repair Existing Road	95,000	LF	10	950,000		
	Snow Fences	5,000	LF	35	175,000		
	Round-Off				1,500	3,900,000	
	Mile 18+00 to 35+00						
	Earthworks	1,465,000	CY	6.60	9,669,000		
	Culverts	3,600	LF	80	288,000		48"ϕ CMP
	Subbase & Base	165,000	CY	15	2,475,000		
	Guard Rail	13,000	LF	25	325,000		
	Repair Existing Road	16,000	LF	10	160,000		
	Snow Fences	1,000	LF	35	35,000		
	Round-Off				48,000		
						13,000,000	
	Mile 35+00 to 39+00						
	Earthwork	445,000	CY	8.30	3,693,500		
	Culverts	1,000	LF	80	80,000		48"ϕ CMP
	Bridge	9,000	SF	150	1,350,000		
	Subbase & Base	38,000	CY	15	570,000		
	Guard Rail	10,000	LF	27	270,000		
	Snow Fences	2,000	LF	35	70,000		
	Round-Off				(33,500)		
						6,000,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Walkway To Gate Shaft						
	Earthwork	1,200	CY	20	24,000		
	Guard Rail	1,000	LF	25	25,000		
	Bridge	200	SF	150	30,000		
	Riprap	100	CY	35	3,500		
	Round-Off				17,500		
						100,000	
	Access Road to Tailrace Tunnel						
	Earthwork	56,000	CY	8	448,000		
	Culverts	100	LF	80	8,000		48"ϕ CMP
	Subbase & Base	2,500	CY	20	50,000		
	Guard Rail	600	LF	25	15,000		
	Round-Off				(21,000)		
						500,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access Road to Downstream Power Tunnel						
	Earthwork	215,000	CY	9.80	2,107,000		
	Culverts	800	LF	80	64,000		48"ø CMP
	Bridge	3,000	SF	150	450,000		
	Subbase & Base	10,000	CY	21	210,000		
	Guardrail	9,000	LF	32	288,000		
	Snowshed & Slide Fall	1,000	LF	800	800,000		
	Round-Off				(19,000)		
						3,900,000	
	Temporary Construction Roads						
	Earthwork	61,000	CY	6	366,000		
	Culverts	600	LF	80	48,000		
	Bridge	3,000	SF	150	450,000		
	Guardrail	2,000	LF	25	50,000		
	Round-Off				(14,000)		
						900,000	
	Road Maintenance						
	Summer Season	36	MO	120,000	4,320,000		
	Winter Season	24	MO	480,000	11,520,000		
	Round-Off				(40,000)		
						15,800,000	
	TOTAL ACCESS & CONSTRUCTION ROADS					44,100,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Transmission Line						
	Clear & Grub	70	MI	225,000	15,750,000		
	Transmission Line	70	MI	344,000	24,080,000		
	Submarine Cable	21	MI	792,000	16,632,000		
	Round-Off				38,000		
						56,500,000	
	TOTAL SPECIFIC CONSTRUCTION COST						
	AT JANUARY 1982 PRICE LEVELS					1,117,500,000	

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CHAKACHAMNA HYDROELECTRIC PROJECT — PROJECT

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	POWER PLANT STRUCTURE & IMPROVEMENTS						
	Valve Chamber						
	Excavation & Supports	10,500	CY	270	2,835,000		
	Concrete & Reinf Steel	6,520	CY	410	2,673,200		
	Struc. Steel & Misc.Metals	52	TON	1,800	93,600		
	Round-Off				(1,800)		
						5,600,000	
	Underground Powerhouse						
	Dewatering		LS		4,100,000		Entire Underground Complex
	Excavation & Supports	64,000	CY	155	9,920,000		
	Drilling-Percus.& Rotary	15,000	LF	30	450,000		2" - 3"ø
	Concrete & Reinf.Steel	14,200	CY	630	8,946,000		
	Struc.Steel & Misc Metals	330	TON	5,300	1,749,000		
	Architectural		LS		1,000,000		
	Round-Off				35,000		
						26,200,000	
	Bus Galleries Between Power-house & Transformer Vaults						
	Excavation & Supports	200	CY	825	165,000		
	Concrete	120	CY	290	34,800		
	Round Off				200		
						200,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Transformer Gallery & Tunnels						
	Excavation & Supports	11,960	CY	290	3,468,400		
	Concrete & Reinf Steel	830	CY	460	381,800		
	Struc Steel & Misc.Metals	120	TON	3,800	456,000		
	Round Off				(6,200)		
						4,300,000	
	Valve Chamber & Transformer						
	Gallery-Access Tunnels						
	Excavation & Supports	1,500	CY	250	375,000		
	Concrete	60	CY	290	17,400		
	Round-Off				7,600		
						400,000	
	Powerhouse Access Tunnel						
	Portal Excav.& Protection	56,000	CY	10	560,000		
	Portal Conc.& Reinf.Steel	1,000	CY	570	570,000		
	Tunnel Excav.& Supports	24,000	CY	300	7,200,000		
	Tunnel Concrete	900	CY	290	261,000		
	Tunnel Misc. Metals	30	TON	11,000	330,000		
	Subsurface Exploration						
	Mobilization		LS		1,500,000		
	Exploratory Adit	1,000	LF	1,800	1,800,000		
	Core drilling	5,000	LF	140	700,000		
	Helicopter Service		LS		600,000		
	Round-Off				(21,000)		
						13,500,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Cable Way						
	Concrete & Reinf. Steel	1,000	CY	700	700,000		
	Misc.Metals & Cable Sup.	26	TON	5,100	132,600		
	Port Panels						
	Round-Off				(32,600)		
						800,000	
	TOTAL POWER PLANT STRUCTURE & IMPROVEMENTS					51,000,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	RESERVOIR, DAM & WATERWAYS						
	Reservoir						
	Water Level Recording		LS			100,000	
	Intake Structure						
	Site Exploration						
	Mobilization		LS		150,000		
	Core Drilling	5,000	LF	80	400,000		
	Helicopter Service		LS		150,000		
	Tunnel Excav.& Supports	12,000	CY	470	5,640,000		
	Tunnel Conc.& Reinf.Steel	100	CY	350	35,000		
	Lake-Tap (Final Round)		LS		3,000,000		L = 26'
	Place & Remove Temp.Conc	600	CY	700	420,000		
	Diving Crew	60	DAYS	10,000	600,000		
	Round-Off				5,000		
						10,400,000	
	Intake Gate Shaft						
	Shaft Excav.& Supports	10,000	CY	360	3,600,000		
	Mass Surface Excav.	50,000	CY	30	1,500,000		
	Concrete & Reinf. Steel	5,700	CY	890	5,073,000		
	Misc. Metals,Gates & Hoist	244	TON	12,500	3,050,000		
	Round-Off				(23,000)		
						13,200,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access Tunnel at Intake						
	Portal Excav. & Protection	6,000	CY	50	300,000		
	Tunnel Excav.& Supports	72,000	CY	295	21,240,000		
	Tunnel Conc. & Reinf.Steel	200	CY	500	100,000		
	Round-Off				(40,000)		
						21,600,000	
	Access Tunnel at Surge Chamber						
	Portal Excav. & Protection	6,000	CY	55	330,000		
	Tunnel Excav.& Supports	23,000	CY	323	7,429,000		
	Tunnel Conc. & Reinf.Steel	2,300	CY	420	966,000		
	Grouting Contact & Pressure	3,400	CF	58	197,200		
	Round-Off				(22,200)		
						8,900,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access Tunnel at Mile 3.5 No.1						
	Portal Excav & Protection	6,000	CY	53	318,000		
	Tunnel Excav & Supports	68,000	CY	297	20,196,000		
	Tunnel Conc & Reinf Steel	500	CY	430	215,000		
	Grouting-Contact & Pressure	1,125	CF	58	65,250		
	Round-Off				5,750		
						20,800,000	
	Access Tunnel at Mile 7.5 No.2						
	Portal Excav & Protection	6,000	CY	54	324,000		
	Tunnel Excav & Supports	45,000	CY	298	13,410,000		
	Tunnel Conc & Reinf Steel	1,600	CY	420	672,000		
	Grouting-Contact & Pressure	2,300	CF	58	133,400		
	Round-Off				(39,400)		
						14,500,000	
	Power Tunnel						
	Excavation & Supports	67,000	LF	7,698	515,766,000		
	Concrete	514,000	CY	334	171,676,000		
	Grouting-Contact & Pressure	464,000	CF	54	25,056,000		
	Round-Off				2,000		
						712,500,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Surge Chamber - Upper						
	Excavation & Supports	35,500	CY	200	7,100,000		
	Concrete & Reinf.Steel	6,100	CY	880	5,368,000		
	Earthworks & Fencing	15,000	CY	27	405,000		Heliport, Storage, Work Area
	Round-Off				27,000		
						12,900,000	
	Penstock-Inclined Section						
	Excavation & Supports	23,400	CY	271	6,341,400		
	Concrete & Reinf. Steel	10,500	CY	837	8,788,500		
	Grouting Contact & Pressure	5,000	CF	52	260,000		
	Round-Off				10,100		
						15,400,000	
	Penstock-Horizontal Section & Elbow						
	Excavation & Supports	14,000	CY	310	4,340,000		
	Concrete $ Reinf. Steel	6,000	CY	365	2,190,000		
	Grouting - Contact	3,000	CF	50	150,000		
	Round-Off				20,000		
						6,700,000	

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	Penstock-Wye Branches to Valve Chamber						
	Excavation & Supports	10,000	CY	432	4,320,000		
	Concrete & Reinf. Steel	7,200	CY	608	4,377,600		
	Steel Liner	650	TON	5,000	3,250,000		
	Grouting-Contact	3,000	CY	50	150,000		
	Round-Off				2,400		
						12,100,000	
	Penstock Between Valve Chamber & Powerhouse						
	Excavation & Supports	1,000	CY	440	440,000		
	Concrete & Backfill	600	CY	550	330,000		
	Round-Off				30,000		
						800,000	
	Draft Tube Tunnels						
	Rock Bolts & Grout	19,000	LF	27	513,000		
	Concrete & Reinf. Steel	3,300	CY	425	1,402,500		
	Round-Off				(15,500)		
						1,900,000	
	Surge Chamber - Tailrace						
	Excavation & Supports	5,000	CY	480		2,400,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Tailrace Tunnel & Structures						
	Cofferdam & Dewatering		LS		2,000,000		
	Portal Excav. & Protection	2,000	CY	65	130,000		
	Concrete & Reinf. Steel	1,200	CY	600	720,000		
	Walkway Bridge		LS		65,000		
	Stoplogs & Hoists	81	TON	8,500	688,500		
	Tunnel Excav. & Supports	25,000	CY	260	6,500,000		
	Plug Excavation	4,000	CY	50	200,000		
	Round-Off				(3,500)		
						10,300,000	
	Tailrace Channel						
	Channel Excavation	100,000	CY	9		900,000	
	River Training Works						
	River Bed Deepening	50,000	CY	10		500,000	
	Mech & Elec.		LS			5,700,000	
	TOTAL RESERVOIR, DAM AND WATERWAYS					871,600,000	

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	Turbines & Generators						300 MW
	Turbines	4	EA	7,970,000	31,880,000		
	Generators	4	EA	5,660,000	22,640,000		
	Round-Off				(20,000)		
						54,500,000	
	Accessory Electrical Equipment						
	Equipment		LS			9,000,000	
	Misc. Power Plant Equipment						
	Crane Bridge	1	EA		900,000		
	Other Power Plant Equip.		LS		6,000,000		
						6,900,000	
	Switchyard Structures						
	Earthworks	15,000	CY	25	375,000		
	Concrete & Reinf. Steel	3,800	CY	640	2,432,000		
	Struc. Steel & Misc.Metals	225	TON	3,500	787,500		
	Round-Off				5,500		
						3,600,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Switchyard Equipment						
	Transformers 105 MVA	5	EA	1,010,000	5,050,000		
	Unit & Line Breakers	7	EA	180,000	1,260,000		
	Switches & Lightn.Arrestors	30	EA	33,000	990,000		
	230 KV Cables	18,000	LF	120	2,160,000		
	Controls & Metr'g Equip.		LS		2,630,000		
	Round Off				10,000		
						12,100,000	
	Comm. Supv. Control Equip.		LS			1,600,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	TRANSPORTATION FACILITIES						
	Port Facilities						
	Causeway	19,600	CY	80	1,568,000		
	Trestle Piles	50	TON	11,300	565,000		L = 150 LF, ϕ12", t = ½"
	Trestle Struct. Steel	110	TON	3,500	385,000		
	Trestle Reinf. Conc.	150	CY	700	105,000		
	Facilities - Allowance		LS		2,000,000		
	Round-Off				(23,000)		
						4,600,000	
	Airport						
	Earthwork	54,500	CY	16	872,000		
	Culverts	1,000	LF	65	65,000		
	Subbase & Base	55,000	CY	14	770,000		
	Building - Allowance		LS		300,000		
	Round-Off				(7,000)		
						2,000,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access & Construction Roads						
	Mile 0+00 to 18+00						
	Earthwork	175,000	CY	6.60	1,155,000		
	Culverts	1,500	LF	65	97,500		
	Bridges	1,400	SF	150	210,000		
	Subbase & Base	85,400	CY	15	1,281,000		
	Guard Rail	1,200	LF	25	30,000		
	Repair Existing Road	95,000	LF	10	950,000		
	Snow Fences	5,000	LF	35	175,000		
	Round-Off				1,500	3,900,000	
	Mile 18+00 to 35+00						
	Earthworks	1,465,000	CY	6.60	9,669,000		
	Culverts	3,600	LF	80	288,000		48"ϕ CMP
	Subbase & Base	165,000	CY	15	2,475,000		
	Guard Rail	13,000	LF	25	325,000		
	Repair Existing Road	16,000	LF	10	160,000		
	Snow Fences	1,000	LF	35	35,000		
	Round-Off				48,000		
						13,000,000	
	Mile 35+00 to 39+00						
	Earthwork	445,000	CY	8.30	3,693,500		
	Culverts	1,000	LF	80	80,000		48"ϕ CMP
	Bridge	9,000	SF	150	1,350,000		
	Subbase & Base	38,000	CY	15	570,000		
	Guard Rail	10,000	LF	27	270,000		
	Snow Fences	2,000	LF	35	70,000		
	Round-Off				(33,500)		
						6,000,000	

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	Walkway To Gate Shaft						
	Earthwork	1,200	CY	20	24,000		
	Guard Rail	1,000	LF	25	25,000		
	Bridge	200	SF	150	30,000		
	Riprap	100	CY	35	3,500		
	Round-Off				17,500		
						100,000	
	Access Road to Tailrace Tunnel						
	Earthwork	56,000	CY	8	448,000		
	Culverts	100	LF	80	8,000		48"ø CMP
	Subbase & Base	2,500	CY	20	50,000		
	Guard Rail	600	LF	25	15,000		
	Round-Off				(21,000)		
						500,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access Road to Downstream Power Tunnel						
	Earthwork	215,000	CY	9.80	2,107,000		
	Culverts	800	LF	80	64,000		48"ϕ CMP
	Bridge	3,000	SF	150	450,000		
	Subbase & Base	10,000	CY	21	210,000		
	Guardrail	9,000	LF	32	288,000		
	Snowshed & Slide Fall	1,000	LF	800	800,000		
	Round-Off				(19,000)		
						3,900,000	
	Temporary Construction Roads						
	Earthwork	61,000	CY	6	366,000		
	Culverts	600	LF	80	48,000		
	Bridge	3,000	SF	150	450,000		
	Guardrail	2,000	LF	25	50,000		
	Round-Off				(14,000)		
						900,000	
	Road Maintenance						
	Summer Season	36	MO	120,000	4,320,000		
	Winter Season	24	MO	480,000	11,520,000		
	Round-Off				(40,000)		
						15,800,000	
	TOTAL ACCESS & CONSTRUCTION ROADS					44,100,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Transmission Line						
	Clear & Grub	70	MI	225,000	15,750,000		
	Transmission Line	70	MI	344,000	24,080,000		
	Submarine Cable	21	MI	792,000	16,632,000		
	Round-Off				38,000		
						56,500,000	
	TOTAL SPECIFIC CONSTRUCTION COST						
	AT JANUARY 1982 PRICE LEVELS					1,117,500,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	POWER PLANT STRUCTURE & IMPROVEMENTS						
	Valve Chamber						
	Excavation & Supports	10,000	CY	275	2,750,000		
	Concrete & Reinf Steel	6,520	CY	410	2,673,200		
	Struc. Steel & Misc.Metals	52	TON	1,800	93,600		
	Round-Off				(16,800)		
						5,500,000	
	Underground Powerhouse						
	Dewatering		LS		4,100,000		Entire Underground Complex
	Excavation & Supports	58,900	CY	168	9,895,200		
	Drilling-Percus.& Rotary	12,700	LF	27	342,900		2" - 3"ø
	Concrete & Reinf.Steel	13,100	CY	630	8,253,000		
	Struc.Steel & Misc Metals	300	TON	5,300	1,590,000		
	Architectural		LS		1,000,000		
	Round-Off				18,900		
						25,200,000	
	Bus Galleries Between Power-house & Transformer Vaults						
	Excavation & Supports	200	CY	825	165,000		
	Concrete	120	CY	290	34,800		
	Round Off				200		
						200,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Transformer Gallery & Tunnels						
	Excavation & Supports	11,960	CY	290	3,468,400		
	Concrete & Reinf Steel	830	CY	460	381,800		
	Struc Steel & Misc.Metals	120	TON	3,800	456,000		
	Round Off				(6,200)		
						4,300,000	
	Valve Chamber & Transformer						
	Gallery-Access Tunnels						
	Excavation & Supports	1,500	CY	250	375,000		
	Concrete	60	CY	290	17,400		
	Round-Off				7,600		
						400,000	
	Powerhouse Access Tunnel						
	Portal Excav.& Protection	56,000	CY	10	560,000		
	Portal Conc.& Reinf.Steel	1,000	CY	570	570,000		
	Tunnel Excav.& Supports	24,000	CY	300	7,200,000		
	Tunnel Concrete	900	CY	290	261,000		
	Tunnel Misc. Metals	30	TON	11,000	330,000		
	Subsurface Exploration						
	Mobilization		LS		1,500,000		
	Exploratory Adit	1,000	LF	1,800	1,800,000		
	Core drilling	5,000	LF	140	700,000		
	Helicopter Service		LS		600,000		
	Round-Off				(21,000)		
						13,500,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Cable Way						
	Concrete & Reinf. Steel	1,000	CY	700	700,000		
	Misc. Metals & Cable Sup.	26	TON	5,100	132,600		
	Port Panels						
	Round-Off				(32,600)		
						800,000	
	TOTAL POWER PLANT STRUCTURE & IMPROVEMENTS					49,900,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	RESERVOIR, DAM & WATERWAYS						
	Reservoir						
	Water Level Recording		LS			100,000	
	Intake Structure						
	Site Exploration						
	Mobilization		LS		150,000		
	Core Drilling	5,000	LF	80	400,000		
	Helicopter Service		LS		150,000		
	Tunnel Excav.& Supports	10,000	CY	510	5,100,000		
	Tunnel Conc.& Reinf.Steel	90	CY	350	31,500		
	Lake-Tap (Final Round)		LS		2,500,000		L = 26'
	Place & Remove Temp.Conc	550	CY	700	385,000		
	Diving Crew	60	DAYS	10,000	600,000		
	Round-Off				(16,500)		
						9,300,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Intake Gate Shaft						
	Excavation & Supports	360	LF	17,500	6,300,000		
	Mass Surface Excavation	50,000	CY	30	1,500,000		
	Concrete & Reinf. Steel	5,200	CY	890	4,628,000		
	Misc. Metals, Gates & Hoist	220	TONS	12,200	2,684,000		
	Access Road	1.25	MI	2,000,000	2,500,000		
	Round Off				(12,000)		
						17,600,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Fish Passage Facilities						
.	Approach Channel						
	Channel Excavation	1,040,000	CY	11.30	11,752,000		
	Slope Protection	90,000	CY	28.00	2,520,000		
	Round				(22,000)		
						14,250,000	
	Upstream Portal						
	Excavation in Rock	64,500	CY	30.00	1,935,000		
	Rock Bolts - Ch, LK, Mesh		LS		544,500		
	Dewatering During Construct.		LS		50,000		
	Fence	400	LF	45.00	18,000		
	Round				2,500		
						2,550,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Upstream Fish Passage Facility						
	Excavation & Support	16,550	CY	163	2,697,650		
	Concrete & Reinf. Steel	5,880	CY	759	4,462,920		
	Misc. Metal, Gates & Crane		LS		1,786,300		
	Electrical & Instrumentation		LS		200,000		
	Round Off				(3,130)		
						9,150,000	
	Downstream Fish Passage						
	Facility						
	Excavation & Support	8,900	CY	191	1,699,900		
	Concrete & Reinf. Steel	2,600	CY	635	1,651,000		
	Misc. Metal, Gates & Crane		LS		2,283,000		
	Electrical & Instrumentation		LS		100,000		
	Round Off				(3,900)		
						5,730,000	
	Access Tunnel						
	Excavation & Support	122,500	CY	303	37,117,500		
	Concrete & Reinf. Steel	22,800	CY	573	13,064,400		
	Misc. Metal		LS		405,000		
	Electrical - Lighting		LS		231,000		
	Round Off				(7,900)		
						50,810,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Fish Passage Facilities						
	Excavation & Support	6,600	CY	53	349,800		
	Concrete & Reinf. Steel	740	CY	778	575,720		
	Misc. Metal, Gate, etc.		LS		434,650		
	Round Off				(170)		
						1,360,000	
	Chakachatna River						
	Flow Regulation						
	River Bed Deepening	10,000	CY	9.50	95,000		
	Rip-Rap	1,000	CY	35.00	35,000		
						130,000	
	Access Road		LS			300,000	
	Access Tunnel to Fish						
	Passage Facilities						
	Portals Excavation	700	CY	93	65,100		
	Tunnel Excavation & Support	3,350	CY	314	1,051,900		
	Round Off				3,000		
						1,120,000	
	Total Fish Facilities					85,400,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Chakachata Dike and Spillway						
	Excavation & Slope Protection	280,000	CY	29.50	8,260,000		
	Concrete & Reinf. Steel	1,100	CY	325	357,500		
	Timber Bridge	2,200	SF	150	330,000		
	Dike	250,000	CY	0.75	187,500		
	Round Off				(35,000)		
						9,100,000	
	Access Tunnel at Surge Chamber						
	Portal Excavation & Protection	6,000	CY	35	210,000		
	Tunnel Excavation & Supports	14,000	CY	317	4,438,000		
	Tunnel Concrete & Reinf. Steel	1,700	CY	420	714,000		
	Grouting Contact & Pressure	2,260	CF	58	131,080		
	Watertight Bulkhead & Frame	27	TON	13,800	372,600		
	Round Off				34,320		
						5,900,000	

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	Power Tunnel TBM						
	Excavation & Supports	53,400	LF	6,110	326,274,000		
	Concrete	267,000	CY	341	91,047,000		
	Grouting	540,000	CF	56.40	30,456,000		
	Round Off				23,000		
						447,800,000	

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	Surge Chamber - Upper						
	Excavation & Supports	27,100	CY	353	9,566,300		
	Concrete & Reinf. Steel	10,000	CY	893	8,930,000		
	Earthwork & Fencing	15,000	CY	27	405,000		
	Round Off				(1,300)		
						18,900,000	
	Penstock - Horizontal						
	Section						
	Excavation & Supports	12,000	CY	334	4,008,000		
	Concrete & Reinf. Steel	5,100	CY	365	1,861,500		
	Grouting - Contact	2,600	CF	50	130,000		
	Round Off				500	6,000,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Penstock-Wye Branches to Valve Chamber						
	Excavation & Supports	9,000	CY	480	4,320,000		
	Concrete & Reinf. Steel	6,100	CY	608	3,708,800		
	Steel Liner	700	TON	5,000	3,500,000		
	Grouting-Contact	7,000	CY	56	392,000		
	Round-Off				(20,800)		
						11,900,000	
	Penstock Between Valve Chamber & Powerhouse						
	Excavation & Supports	850	CY	440	374,000		
	Concrete & Backfill	500	CY	550	275,000		
	Round-Off				(49,000)		
						600,000	
	Draft Tube Tunnels						
	Rock Bolts & Grout	15,000	LF	29	435,000		
	Concrete & Reinf. Steel	2,975	CY	425	1,264,375		
	Round-Off				625		
						1,700,000	
	Surge Chamber - Tailrace						
	Excavation & Supports	5,000	CY	480		2,400,000	

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	Tailrace Tunnel & Structures						
	Cofferdam & Dewatering		LS		2,000,000		
	Portal Excav. & Protection	2,000	CY	65	130,000		
	Concrete & Reinf. Steel	1,200	CY	600	720,000		
	Walkway Bridge		LS		65,000		
	Stoplogs & Hoists	81	TON	8,500	688,500		
	Tunnel Excav. & Supports	20,000	CY	290	5,800,000		
	Plug Excavation	4,000	CY	50	200,000		
	Round-Off				(3,500)		
						9,600,000	
	Tailrace Channel						
	Channel Excavation	80,000	CY	9	720,000		
					(20,000)		
						700,000	
	River Training Works						
	River Bed Deepening	50,000	CY	10		500,000	
	Mech & Elec.		LS			6,100,000	
	TOTAL RESERVOIR, DAM AND WATERWAYS					633,600,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Turbines & Generators						330 MW
	Turbines	4	EA	8,480,000	33,920,000		
	Generators	4	EA	6,000,000	24,000,000		
	Round-Off				(20,000)		
						57,900,000	
	Accessory Electrical Equipment						
	Equipment		LS			9,500,000	
	Misc. Power Plant Equipment						
	Crane Bridge	1	EA		930,000		
	Other Power Plant Equip.		LS		6,370,000	7,300,000	
	Switchyard Structures						
	Earthworks	15,000	CY	25	375,000		
	Concrete & Reinf. Steel	3,800	CY	640	2,432,000		
	Struc. Steel & Misc.Metals	225	TON	3,500	787,500		
	Round-Off				5,500		
						3,600,000	

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DATE

SHEET 15 OF 20

ALTERNATIVE E

NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Switchyard Equipment						
	Transformers 105 MVA	5	EA	1,030,000	5,150,000		
	Unit & Line Breakers	7	EA	185,000	1,295,000		
	Switches & Lightn.Arrestors	30	EA	34,000	1,020,000		
	230 KV Cables	18,000	LF	130	2,340,000		
	Controls & Metr'g Equip.		LS		2,700,000		
	Round Off				(5,000)		
						12,500,000	
	Communication and Supv Control Equip.		LS			1,600,000	

H&CF CSE 523 (3-80)

ESTIMATE SUMMARY

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NOV. 1982
DATE

CHAKACHAMNA HYDROELECTRIC PROJECT
PROJECT

ALASKA POWER AUTHORITY
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ALTERNATIVE E

NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	TRANSPORTATION FACILITIES						
	Port Facilities						
	Causeway	19,600	CY	80	1,568,000		
	Trestle Piles	50	TON	11,300	565,000		L = 150 LF, ϕ12", t = ½"
	Trestle Struct. Steel	110	TON	3,500	385,000		
	Trestle Reinf. Conc.	150	CY	700	105,000		
	Facilities - Allowance		LS		2,000,000		
	Round-Off				(23,000)		
						4,600,00	
	Airport						
	Earthwork	54,500	CY	16	872,000		
	Culverts	1,000	LF	65	65,000		
	Subbase & Base	55,000	CY	14	770,000		
	Building - Allowance		LS		300,000		
	Round-Off				(7,000)		
						2,000,000	

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CHAKACHAMNA HYDROELECTRIC PROJECT
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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access & Construction Roads						
	Mile 0+00 to 18+00						
	Earthwork	175,000	CY	6.60	1,155,000		
	Culverts	1,500	LF	65	97,500		36"ϕ CMP
	Bridges	1,400	SF	150	210,000		
	Subbase & Base	85,400	CY	15	1,281,000		
	Guard Rail	1,200	LF	25	30,000		
	Repair Existing Road	95,000	LF	10	950,000		
	Snow Fences	5,000	LF	35	175,000		
	Round-Off				1,500		
						3,900,000	
	Mile 18+00 to 35+00						
	Earthworks	1,465,000	CY	6.60	9,669,000		
	Culverts	3,600	LF	80	288,000		48"ϕ CMP
	Subbase & Base	165,000	CY	15	2,475,000		
	Guard Rail	13,000	LF	25	325,000		
	Repair Existing Road	16,000	LF	10	160,000		
	Snow Fences	1,000	LF	35	35,000		
	Round-Off				48,000		
						13,000,000	
	Mile 35+00 to 39+00						
	Earthwork	445,000	CY	8.30	3,693,500		
	Culverts	1,000	LF	80	80,000		48"ϕ CMP
	Bridge	9,000	SF	150	1,350,000		
	Subbase & Base	38,000	CY	15	570,000		
	Guard Rail	10,000	LF	27	270,000		
	Snow Fences	2,000	LF	35	70,000		
	Round-Off				(33,500)		
						6,000,000	

B&CF CSE 523 (3-80)

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Walkway To Gate Shaft						
	Earthwork	1,200	CY	20	24,000		
	Guard Rail	1,000	LF	25	25,000		
	Bridge	200	SF	150	30,000		
	Riprap	100	CY	35	3,500		
	Round-Off				17,500		
						100,000	
	Access Road to MacArthur Valley						
	Earthwork	545,000	CY	7	3,815,000		
	Culverts	2,400	LF	75	180,000		36"ø and 48"ø CMP
	Bridge Improvements	9,000	SF	70	630,000		
	Subbase & Base	105,000	CY	15	1,575,000		
	Guard Rail	6,000	LF	25	150,000		
	Snow Fences	3,000	LF	35	105,000		
	Round-Off				45,000		
						6,500,000	
	Access Road to Tailrace Tunnel						
	Earthwork	56,000	CY	8	448,000		
	Culverts	100	LF	80	8,000		48"ø CMP
	Subbase & Base	2,500	CY	20	50,000		
	Guard Rail	600	LF	25	15,000		
	Round-Off				(21,000)		
						500,000	

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ALTERNATIVE E

CHAKACHAMNA HYDROELECTRIC PROJECT — PROJECT

ALASKA POWER AUTHORITY — PREPARED FOR

14879-001 — JOB NO.

NOV. 1982 — DATE

NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Access Road to Downstream Power Tunnel						
	Earthwork	215,000	CY	9.80	2,107,000		
	Culverts	800	LF	80	64,000		48"ø CMP
	Bridge	3,000	SF	150	450,000		
	Subbase & Base	10,000	CY	21	210,000		
	Guardrail	9,000	LF	32	288,000		
	Snowshed & Slide Fall	1,000	LF	800	800,000		
	Round-Off				(19,000)		
						3,900,000	
	Temporary Construction Roads						
	Earthwork	61,000	CY	6	366,000		
	Culverts	600	LF	80	48,000		48"ø CMP
	Bridge	3,000	SF	150	450,000		
	Guardrail	2,000	LF	25	50,000		
	Round-Off				(14,000)		
						900,000	
	Road Maintenance						
	Summer Season	45	MO	150,000	6,750,000		
	Winter Season	30	MO	600,000	18,000,000		
	Round-Off				50,000		
						24,800,000	
	TOTAL ACCESS & CONSTRUCTION ROADS					59,600,000	

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NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COSTS	AMOUNT	TOTALS	REMARKS
	Transmission Line						
	Clear & Grub	82	MI	225,000	18,450,000		
	Transmission Line	82	MI	343,000	28,126,000		
	Submarine Cable	21	MI	792,000	16,632,000		
	Round-Off				(8,000)		
						63,200,000	
	TOTAL SPECIFIC CONSTRUCTION						
	COST AT JANUARY 1982 PRICE						
	LEVELS					905,300,000	

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