SUSITNA HYDROELECTRIC PROJECT

FERC LICENSE APPLICATION

EXHIBIT A

FIRST DRAFT

SEPTEMBER 17, 1982

Prepared by:

ACRES

ALASKA POWER AUTHORITY

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EXHIBIT A - PROJECT DESCRIPTION

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EXHIBIT A - PROJECT DESCRIPTION

The Susitna Hydroelectric project will comprise two major developments on the Susitna River some 180 miles north and east of Anchorage, Alaska. The first phase of the project will be the Watana Project which will incorporate an earthfill dam, together with associated diversion, spillway, and power facilities. The second phase will include the Devil Canyon concrete arch dam and associated facilities.

The description of the Watana project is presented in the following Sections 1 through 6; the Devil Canyon project is described in Sections 7 through 12. Reference drawings will be found in Exhibit F.

1 - PROJECT STRUCTURES - WATANA DEVELOPMENT

1.1 - General Arrangement

The Watana Dam will create a reservoir approximately 48 miles long, with a surface area of 38,000 acres, and a gross storage capacity of 9,500,000 acre-feet at elevation 2185, the normal maximum operating level.

The maximum water surface elevation during flood conditions will be 2201. The minimum operating level of the reservoir will be 2045, providing a live storage during normal operation of 4,200,000 arce-feet.

The dam will be an embankment structure with a central core. The nominal crest elevation of the dam will be 2205, with a maximum height of 885 feet above the foundation and a crest length of 4,100 feet. The embankment crest will initially be constructed to elevation 2210 to allow for potential seismic settlement. The total volume of the structure will be approximately 62,000,000 cubic yards. During construction, the river will be diverted through two concrete-lined diversion tunnels, each 38 feet in diameter and 4100 feet long, on the north bank of the river.

The power intake will be located on the north bank with an approach channel excavated in rock. The intake will be a concrete structure with multi-level gates capable of operation over the full 140 feet drawdown range. From the intake structure, six concrete-lined penstocks, each 17 feet in diameter, will lead to an underground powerhouse complex housing six Francis turbines with a rated capacity of 170 MW and six semi-umbrella type generators each rated at 190 MVA. The generators will be capable of delivering 115 percent of rated MVA continuously (195.5 MVA) without exceeding 80°C temperature rise.

Access to the powerhouse complex will be by means of an unlined access tunnel and a road which will pass from the crest of the dam, down the south bank of the river valley and across the embankment near the downstream toe. Turbine discharge will flow through six draft tube tunnels to a surge chamber downstream of the powerhouse. The surge chamber will discharge to the river through two 34-foot diameter concrete-lined tailrace tunnels. A separate transformer gallery just upstream from the powerhouse cavern will house nine single-phase 15/345 kv transformers (three transformers per group of two generators). The transformers will be connected by three 345 kV single-phase, oil-filled cables through two cable shafts to the switchyard at the surface.

Outlet facilities will also be located on the north bank to discharge all flood flows of up to 33,000 cfs, the estimated 50-year flood. The upstream gate structure will be adjacent to the power intake and will convey flows through a 28 feet diameter concrete-lined tunnel to six fixed-cone discharge valves downstream of the dam. These valves will be housed beneath the spillway flip bucket and will be used to dissipate energy and eliminate undesirable nitrogen supersaturation in the river downstream from the dam during spillway operations. The main spillway will also be located on the north bank. This spillway will consist of an upstream ogee control structure with three vertical fixed-wheel gates and an inclined concrete chute and flip bucket designed to pass a maximum discharge of 115,000 cfs. This spillway, together with the outlet facilities will thus be capable of discharging the estimated 10,000-year flood. An emergency spillway and fuse plug on the right bank will provide sufficient additional capacity to permit discharge of the Probable Maximum Flood (PMF) without overtopping the dam. Emergency release facilities will be located in one of the diversion tunnels after closure to allow lowering of the reservoir over a period of time to permit emergency inspection or repair of impoundment structures.

A local depression on the north rim of the reservoir upstream of the dam will be closed by a low freeboard dike, crest elevation 2210. Provision will be made for monitoring potential seepage through this area and placement of approximate filter blankets at Tsusena Creek downstream.

1.2 - Main Dam

The main dam at Watana will be located at mile 184 above the mouth of the Susitna River, in a broad U-shaped valley approximately 2.5 miles upstream of the Tsusena Creek confluence. The dam will be of compacted earth and rockfill construction and will consist of a central impervious core protected by fine and coarse filters upstream and downstream. The downstream outer shell will consist of rock fill and alluvial gravel underlain by a toe drain and filter; and the upstream outer shell of clean alluvial gravel. A typical cross section is shown on Plate 9 and is described below.

(a) Typical Cross Section

The central core slopes are 1H:4V with a top width of 35 feet. The thickness of the core at any horizontal section will be slightly more than 0.5 times the head of water at that section. Minimum core-foundation contact will be 50 feet, requiring flaring of the cross section at each end of the embankment.

The upstream and downstream filter zones will increase in thickness from 45 and 30 feet respectively near the crest of the dam to a maximum in excess of 100 feet at the filter foundation contact. They are sized to provide protection against possible piping through transverse cracks that could occur because of settlement or resulting from internal displacement during a seismic event.

The shells of the dam will consist primarily of compacted alluvial gravels. The saturated upstream shell will consist of compacted clean alluvial gravels processed to remove fines so that not more than 10 percent of the materials is less than 3/8-inch in size to minimize pore pressure generation and ensure rapid dissipation should seismic shaking occur. The downstream shell will be unsaturated and therefore will not be affected by pore pressure generation during a seismic event. This will be constructed with compacted, unprocessed alluvial gravels, and rockfill from the surface or underground excavations.

Protection against wave and ice action on the upstream slope will consist of a 10-foot layer of riprap comprising quarried rock up to 36 inches in size.

The volume of material required to construct the Watana Dam is presently estimated as follows:

- Core material: 8,250,000 cubic yards
- Fine filter material: 4,260,000 cubic yards
- Coarse filter material: 3,560,000 cubic yards
- Gravel and rockfill material: 45,500,000 cubic yards

(b) Crest Details and Freeboard

The typical crest detail is shown in Plate 9. Because of the narrowing at the dam crest, the filter zones are reduced in width and the upstream and downstream coarse filters are eliminated. A layer of filter fabric is incorporated to protect the core material from damage by frost penetration and dessication, and to act as a coarse filter where required.

The nominal crest elevation of the Watana Dam, after estimated static and seismic settlement have taken place, will be 2205.

Allowances will be made during construction of the dam to allow for static settlement of the fill following completion, settlement on saturation of the upstream shell, and possible settlement because of seismic shaking.

An allowance will be made for settlement due to seismic loading of up to 0.5 percent of the height of the dam, or approximately 5 feet. The elevation at the center of the dam prior to any seismic settlement will therefore be 2210. At each abutment, the crest elevation will be 2207, allowing for 2 feet of seismic settlement. Under normal operating conditions, the minimum freeboard relative to the maximum operating pool elevation of 2185 will therefore be 20 feet, not including settlement allowances.

During construction of the dam, additional allowances will be made for post-construction settlement of the dam under its own weight and for the effects of saturation on the upstream gravel fill when the reservoir is first filled. These allowances will be provided for in construction specifications and are consequently not shown on the drawings at this time. For initial cost estimating purposes, 1 percent of the height of the dam has been allowed, or approximately 9 feet. The additional height constructed into the dam for these settlements will be accomplished by steepening both slopes above approximately Elevation 1850. These settlement allowances are conservative when compared with observed settlements of similar structures. However, provision will be made during construction for placement of additional fill at the crest should settlements exceed these estimates.

The freeboard allowance of 20 feet is based on the worst conceivable combination of flood, wave and run up water levels which may occur after all settlement has taken place.

Ultimate security against overtopping of the main dam is provided by the emergency spillway. Under normal operation this spillway is sealed by a fuse plug dam across the entrance channel. This plug is a gravel dam with a lowest crest elevation of 2200 and with strict design of the core, upstream face, and shell materials to ensure that it will erode rapidly if overtopped, allowing flood flows to be discharged freely through the emergency spillway. The maximum reservoir level during passage of the PMR is estimated as 2201.5 prior to erosion of the plug. The location and typical cross section through the fuse plug are shown on Plate 20.

(c) <u>Grouting and Pressure Relief System</u>

A combination of consolidation grouting and cutoff curtain grouting and installation of a downstream pressure relief (drainage) system will be undertaken for the Watana dam.

The curtain grouting and drilling for the pressure relief system will be largely carried out from galleries in the rock foundation in the abutments and beneath the dam. Details of the grouting, pressure relief and galleries are shown on Plate 10.

(d) <u>Instrumentation</u>

Instrumentation will be installed to provide monitoring of performance of the dam and foundation during construction as well as during operation. Instruments for measuring internal vertical and horizontal displacements, stresses and strains, and total and fluid pressures, as well as surface monuments and markers will be installed. Estimates of quantities of instrumentation have been allowed for conservatively on the basis of currently available geotechnical data for the site. These include:

- Piezometers

Piezometers are used to measure static pressure of fluid in the pore spaces of soil, rockfill and in the rock foundation.

- Internal Vertical Movement Devices

  - Cross-arm settlement devices as developed by the USBR.

  - Various versions of the taut-wire devices which have been developed to measure internal settlement.

  - Hydraulic-settlement devices of various kinds.

- Internal Horizontal Movement Devices

  - Taut-wire arrangements.
  - Cross-arm devices.
  - Inclinometers.
  - Strain meters.

- Other Measuring Devices

  - Stress meters.
  - Surface monuments and alignment markers.
  - Seismographic records and seismoscopes.
  - Flow meters to record discharge from drainage and pressure relief system.

1.3 - Diversion

(a) Tunnels

Diversion of the river flow during construction will be accomplished with two 38 foot diameter circular diversion tunnels. The tunnels will be concrete-lined and located on the north bank of the river. The tunnels are 4,050 feet and 4,140 feet in length. The diversion tunnels are shown in plan and profile on Plate 11.

The tunnels are designed to pass a flood with a return frequency of 1:50 years, equivalent to peak inflow of 81,100 cfs. Routing effects are small and thus, at peak flow the tunnels will discharge 80,500 cfs. The estimated maximum water surface elevation upstream of the cofferdam for this discharge will be 1536.

The upper tunnel (Tunnel No. 1) will be converted to the permanent low level outlet after construction. A local enlarging of the tunnel diameter to 45 feet will accommodate the low level outlet gates and expansion chamber.

(b) Cofferdams

The upstream cofferdam will be a zoned embankment founded on the closure dam (see Plate 12). The closure dam will be constructed to Elevation 1475 based on a low water elevation of 1470, and will consist of coarse material on the upstream side grading to finer material on the downstream side. Provision has been made for a cut-off through the river bed alluvium to bedrock to control seepage during dam construction. The cement/bentonite slurry wall cut-off and downstream pumping system is shown on Plate 12.

Above Elevation 1475 the cofferdam will be a zoned embankment consisting of a central core, fine and coarse upstream and downstream filters, and rock and/or gravel supporting shell zones with riprap on the upstream face to resist ice action. This cofferdam will provide a 9 foot freeboard for wave runup and ice protection.

The downstream cofferdam will consist of only a closure dam constructed from approximate Elevation 1440 to 1472, and consisting of coarse material on the downstream side grading to finer material on the upstream side. Control of underseepage similar to that for the upstream cofferdam will be required.

(c) Tunnel Portals and Gate Structures

A reinforced concrete gate structure will be located at the upstream end of each tunnel, each housing two closure gates (see Plate 13).

Each gate will be 38 foot high by 15 foot wide separated by a center concrete pier. The gates will be of the fixed roller vertical lift type operated by a wire rope hoist. The gate hoist will be located in an enclosed, heated housing. Provision will be made for heating the gates and gate guides. The gate in Tunnel No. 1 will be designed to operate with the reservoir at Elevation 1540, a 50 foot operating head. The gate in Tunnel No. 2 will be designed to operate with the reservoir at Elevation 1540, a 120 foot operating head. The gate structures for each tunnel will be designated to withstand external (static) heads of 130 feet (No. 1) and 520 feet (No. 2), respectively. The downstream portals will be reinforced concrete structures with guides for stoplogs.

(d) Final Closure and Reservoir Filling

As discussed above, the upper diversion tunnel (No. 1) will be converted to a low level outlet or emergency release facility during construction.

It is estimated one year will be required to construct and install the permanent low level outlet in the existing tunnel. This will require that the lower tunnel (No. 2) pass all flows during this period. The main dam will, at this time, be at an elevation sufficient to allow a 100 year recurrence interval flood (90,000 cfs) to pass through Tunnel No. 2. This flow will result in a reservoir elevation of 1625. During the construction of the low level outlet, the intake operating gate in the upper tunnel (No. 1) will be closed. Prior to commencing operation of the low level outlet, coarse trashracks will be installed in the Tunnel No. 1 intake structure in the slots provided.

Upon commencing operation of the low level outlet, the lower tunnel (No. 2) will be closed with the intake gates, and construction of the permanent plug and filling of the reservor will commence.

When the lower tunnel (No. 2) is closed the main dam crest will have reached an elevation sufficient to start filling the reservoir and still have adequate storage available to store a 250 year recurrence period flood.

During the filling operation, the low level outlet will pass average summer flows of up to 6,000 cfs and winter flows of up to 800 cfs. In case of a large flood occurring during the filling operation, the low level outlet would be opened to its maximum capacity of 30,000 cfs until the reservoir pool was lowered to a safe level.

The filling of the reservoir is estimated to take 4 years to complete to the full reservoir operating elevation of 2185. After 3 years of filling the reservoir will be at Elevation 2150 and will allow operation of the powerplant to commence.

The filling sequence is based on the main dam elevation at any time during construction and the capability of the reservoir storage to absorb the inflow volume from a 250 year recurrence period flood without overtopping the main dam.

1.4 - Emergency Release Facilities

As discussed above, the upper diversion Tunnel No. 1 will be converted to a permanent low level outlet, or emergency release facility. This facility will be installed in two plugs, separated by an expansion chamber, and used to pass the required minimum discharge during the reservoir filling period. They will also be used for draining the reservoir in the event of an emergency.

The facility will have a capacity of 30,000 cfs at full reservoir pool elevation. It will be capable of drawing the reservoir down in 14 months under average inflow conditions, initially in conjunction with the main spillway and outlet facilities. The reservoir drawdown time incorporating the low level is presented graphically in Figure A.1 for various "start" times during the year.

Each plug will contain three water passages in the configuration shown in Plate 21. Each passage in the upstream plug will be provided with two bonnetted type high pressure slide gates, the upstream gate serving as a guard to the downstream gate. The downstream plug will also contain three water passages, each with a single gate.

The 7.5 feet by 11.5 feet gates will be designed to withstand a total static head of about 740 feet, but will be operated under a head of 600 feet or less.

During operation, the operating gate opening in the upstream plug will be equal to the opening of the gate in the downstream plug, to effectively balance the head losses across the gates. The maximum net operating head across a gate is not expected to exceed 340 feet.

Each gate will be equipped with a hydraulic cylinder operator designed to raise or lower the gate against a maximum head of 560 feet. Three hydraulic units will be installed, one for the emergency gates, one for the upstream operating gates and one for the downstream operating gates. Each gate will have an opening/closing time of 30 minutes. A grease injection system will be installed in each gate to reduce frictional forces when the gates are operated.

The design of the gate will be such that the hydraulic cylinder as well as the cylinder packing may be inspected and repaired without dewatering the area around the gate. All gates may be locally or remotely operated.

To prevent concrete erosion, the conduits in each of the tunnel plugs will be steel lined. An air vent will be installed at the downstream side of the gate in the downstream plug. Energy dissipation at the downstream tunnel exit will be accomplished by means of a concrete flip bucket placed in the exit channel (Plate 22).

1.5 - Outlet Facilities

The primary function of the outlet facilities will be to discharge floods with recurrence frequencies of up to once in 50 years after they have been routed through the Watana reservoir. The use of fixed cone discharge valves will ensure that downstream erosion will be minimal and the dissolved nitrogen content in the discharges will be reduced sufficiently to avoid harmful effects on the downstream fish population. A secondary function will be to provide the capability to rapidly draw down the reservoir during an extreme emergency situation.

The facilities will be located on the north bank, and will consist of a gate structure, pressure tunnel, and an energy dissipation and control structure housing located beneath the spillway flip bucket. This structure will accommodate six fixed-cone valves which will discharge into the river 105 feet below.

(a) Approach Channel and Intake

The approach channel to the outlet facilities will be shared with the power intake. The channel will be 350 feet wide and excavated to a maximum depth of approximately 150 feet in the bedrock with an invert elevation of 2010. The gate structure will be founded deep in the rock at the forebay end of the channel. The single intake passage will have an invert elevation of 2012. It will be divided upstream by a central concrete pier which will support steel trashracks located on the face of the structure, spanning the openings to the water passage. The racks will be split into panels mounted one above the other and run in vertical steel guides installed at the upstream face. The trashrack panels can be raised and lowered for cleaning and maintenance by a mobile gantry crane located at deck level.

Two fixed wheel gates will be located downstream of the racks, between the pier and each of the sidewalls. These gates will be operated by a mechanical hoist mounted above the deck of the structure. The fixed wheel gates will not be used for flow control but will function as closure gates to isolate the downstream tunnel and allow dewatering for maintenance of the tunnel or ring gates located in the discharge structure. Stoplog guides will be provided upstream of the two fixed wheel gates to permit dewatering of the structure and access to the gate guides for maintenance.

(b) Intake Gates and Trashracks

The gates will be of the fixed wheel vertical lift type with downstream skinplate and seals. The nominal gate size will be 18 feet wide by 30 feet high. Each gate will be operated by a single drum wire rope hoist mounted in an enclosed tower structure at the top of the intake. The height of the tower structure will permit raising the gates to the intake deck for inspection and maintenance.

The gates will be capable of being lowered either from a remote control room or locally from the hoist area. Gate raising will be from the hoist area only.

The trashracks will have a bar spacing of 7 inches, and will be designed for a maximum differential head of 40 feet. The maximum net velocity through the racks will be 12 feet/s. Provision will be made for monitoring the head loss across the trashracks.

(c) Shaft and Tunnel

Discharges will be conveyed from the upstream gate structure by a concrete-lined tunnel terminating in a steel liner and manifold. The manifold will branch into six steel-lined tunnels which will run through the main spillway flip bucket structure to the fixed cone valves mounted in line with the downstream face.

The water passage will be 28 feet in diameter as far as the steel manifold. The upstream concrete-lined portion will run a short distance horizontally from the back of the intake structure before dipping at an angle of 55° to a lower level tunnel of similar cross section. The lower tunnel will run at a 5% gradient to a centerline elevation of 1560, approximately 450 feet upstream of the flip bucket. At this point, the depth of overlying rock is insufficient to withstand the large hydrostatic pressure which will occur within the tunnel. Downstream of this point the tunnel will be steel lined. The steel liner will be 28 feet in diameter and embedded in mass concrete filling the space between the liner and the surrounding rock. The area between the outside face of the liner and the concrete will be contact grouted.

(d) Discharge Structure

The concrete discharge structure is shown on Plate 17. It will form a part of the flip bucket for the main spillway and will house the fixed cone valves and individual upstream ring follower gates. The valves will be set with a centerline elevation of 1560 and will discharge into the river approximately 105 feet below. Openings for the valves will be formed in the concrete and the valves will be recessed within these openings sufficiently to allow enclosure for ease of maintenance and heating of the moveable valve sleeves. An access gallery upstream from the valves will run the length of the discharge structure, and will terminate in the access tunnel and access road on either side of the structure. Housing for the ring follower gates will be located upstream from the fixed cone gate chambers. The ring follower gates will operate in the steel liners and will serve to isolate the discharge valves. Provision will be made for relatively easy equipment maintenance and removal by means of a 25 ton service crane, transfer trolley and individual 25 ton monorail hoists.

(e) Fixed Cone Discharge Valves

Six 78-inch diameter fixed-cone discharge valves will be installed at the downstream end of the outlet manifold, as shown on Plate 17. The valves will be operated by two hydraulic cylinder operators. The valves may be operated either locally or remotely.

(f) Ring Follower Gates

A ring follower gate will be installed upstream of each valve and will be used:

- To permit inspection and maintenance of the fixed-cone valves;

- To relieve the hydrostatic pressure on the fixed-cone valves when they are in the closed position; and

- To close against flowing water in the event of malfunction or failure of the valves.

The ring follower gates will have a nominal diameter of 90 inches and will be designed to withstand a total static head of 630 feet.

The ring follower gates will be designed to be lowered under flowing water conditions and raised under balanced head conditions. A operated by hydraulic cylinders from either a local or remote location.

(g) Discharge Area

Immediately downstream of the discharge structure, the rock will be excavated at a slope of 2H:3V to a lower elevation of 1510. face will be heavily reinforced by rock bolts and protected by a concrete slab anchored to the face. The lower level will consist of unlined rock extending to the river.

1.6 - Main Spillway

The main spillway will provide discharge capability for floods exceeding the capacity of the outlet facilities. The combined total capacity of the main spillway and outlet facilities will be sufficient to pass routed floods with a frequency of occurrence of up to once in 10,000 years.

The main spillway, shown on Plate 14, will be located on the north bank of the river and will consist of an approach channel, a gated ogee control structure, a concrete-lined chute, and a flip bucket.

The spillway is designed to discharge flows of up to 115,000 cfs with a corresponding reservoir elevation of 2192. The total head dissipated by the spillway is approximately 730 feet.

(a) Approach Channel and Control Structure

The approach channel will be excavated to a maximum depth of approximately 100 feet into rock. It is located on the south side of the power intake and, in order to minimize its length, it is partially integrated with the power approach channel upstream of the intake structure.

The concrete control structure will be located at the end of the approach channel, adjacent to the right dam abutment in line with the dam crest. Flows will be controlled by three 49 feet high by 36 feet wide vertical lift gates, as shown on Plate 15. The structure will be constructed in individual monoliths separated by construction joints. The main access route to the dam will pass across the roadway deck and along the dam crest.

Hydraulic model tests will be undertaken during the detailed design stage to confirm the precise geometry of the control structure.

The sides of the approach channel will be excavated to 1H:4V slopes. Only localized rock bolting and shotcrete support are required. The control structure will be founded deep in sound rock and consolidation grouting is not anticipated. However, minor shear or fracture zones passing through the foundation may require dental excavation, concrete backfill and/or consolidation grouting. The slope of the contact surface between the dam core and the spillway control structure will be constructed at 1H:3V to ensure sufficient contact stress and therefore prevent leakage.

The main dam grout curtain and drainage system will pass beneath the structure. Access to the grouting tunnels will be via a vertical shaft within the control structure side wall and a gallery running through the ogee weir.

(b) Spillway Gates and Stoplogs

The three spillway gates will be of the fixed wheel vertical lift type operated by double drum wire rope hoists located in an enclosed tower structure. The gate size is 36 feet wide by 49 feet high, including freeboard allowance. The gates will have upstream skinplates and will be totally enclosed to permit heating in the event that winter operation is necessary. Provision will also be made for heating the gate guides.

The height of the tower and bridge structure will permit raising of the gates above the top of the spillway pier for gate inspection and maintenance.

An emergency engine will be provided to enable the gates to be raised in the event of loss of power to the spillway gate hoist motors.

Stoplog guides will be installed upstream of each of the three spillway gates. One set of stoplogs will be provided to permit servicing of the gate guides.

(c) Spillway Chute

The control structure will discharge down an inclined chute that tapers slightly until a width of 80 feet is reached. A constant width of 80 feet is maintained over the remainder of its length. Convergence of the chute walls will be gradual to minimize any shock wave development.

The chute section will be rectangular in cross section, excavated in rock, and lined with concrete anchored to the rock. An extensive underdrainage system is provided to ensure stability of the structure. The dam grout curtain and drainage system will also extend under the spillway control structure utilizing a gallery through the mass concrete rollway. A system of box drains will be constructed in the rock under the concrete slab in a herringbone pattern at 20 feet spacing for the entire length of the spillway. To avoid blockage of the system by freezing of the surface drains a drainage gallery will be excavated at 30 feet deep over the entire length of the spillway. Drain holes from the surface drains will intersect the gallery. Drainage holes drilled into the high rock cuts will also ensure increased stability of excavations.

A series of four aeration galleries will be provided at intervals down the chute to prevent cavitation damage of the concrete. Details of these aeration devices are shown in Plate 16.

(d) Flip Bucket

The function of the flip bucket will be to direct the spillway flow clear of the concrete structures and well downstream into the river below. A mass concrete block will form the flip bucket for the main spillway. Detailed geometry of the bucket, as well as dynamic pressures on the floor and walls of the structure, will be confirmed by model studies.

1.7 - Emergency Spillway

The emergency spillway will be located on the right side of the river upstream of the main spillway and power intake structure (see Plate 20). The emergency spillway will consist of a long straight chute excavated in rock and leading in the direction of Tsusena Creek. An erodible fuse plug, consisting of an impervious core and fine gravel materials, will be constructed at the upstream end. The plug will be designed to wash away when overtopped, releasing flows of up to 160,000 cfs in excess of the combined main spillway and outlet facility capacities, thus preventing overtopping of the main dam under PMF conditions.

(a) Fuse Plug and Approach Channel

The approach channel to the fuse plug will be excavated in rock and will have a width of 310 feet and invert elevation of 2170. The main access road to the dam and powerhouse will cross the channel by means of a bridge. The fuse plug will close the approach channel, and will have a maximum height of 31.5 feet with a crest elevation of 2201.5. The plug will have a core up to 10 feet wide, steeply inclined in the upstream direction, with fine filter zones upstream and downstream. It will be supported on a downstream erodible shell of crushed stone or gravel up to 1.5 inches in diameter. The crest of the plug will be 10 feet wide and will be traversed by a 1.5 foot deep pilot channel. The principle of the plug is based on erosion progressing rapidly downward and laterally from the pilot channel as soon as water levels rise above the channel invert.

(b) Discharge Channel

The rock channel downstream of the fuse plug will narrow to 200 feet and continue in a straight line over a distance of 5,000 feet at gradients of 1.5 percent to 5 percent in the direction of Tsusena Creek. The flow will discharge into a small valley on the west side of and separate from the area of the relict channel. It is estimated that flows down the channel would continue for a period of 20 days under PMF conditions. Some erosion in the channel would occur, but the integrity of the main dam would not be impaired. The reservoir would be drawn down to Elevation 2170.

Reconstruction of the fuse plug would be required prior to refilling of the reservoir.

1.8 - Power Intake

[Note: This section will undergo revision after resolution of the design drawdown.]

(a) Intake Structure

The power intake will be a concrete structure located deep in the rock on the right bank. Access to the structure will be by road from the south side of the emergency spillway bridge.

In order to draw from the reservoir surface over a drawdown range of 140 feet, four openings will be provided in the upstream concrete wall of the structure for each of the six independent power intakes. The upper opening will always be open, but the lower three openings can be closed off by sliding steel shutters operated in a common guide. All openings will be protected by upstream trashracks. A heated boom will operate in guides upstream of the racks following the water surface, keeping the racks ice free.

A lower control gate will be provided in each intake unit. A single upstream bulkhead gate will be provided for routine maintenance of the six intake gates. In an emergency, stoplogs can be installed on the upstream wall of the power intake for work on the trashracks or shutter guides.

The overall base width of the intake will be 300 feet, providing a minimum spacing of penstock tunnel excavations of 2.5 times the excavated diameter.

The upper level of the concrete structure will be set at Elevation 2200, corresponding to the maximum anticipated flood level. The level of the lowest intake is governed by the vortex criterion for flow into the penstock from the minimum reservoir level elevation of 2045. The foundation of the structure will be approximately 200 feet below existing ground level and is expected to be in sound rock.

Mechanical equipment will be housed in a steel-frame building on the upper level of the concrete structure. The general arrangement of the power intake is shown on Plate 26.

(b) Approach Channel

The overall width of the approach channel is governed by the combined width of the power intake and the outlet facilities gate structure, and will be approximately 350 feet. The length of the channel will be 1,000 feet.

The maximum flow in the intake approach channel will occur when six machines are operating and the outlet facilities are discharging at maximum design capacity. With the reservoir drawn down to elevation 2045, the velocity in the approach channel will be 3.5 ft/s, which will not cause any erosion problems. Velocities of 10 ft/s may occur where the intake approach channel intersects the approach channel to the main spillway.

(c) Mechanical Arrangement

(i) Ice Boom

A heated boom will be installed in guides immediately upstream of the trashracks for each of the six power intakes. The boom will be operated by a movable hoist and will automatically follow the reservoir level. The boom will serve to minimize ice accumulation in the trashrack and intake shutter area, and prevent thermal ice-loading on the trashracks.

(ii) Trashracks

Each of the six power intakes will have four sets of trashracks, one set in front of each intake opening. Each set of trashracks will be in two sections to facilitate handling by the intake service crane. Each set of trashracks will cover an opening 30 feet wide by 24 feet high. The trashracks will have a bar spacing of 6 inches and will be designed for a maximum differential head of 20 feet.

(iii) Intake Shutters

Each of the six power intakes will have three intake shutters which will serve to prevent flow through the openings behind which the shutters will be installed. As the reservoir level drops, the sliding shutters will be removed as necessary using the intake service crane.

Each of the shutters will be designed for a differential head of 25 feet. The lowest shutter at each power intake will incorporate a flap gate which, with 25 feet differential head across the shutter, will allow maximum turbine flow through the gate. This will prevent failure of the shutters in the event of accidental blocking of all intake openings.

The shutter guides will be heated to facilitate removal in sub-freezing weather. In addition, a bubbler system will be provided in the intake behind the shutters to keep the intake structure water surface free of ice.

(iv) Intake Service Crane

A single, overhead, traveling-bridge type intake service crane will be provided in the intake service building. The crane will be used for:

- Servicing the ice bulkhead and ice bulkhead hoist;
- Handling and cleaning the trashracks;
- Handling the intake shutters;
- Handling the intake bulkhead gates; and
- Servicing the intake gate and hoist.

The overhead crane will have a double point lift and followers for handling the trashrack shutters and bulkhead gates. The crane will be radio-controlled with a pendant or cab control for backup.

(v) Intake Bulkhead Gates

One set of intake bulkhead gates will be provided for closing any one of the six intake openings upstream from the intake gates. The bulkhead gates will be used to permit inspection and maintenance of the intake shutters and intake guides. The gates will be designed to withstand full differential pressure.

(vi) Intake Gates

The intake gates will close a clear opening of 17 feet x 17 feet. They will be of the vertical fixed wheel lift type with upstream seals and skinplate.

Each gate will be operated by a hydraulic cylinder type hoist. The length of a cylinder will allow withdrawal of the gate from the water flow. The intake service crane will be used to raise the gate above deck level for maintenance. The gates will normally be closed under balanced flow conditions to permit dewatering of the penstock and turbine water passages for inspection and maintenance of the turbines. The gates will also be designed to close in an emergency with full turbine flow conditions in the event of loss of control of the turbine.

1.9 - Penstocks

The general arrangement of the penstocks is shown on Plates 23 and 25.

Six penstocks will be provided to convey water from the power intake to the powerhouse, one penstock for each generating unit. Each penstock will be a concrete lined rock tunnel, 17 feet internal diameter. The mininum lining thickness will be 12 inches, which will be increased as appropriate to withstand design internal pressures. The lateral spacing between penstocks will be 50 feet on centers at the intake and this will increase to 60 feet on centers at the powerhouse. The difference in lateral spacing will be taken out at the upper horizontal bend. The inclined sections of the concrete-lined penstocks will be at 55° to the horizontal.

The design static head on each penstock is 763 feet at centerline distributor level (Elevation 1422). An allowance of 35 percent has been made for pressure rise in the penstock caused by hydraulic transients.

(a) Steel Liner

The rock immediately adjacent to the powerhouse cavern will be incapable of resisting the internal hydraulic forces within the penstocks. Consequently, the first 50 feet of each penstock upstream of the powerhouse will be reinforced by a steel liner designed to resist the maximum design head, without support from the surrounding rock. Beyond this section the steel liner will be extended a further 150 feet, and support from the surrounding rock will be assumed, up to a maximum of 50 percent of the design pressure.

The steel liner will be surrounded by a concrete infill, with a minimum thickness of 24 inches. The internal diameter of the steel lining will be 15 feet. A steel transition will be provided between the liner and the 17-foot diameter concrete-lined penstock.

(b) Concrete Lining

The penstocks will be fully lined with concrete from the intake to the steel lined section, the thickness of lining varying with the external hydrostatic head. The internal diameter of the concrete lined penstock will be 17 feet. The minimum lining thickness will be 12 inches.

(c) Grouting and Pressure Relief System

A comprehensive pressure relief system will protect the underground caverns against seepage from the high pressure penstock. The system will comprise small diameter boreholes set out to intercept the jointing in the rock. A grouting and drainage gallery will be located upstream of the transformer gallery.

1.10 - Powerhouse

The underground powerhouse complex will be constructed beneath the north abutment of the dam. This will require the excavation in rock of three major caverns, the powerhouse, transformer gallery, and surge chamber with interconnecting rock tunnels for the draft tubes and isolated phase bus ducts.

Unlined rock tunnels, with concrete inverts where appropriate, will be provided for vehicular access to the three main rock caverns and the penstock construction adit. Vertical shafts will be provided for personnel access to the underground powerhouse, for cable ducts from the transformer gallery, for surge chamber venting and for the heating and ventilation system.

The general layout of the powerhouse complex is shown in plan and section in Plates 27 and 28, and in isometric projection in Plate 24. The transformer gallery will be located on the upstream side of the powerhouse cavern; the surge chamber will be located on the downstream side.

The draft tube gate gallery and crane will be located in the surge chamber cavern, above the maximum anticipated surge level. Provision will also be made in the surge chamber for tailrace tunnel intake stoplogs, which will be handled by the same crane.

(a) Access Tunnels and Shafts

Vehicular access to the underground facilities at Watana will be provided by a single unlined rock tunnel from the north bank area adjacent to the diversion tunnel portal. The access tunnel will cross over the diversion tunnels and then descend at a uniform gradient to the south end of the powerhouse cavern at generator floor level, Elevation 1463. Separate branch tunnels from the main tunnel will provide access to the transformer gallery at Elevation 1507, the penstock construction adit at Elevation 1420, and the surge chamber at Elevation 1500. The maximum gradient will be 6.9 percent on the construction access tunnel and on the permanent access tunnels.

The cross section of the access tunnel has a modified horseshoe shape, 35 feet wide by 28 feet high. The access tunnel branch to the surge chamber and draft tube gallery will have a reduced section, consistent with the anticipated size of vehicle and loading required.

The main access shaft will be at the north end of the powerhouse cavern, providing personnel access from the surface control building by elevator. Access tunnels will be provided from this shaft for pedestrian access to the transformer gallery and the draft tube gate gallery. Elevator access will also be provided to the fire protection head tank, located approximately 250 feet above powerhouse level. The main access shaft will be 20 feet in internal diameter with a concrete lining of 9 to 18 inches.

(b) Powerhouse Cavern

The main powerhouse cavern is designed to accommodate six vertical shaft Francis turbines, in line, with direct coupling to synchronous generators. Each unit has a nominal output of 170 MW.

The length of the cavern will allow for a unit spacing of 60 feet, with a 110-foot long service bay at the south end for routine maintenance and for construction erection. Vehicular access will be by tunnel to the generator floor at the south end of the cavern; pedestrian access will be by elevator from the surface control building to the north end of the cavern. Multiple stairway access points will be available from the main floor to each gallery level. Access to the transformer gallery from the powerhouse will be by tunnel from the main access shaft, or by stairway through each of the isolated phase bus shafts. A service elevator will be provided from the maintenance area on the main floor level to the machine shop and stores area on the turbine floor level.

Hatches will be provided through all main floors for installation and maintenance of heavy equipment using the powerhouse cranes.

(c) Transformer Gallery

The transformers will be located underground in a separate gallery, 120 feet upstream from the main powerhouse cavern, with three connecting tunnels for the isolated phase bus. There will be nine single-phase transformers rated at 15/345 kV, 122 MVA, installed in groups of three transformers for two generating units. Generator circuit breakers will be installed in the powerhouse on the lower generator floor level.

The transformer gallery is 45 feet wide, 40 feet high, and 414 feet long; the bus tunnels are 16 feet wide and 16 feet high.

High voltage cables will be taken to the surface by two cable shafts, each with an internal diameter of 7.5 feet. Provision has been made for installation of an inspection hoist in each shaft. A spare transformer will be located in the transformer gallery, and a spare HV circuit will also be provided for improved reliability. The station service auxiliary transformers (2 MVA) and the surface auxiliary transformer (7.5/10 MVA) will be located in the bus tunnels. Generator excitation transformers will be located in the powerhouse on the main floor.

Vehicle access to the transformer gallery will be the main powerhouse access tunnel at the south end. Pedestrian access will be from the main access shaft or through each of the three isolated phase bus tunnels.

(d) Surge Chamber

A surge chamber will be provided 120 feet downstream from the powerhouse cavern to control pressure fluctuations in the turbine draft tubes and tailrace tunnels under transient load conditions, and to provide storage of water for the machine start-up sequence.

The chamber will be common to all six draft tubes, and under normal operation will discharge equally to the two tailrace tunnels. The overall surge chamber size is 360 feet long, 50 feet wide, and 145 feet high (including the draft tube gate gallery).

The draft tube gate gallery and crane will be located in the same cavern, above the maximum anticipated surge level. The crane has also been designed to allow installation of tailrace tunnel intake stoplogs for emergency closure of either tailrace tunnel.

The chamber will generally be an unlined rock excavation, with localized rock support as necessary for stability of the roof arch and walls. The gate guides for the draft tube gates and tailrace stoplogs will be of reinforced concrete, anchored to the rock by rockbolts.

Access to the draft tube gate gallery will be by an adit from the main access tunnel. This access will be widened locally for storage of tailrace tunnel intake stoplogs.

(e) Grouting - Pressure Relief System

Control of seepage in the powerhouse area will be achieved by a grout curtain upstream of the transformer gallery and an arrangement of drainage holes downstream of this curtain. In addition, drain holes will be drilled from the caverns extending to a depth greater than the rock anchors. Seepage water will be collected by surface drainage channels and directed into the powerhouse drainage system.

(f) Cable Shafts

Cable shafts are 8.5 feet in excavated diameter. Although not required for rock stability, a 6-inch thick concrete lining has been specified for convenience of installing hoist, stairway and cable supports.

(g) Draft Tube Tunnels

The draft tube tunnels will be shaped to provide a transition to a uniform horseshoe section of 19 feet diameter with a 2.5 feet minimum thickness concrete lining. The initial rock support will be concentrated at the junctions with the powerhouse and surge chamber where the two free faces give greatest potential for block instability.

1.11 - Tailrace

Two tailrace pressure tunnels will be provided at Watana to carry water from the surge chamber to the river. The tunnels will have a modified horseshoe cross-section with a major internal dimension of 34 feet.

The tunnels will be fully concrete-lined throughout, with a minimum concrete thickness of 12 inches and a length of 1,800 feet. The tailrace tunnels will be arranged to discharge into the river between the main dam and the main spillway.

The upstream sections of the tailrace tunnels are on bearing 249° and parallel the main access tunnel. The southern tunnel joins the lower diversion tunnel and utilizes the diversion portal for the tailrace outlet. The northern tunnel changes direction at the downstream end to bear 238° and the portal is situated between the diversion tunnel portals and the spillway flip bucket. The tunnels are concrete-lined for hydraulic considerations.

The downstream portal of the northern tunnel is located between the spillway flip bucket and diversion tunnel portal. A rock berm will be left in place to the south of the portal to separate the outlet and diversion tunnel channels.

The tailrace portals will be reinforced concrete structures designed to reduce the outlet flow velocity, and hence the velocity head loss at the exit to the river.

1.12 - Access Roads

To be added in October.

1.13 - Site Facilities

(a) General

The construction of the Watana development will require various facilities to support the construction activities throughout the entire construction period. Following construction, the operation of the Watana hydroelectric development will require certain permanent staff and facilities to support the permanent operation and maintenance program.

The most significant item among the site facilities will be a combination camp and village that will be constructed and maintained at the project site. The camp/village will be largely a self-sufficient community housing 4,000 people during construction of the project. After construction is complete, it is planned to dismantle and demobilize most of the facility and to reclaim the area. The dismantled buildings and other items from the camp will be used as much as possible during construction of the Devil Canyon development. Other site facilities include contractors' work areas, site power, services, and communications. Items such as power and communications will be required for construction operations independent of camp operations. The same will be true regarding a hospital or first aid room.

Permanent facilities required will include a permanent town or small community for approximately 130 staff members and their families. Other permanent facilities will include a maintenance building for use during subsequent operation of the power plant.

A conceptual plan for the permanent town is shown on Plate 38.

(b) Temporary Camp and Village

The proposed location of the camp and village will be on the north bank of the Susitna River between Deadman and Tsusena Creek, approximately 2.5 miles northeast of the Watana Dam. The north side of the Susitna River was chosen because the main access will be from the north and south-facing slopes can be used for siting the structures. The location is shown in Plate 36.

The camp will consist of portable woodframe dormitories for bachelors with modular mess halls, recreational buildings, bank, post office, fire station, warehouses, hospital, offices, etc. The camp will be a single status camp for approximately 3,600 workers.

The village, accommodating approximately 350 families, will be grouped around a service core containing a school, gymnasium, stores, and recreation area.

The village and camp areas will be separated by approximately 1.5 miles to provide a buffer zone between areas. The hospital will serve both the main camp and village.

The camp location will separate living areas from the work areas by a mile or more and keep travel time to work to less than 15 minutes for most personnel.

The camp/village will be constructed in stages to accommodate the peak work force. The facilities have been designed for the peak work force plus 10 percent for turnover. The turnover will include allowances for overlap of workers and vacations. The conceptual layouts for the camp and village are presented on Plate 37 and 38.

(i) Site Preparation

Both the camp and the village areas will be cleared and in select areas, filter fabric will be installed, and granular material placed over it for building foundations. At the village site, selected areas will be left with trees and natural vegetation intact. Topsoil stripped from the adjacent dam borrow area will be utilized to reclaim camp and village sites.

Both the main camp and the village site have been selected to provide well-drained land with natural slopes of 2 to 3 percent.

(ii) Facilities

Construction camp buildings will consist largely of trailer-type factory-built modules assembled at site to provide the various facilities required. The modules will be fabricated complete with heating, lighting and plumbing services, interior finishes, furnishings, and equipment. Larger structures such as the central utilities building, warehouses and hospital will be pre-engineered, steel-framed structures with metal cladding.

(c) Permanent Town

The permanent town will be located at the north end of the temporary village (see Plate 36) and be arranged around a small lake for aesthetic purposes.

The permanent town will consist of permanently constructed buildings. The various buildings in the permanent town are listed below:

- Single family dwellings;
- Multifamily dwellings;
- Hospital;
- School;
- Fire station;
- A town center will be constructed and will contain the following:
  - a recreation center
  - a gymnasium and swimming pool
  - a shopping center

The concept of building the permanent town at the beginning of the construction period and using it as part of the temporary village was considered. This concept was not adopted, since its intended occupancy and use is a minimum of 10 years away, and the requirements and preferences of the potential long-term occupants cannot be predicted with any degree of accuracy.

(d) Site Power and Utilities

(i) Power

Electrical power will be required to maintain the camp/village and construction activities. A temporary 138 kV transmission line will be constructed along the Denali access route for use during the construction phase. This line will draw power from the Willow-Healey intertie which is currently under construction. After the Watana development is complete and the 345 kV transmission line supplying power to the Intertie from Watana is complete, this temporary line will be removed.

During the first two years of construction (1985 and 1986), until the 138 kV line is complete, the power supply will come from diesel generators. These generators will remain on site after 1987 as standby power supply. The peak demand during the peak camp population year is estimated at 13 MW for the camp/village and 7 MW for construction requirements totaling 20 MW of peak demand. The distribution system in the camp/village and construction area will be 4.16 kV.

Power for the permanent town will be supplied from the station service system after the power plant is in operation.

(ii) Water

The water supply system will provide for potable water and fire protection for the camp/village and selected contractors' work areas. The estimated peak population to be served will be 4,720 (3,600 in the camp and 1,120 in the village).

The principal source of water will be Tsusena Creek, with a back up system of wells drawing on ground water. The water will be treated in accordance with the Environmental Protection Agency's (EPA) primary and secondary requirements.

A system of pumps and storage reservoirs will provide the necessary system capacity. The distribution system will be contained within utilidors constructed using plywood box sections integral with the permawalks. The distribution and location of major components of the water supply system are presented in Plate 36. Details of the utilidors are presented in Plate 39.

(iii) Waste Water

A waste water collection and treatment system will serve the camp/village. One treatment plant will serve the camp/village using gravity flow lines with lift stations will be used to collect the waste water from all of the camp and village facilities. The "in-camp" and "in-village" collection systems will be run through the utilidors so that the collection system will be protected from freezing.

The chemical toilets located around the construction site will be serviced by sewage trucks, which will discharge directly into the sewage treatment plant. The sewage treatment system will be a biological system with lagoons designed to meet Alaskan and EPA standards. The sewage plant will discharge its treated effluent through a force main to Deadman Creek. All treated sludge will be disposed in a solid waste sanitary landfill.

The location of the treatment plant is shown in Plate 37. The location was selected to avoid unnecessary odors in the camp as the winds are from the southeast only 4 percent of the time, which is considered minimal.

(e) Contractor's Area

The onsite contractors will require office, shop, and general work areas. Partial space required by the contractors for fabrication shops, maintenance shops, storage or warehouses, and work areas, will be located between the main camp and the main access road.

1.14 - Relict Channel

A relict channel exists on the north bank of the reservoir approximately 2600 feet upstream of the dam. This channel runs from the Susitna River gorge to Tsusena Creek, a distance of about 1.5 miles. The surface elevation of the lowest saddle is approximately 2205, and depths of up to 454 feet of glacial deposits have been identified. This channel represents a potential source of leakage from the Watana reservoir. Along the buried channel thalweg, the highest, or controlling bedrock surface is some 450 feet below reservoir level, while along the shortest leakage path between the reservoir and Tsusena Creek the highest rock surface is some 250 feet below reservoir level. The maximum average hydraulic gradient along any flow path in the buried channel from the edge of pool to Tsusena Creek is approximately 9 percent, while the average gradient is believed to be less than 6 percent. There is no indication of any existing water-level connection between the Susitna River and Tsusena Creek. Tsusena Creek at the relict channel outlet area, is at least 120 feet above the natural river level. There are several surface lakes within the channel area, and some artesian water is present in places. Zones of permafrost have also been identified throughout the channel area.

To preserve the integrity of the rim of the Watana reservoir and to control losses due to potential seepage, a number of remedial measures will be undertaken. These measures are designed to deal with potential problems which may arise due to settlement of the reservoir rim, subsurface flows, permafrost and liquefaction during earthquakes.

(a) Surface Flows

To eliminate the potential problems associated with settlement and breaching of a saddle dam allowing surface flows through the buried channel area, the maximum operating level of the reservoir has been set at 2185 feet, leaving a natural saddle width of at least 1,500 feet of ground above pool level at this elevation. A freeboard dike with a crest elevation of 2210 will be constructed to provide protection against extreme reservoir wave levels under PMF conditions. The shortest distance between the toe of the dike and the edge of the Elevation 2185 reservoir pool is at least 450 feet, and under a PMF flood, the static water level will just reach the toe of the dike before the emergency fuse plug washes out. The freeboard dike will consist of compacted granular material placed on a prepared foundation from which all surface soils and organic materials will be removed.

(b) Subsurface Flows

The potential for progressive piping and erosion in the area of discharge into the Tsusena Creek will be controlled by the placement of properly graded granular materials to form a filter blanket over any zones of emergence. Further field investigations will be carried out to fully define critical areas, and only such areas will be treated. Continuous monitoring of the outlet area will be undertaken for a lengthy period after reservoir filling to ensure that a state of equilibrium is established with respect to permafrost and seepage gradients in the buried channel area.

If the permeability of the base alluvium is found to be excessive, a provision will also be made to carry out grouting of the upstream alluvium at a natural narrow reach to reduce the total leakage.

(c) Permafrost

Thawing of permafrost will occur, and may have an impact on subsurface flows and ground settlement. Although no specific remedial work is foreseen at this time, flows, ground water elevation, and ground surface elevation in the buried channel area will be carefully and continuously monitored by means of appropriate instrumentation systems and any necessary maintenance work carried out to maintain freeboard and control seepage discharge.

(d) Liquefaction

To guarantee the integrity of the reservoir rim through the channel area requires that either:

- There is no potential for a liquefaction slide into the reservoir, or

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

Any requirement of remedial treatment will depend on the location and extent of critical zones and could range from stabilization by compaction (vibroflotation), grouting techniques (either cement, colloidal or chemical grouting), or in the limit, removal of material, and replacement with compacted nonsusceptable fill.

Available geotechnical information indicates that the potential for liquefaction realistically exists only in the upper 140 feet of glacial deposits in the relict channel. Further geotechnical studies will be undertaken to fully define the extent and characteristics of these materials. Provisions will be made in design for treatment to cover the worst conditions identified. These measures include:

- Densification

  Layers within about 100 feet of the surface could be compacted by vibroflotation techniques to eliminate the risk of liquefaction and provide a stable zone by increasing the relative density of the in-situ material.

- Stabilization

  Critical layers at any depth could be grouted, either with cement for fine gravels and coarse sands or by chemical grouting for fine sands and silts.

- Removal

  This could range from the replacement of critical material near the valley slopes with high-quality, processed material, which would stabilize the toe of a potential slide and so prevent the initiation of failure that might otherwise cut back and cause major failures, to the excavation, blending, and replacement of large voluems of material to provide a stable zone.

The most positive solution to a worst case scenario is the replacement of the critical zone with material that would not liquefy. This would involve, in effect, the rearrangement of the in-place materials to create an underground dam section constructed of selected materials founded on the dense till layer beneath the critical alluvium. Such an operation will require the excavation of a trench up to 135 feet deep with a surface width up to 1,000 feet. Selected materials would be compacted to form a central stable zone while surplus and unsuitable materials would be placed on both sides of this central "dam" to complete backfilling to ground surface. The central zone would be designed to remain stable in the event that all upstream material did slide into the reservoir. Such a structure would be about 5,000 feet long, with a total cut volume of about 13 million cubic yards, of which 4-1/2 million cubic yards could be used in the compacted center zone. The cost of such work is estimated to be about $100 million. Although this is considered an unlikely scenario, contingency allowances will be adequate to cover this cost.

2 - RESERVOIR DATA - WATANA

The Watana reservoir, at normal operating level of 2185 feet (mean sea level) will be approximately 48 miles long with a maximum width in the order of 5 miles. The total water surface area at normal operating level is 37,800 acres.

3 - TURBINES AND GENERATORS - WATANA

3.1 - Unit Capacity

The Watana powerhouse will have six generating units with a nominal capacity of 170 MW corresponding to the minimum December reservoir level (elevation 2117) and a corresponding gross head of 662 feet on the station.

The head on the plant will vary from 590 feet to approximately 735 feet.

The rated head for the turbine has been established at 680 feet, which is the weighted average operating head on the station. The rated turbine output is 250,000 hp (186.5 MW) at full gate.

The generator rating has been selected as 190 MVA with a 90 percent power factor. The generators will be capable of a continuous 15 percent overload allowing a unit output of 196 MW. At maximum reservoir water level, the turbines will be operated below maximum output to avoid overloading of the generators.

3.2 - Turbines

The turbines will be of the vertical shaft Francis type with steel spiral casing and a concrete elbow-type draft tube. The draft tube will comprise a single water passage without a center pier.

The rated output of the turbines will be 250,000 hp at 680 feet rated net head. Maximum and minimum heads on the units will be 728 feet and 576 feet respectively. The full gate output of the turbines will be about 275,000 hp at 728 feet net head and 195,000 hp at 576 feet net heat. Overgating of the turbines may be possible, providing approximately 5 percent additional power; however, at high heads the turbine output will be restricted to avoid overloading the generators. The best efficiency point of the turbines will be established at the time of preparation of bid documents for the generating equipment and will be based on a detailed analysis of the anticipated operating range of the turbines. For preliminary design purposes, the best efficiency (best gate) output of the units has been assumed as 85 percent of the full gate turbine output.

The full gate and best gate efficiencies of the turbines will be about 91 percent and 94 percent respectively at rated head. The efficiency will be about 0.5 percent lower at maximum head and 1 percent lower at minimum head.

3.3 - Generators

(a) Type and Rating

The six generators in the Watana powerhouse will be of the vertical shaft, overhung type directly connected to the vertical Francis turbines. The arrangement of the units is shown in Plates 27 and 28 and the single line diagram is shown in Plate 32.

The optimum arrangement at Watana will consist of two generators per transformer bank, with each transformer bank comprising three single-phase transformers. The generators will be connected to the transformers by isolated phase bus through generator circuit breakers directly connected to the isolated phase bus ducts.

Each generator will be provided with a high initial response static excitation system. The units will be controlled from the Watana surface control room, with local control facility also provided at the powerhouse floor. The units will be designed for black start operation.

The generators are rated as follows:

Rated Capacity:	190 MVA, 0.9 power factor
Rated Power:	170 MW
Rated Voltage:	15 kV, 3 phase, 60 Hertz
Synchronous Speed:	225 rpm
Inertia Constant:	3.5 MW-sec/MVA
Transient Reactance:	28 percent (maximum)
Short Circuit Ratio:	1.1 (minimum)
Efficiency at Full Load:	98 percent (minimum)

The generators will be of the air-cooled type, with water-to-air heat exchangers located on the stator periphery. The ratings given above are for a temperature rise of the stator and rotor windings not exceeding 60°C with cooling air at 40°C.

The generators will be capable of delivering 115 percent of rated MVA continuously (195.5 MW) at a voltage of ± 5 percent without exceeding 80°C temperature rise in accordance with ANSI Standard C50.10.

The generators will be capable of continuous operation as synchronous condensers when the turbine is unwatered, with an underexcited reactive power rating of 140 MVAR and an overexcited rating of 110 MVAR. Each generator will be capable of energizing the transmission system without risk of self-excitation.

The design data of the generators stated above should be reviewed during the detailed design stage for overall economic and technical design and performance requirements of the power plant and the power system.

The design data of the generators stated above should be reviewed during the detailed design stage for overall economic and technical design and performance requirements of the power plant and the power system.

(b) Unit Dimensions

Approximate dimensions and weights of the principal parts of the generator are given below:

Stator pit diameter:	36 feet
Rotor diameter:	22 feet
Rotor length (without shaft):	7 feet
Rotor weight:	385 tons
Total weight:	740 tons

It should be noted that these are approximate figures and they will vary between manufacturers.

(c) Generator Excitation System

The generator will be provided with a high initial response type static excitation system supplied with rectified excitation power from transformers connected directly to the generator terminals. The excitation system will be capable of supplying 200 percent of rated excitation field (ceiling voltage) with a generator terminal voltage of 70 percent. The power rectifiers will have a one-third spare capacity to maintain generation even during failure of a complete rectifier module.

The excitation system will be equipped with a fully static voltage regulating system maintaining output from 30 percent to 115 percent, within ± 0.5 percent accuracy of the voltage setting. Manual control will be possible at the excitation board located on the powerhouse floor, although the unit will normally be under remote control.

3.4 - Governor System

The governor system which control the generating unit will include a governor actuator and a governor pumping unit. A single system will be provided for each unit. The governor actuator will be the electric hydraulic type and will be connected to the computerized station control system.

4 - TRANSMISSION LINES - FROM WATANA TO INTERTIE AND INTERITE TO ANCHORAGE/FAIRBANKS

4.1 - Transmission Requirements

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

4.2 - Description of Facilities

The project transmission system will ultimately comprise the following components:

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

Substations for this system will be located at each power site and also at Ester (Fairbanks), Willow, Knik Arm (east shore), and University (Anchorage). The Ester substation will provide a connection of Susitna power to the Golden Valley Electric Association (GVEA) system and the University substation to the Chugach Electric Association (CEA) and Anchorage Municipal Light and Power (AMLP) systems. The segment of the system between Willow and Healy will incorporate and include the intertie which is currently being constructed as a single line to be operated initially at 138 kV and subsequently upgraded to 345 kV.

The selected route is shown in Figures 1 through 14. [To be included later].

The required right-of-way will vary from 400 feet for 3 lines to 700 feet for 5 lines. The corridor and route selection process was based on evaluation of technical, economic, and environental criteria and a number of alternatives. Particular emphasis was placed on satisfying regulatory and permit requirements, aesthetics and avoidance of developed areas.

The selected tower design consists of a hinged-guyed, two-legged steel X-tower, similar to that used for the intertie. Design features of these towers include hinged connections between the leg members and foundations and longitudinal guy systems which provide flexibility and stability. These are important considerations in the unique soil and climate conditions in this area of Alaska. The arrangement will result in relatively smaller loads on the foundations. The recommended types of foundations are the rock anchor and the pile foundation. The selected design is considered to be a sound compromise of realibility, durability, economy, and aesthetics.

4.3 - Construction Staging

The initial development of Watana will require staged development of transmission facilities to Fairbanks and Anchorage. The first stage is shown in solid lines and includes the following:

Substations	Line Section	Number of Circuits
Watana	Watana to Devil Canyon	2
Devil Canyon	Devil Canyon to Willow	2
Willow	Willow to Kwik Arm	2
Knik Arm	Knik Arm Crossing	2
University (Anchorage)	Knik Arm to University	2
Ester (Fairbanks)	Devil Canyon to Fairbanks	2

The transmission will consist of two circuits from Watana to the load centers. The conductor for the sections from Watana to Knik Arm, and Watana to Fairbanks will consist of bundled 2 x 954 kcmil, ACSR. The section between Knik Arm and University will employ bundled 2 x 1351 kcmil, ACSR. The submarine cable crossing will consist of two circuits. The cable will be single conductor, 3.45 kV self-contained oil-filled. For project purposes, the cable size will be 500 mm^2. A size of up to 1500 mm^2 may be installed if duty requirements are increased. For reliability, a spare cable will be included on a standby basis.

The Matnuska Electric Association will be serviced from the Willow and Knik Arm substations via step down transformers to suit the local voltage. Chugach Electric Association, Anchorage Municipal Light and Power and Golden Valley Electric Association will be serviced through the University substation in Anchorage and Ester substation at Fairbanks.

5 - APPURTENANT MECHANICAL AND ELECTRICAL EQUIPMENT - WATANA

5.1 - Miscellaneous Mechanical Equipment

(a) Powerhouse Cranes

Two overhead traveling bridge type powerhouse cranes will be installed in the powerhouse. The cranes will be used for:

- Installation of turbines, generators, and other powerhouse equipment; and

- Subsequent dismantling and reassembly of equipment during maintenance overhauls.

Each crane will have a main and auxiliary hoist. The combined capacity of the main hoist for both cranes will be sufficient for the heaviest equipment lift, which will be the generator rotor, plus an equalizing beam. A crane capacity of 205 tons has been established. The auxiliary hoist capacity will be about 25 tons.

(b) Draft Tube Gates

Draft tube gates will be provided to permit dewatering of the turbine water passages for inspection and maintenance of the turbines. The draft tube gate openings (one opening per unit) will be located in the surge chamber. The gates will be of the bulkhead type, installed under balanced head conditions using the surge chamber crane. Four sets of gates have been assumed for the six units, with each gate 20 feet wide by 10 feet high.

(c) Surge Chamber Gate Crane

A crane will be installed in the surge chamber for installation and removal of the draft tube gates as well as the tailrace tunnel intake stoplogs. The crane will either be a monorail (or twin monorail) crane, a top running crane, or a gantry crane. The crane will be about 30 tons in capacity, and will have a two point lift.

(d) Miscellaneous Cranes and Hoists

In addition to the powerhouse cranes and surge chamber gate crane, the following cranes and hoists will be provided in the power plant:

- A 5-ton monorail hoist in the transformer gallery for transformer maintenance;

- A 4-ton monorail hoist in the circuit breaker gallery for handling the main circuit breakers;

- Small overhead jib or A-frame type hoists in the machine shop for handling material; and

- A-frame or monorail hoists for handling miscellaneous small equipment in the powerhouse.

(e) Elevators

Access and service elevators will be provided for the power plant as follows:

- An access elevator from control buildings to powerhouse;
- A service elevator in the powerhouse service bay; and
- Inspection hoists in the cable shafts.

(f) Power Plant Mechanical Service Systems

The mechanical service systems for the power plant can be grouped into six major categories:

(i) Station Water Systems

The station water systems will include the water intake, cooling water systems, turbine seal water systems, and domestic water systems. The water intakes will supply water for the various station water systems in addition to fire protection water.

(ii) Fire Protection System

The power plant fire protection system will consist of a fire protection water system with fire hose stations located throughout the powerhouse and transformer gallery; sprinkler systems for the generators, transformers, and the oil rooms; and portable fire extinguishers located in strategic areas of the powerhouse and transformer gallery. Fire hose stations will be provided on all floors of the powerhouse, in the transformer gallery, and in the bus tunnels.

(iii) Compressed Air Systems

Compressed air will be required in the powerhouse for the following:

- Service air;
- Instrument air;

- Generator brakes;
- Draft tube water level depression;
- Air blast circuit breakers; and
- Governor accumulator tanks.

For the preliminary design, two compressed air systems have been assumed: a 100-psig air system for service air, brake air, and air for draft tube water level depression; and a 1,000-psig high-pressure air system for governor air and circuit breaker air. For detailed plant design, a separate governor air system and circuit-breaker air system may be provided.

(iv) Oil Storage and Handling

Facilities will be provided for replacing oil in the transformers and for topping-up or replacing oil in the turbine and generator bearings and the governor pumping system.

For preliminary design purposes, two oil rooms have been included, one in the transformer gallery and one in the powerhouse service bay.

(v) Drainage and Dewatering Systems

The drainage and dewatering systems will consist of:

- A unit dewatering and filling system;
- A clear water discharge system; and
- A sanitary drainage system.

The unit dewatering and filling systems will consist of two sumps each with two dewatering pumps and associated piping and valves from each of the units. To prevent station flooding, the sump will be designed to withstand maximum tailwater pressure. A valved draft tube drain line will connect to a dewatering header running along the dewatering gallery. The spiral case will be drained by a valved line connecting the spiral case to the draft tube. Suitable provisions will be necessary to insure that the spiral case drain valve is not open when the spiral case is pressurized to headwater level. The dewatering pump discharge line will discharge water into the surge chamber. The general procedure for dewatering a unit will be to close the intake gate, drain the penstock to tailwater level through the unit, then install the draft tube gates open the draft tube and spiral case drains to dewater the unit. Unless the drainage gallery is below the bottom of the draft tube elbow, it will not be possible to completely dewater the draft tube through the dewatering header. If necessary, the remainder of the draft tube can be unwatered using a submersible pump lowered through the draft tube access door. Unit filling to tailwater level will be accomplished from the surge chamber through the dewatering pump discharge line (with a bypass around the pumps) and then through the draft tube and spiral case drain lines. Alternatively, the unit can be filled to tailwater level through the draft tube drain line from an adjacent unit. Filling the unit to headwater pressure will be accomplished by "cracking" the intake gate and raising it about 2 to 4 inches.

(vi) Heating, Ventilation, and Cooling

The heating, ventilation, and cooling system for the underground power plant will be designed primarily to maintain suitable temperatures for equipment operation and to provide a safe and comfortable atmosphere for operating and maintenance personnel.

The power plant will be located in mass rock which has a constant year around temperature of about 40°F. Considering heat given off from the generators and other equipment, the primary requirement will be for air cooling. Initially, some heating will be required to offset the heat loss to the rock, but after the first few years of operation an equilibrium will be reached with a powerhouse rock surface temperature of about 60 to 70°F.

(g) Surface Facilities Mechanical Service Systems

The mechanical services at the control building on the surface will include:

- A heating, ventilation, and air conditioning system for the control room;

- Domestic water and washroom facilities; and

- A halon type fire protection system for the control room.

Domestic water will be supplied from the powerhouse domestic water system, with pumps located in the powerhouse and piping up through the access shaft. Sanitary drainage from the control building will drain to the sewage treatment plant in the powerhouse through piping in the access tunnel.

The standby generator building will have the following services:

- A heating and ventilation system;

- A fuel oil system with buried fuel oil storage tanks outside the building, and transfer pumps and a day tank within the building; and

- A fire protection system of the carbon dioxide or halon type.

(h) Machine Shop Facilities

A machine shop and tool room will be located in the powerhouse service bay area with sufficient equipment to take care of all normal maintenance work at the plant, as well as machine shop work for the larger components at Devil Canyon.

5.2 - Accessory Electrical Equipment

The accessory electrical equipment described in this section includes the following:

. Main generator step-up 15/345 kV transformers;
. Isolated phase bus connecting the generator and transformers;
. Generator circuit breakers;
. 345 kV oil-filled cables from the transformer terminals to the switchyard;
. Control systems of the entire hydro plant complex; and
. Station service auxiliary AC and DC systems.

Other equipment and systems described include grounding, lighting system, and communications.

The main equipment and connections in the power plant are shown in the single line diagram, Plate 32. The arrangement of equipment in the powerhouse, transformer gallery, and cable shafts is shown on Plates 27 through 29.

(a) Transformers and H.V. Connections

Nine single-phase transformers and one spare transformer will be located in the transformer gallery. Each bank of three single-phase transformers will be connected to two generators through generator circuit breakers by isolated phase bus located in individual bus tunnels. The HV terminals of the transformer will be connected to the 345 kV switchyard by 345 kV single-phase oil-filled cable installed in 700-footlong vertical shafts. There will be two sets of three single- phase 345 kV oil-filled cables installed in each cable shaft. One set will be maintained as a spare three phase cable circuit in the second cable shaft. These cable shafts will also contain the control and power cables between the powerhouse and the surface control room, as well as emergency power cables from the diesel generators at the surface to the underground facilities.

(b) Main Transformers

The nine single-phase transformers (three transformers per group of two generators) and one spare transformer, will be of the two winding, oil-immersed, forced-oil water-cooled (FOW) type, with rating and electric characteristics as follows:

Rated capacity:	145 MVA
High voltage winding:	345 / 3 kV, Grounded Y
Basic insulation level (BIL) of H.V. winding:	1300 kV
Low voltage winding:	15 kV, Delta
Transformer impedance:	15 percent

The temperature rise above air ambient temperature of 40°C is 55°C for the windings for continuous operation at the rated kVA.

Fire walls will separate each single-phase transformer. Each transformer will be provided with fog-spray water fire protection equipment, automatically operated from heat detectors located on the transformer.

(c) Generator Isolated Phase Bus

The isolated phase bus main connections will be located between the generator, generator circuit breaker, and the transformer.

Tap-off connections will be made to the surge protection and potential transformer cubicle, excitation transformers, and station service transformers. Bus duct ratings are as follows:

	Generator Connection	Transformer Connection
Rated current, amps	9,000	18,000
Short circuit current momentary, amps	240,000	240,000
Short circuit current, symmetrical, amps	150,000	150,000
Basic insulation level, kV (BIL)	150	150

The bus conductors will be designed for a temperature rise of 65°C above 40°C ambient temperature.

(d) Generator Circuit Breakers

The generator circuit breakers will be of the enclosed air circuit breaker design suitable for mounting in line with the generator isolated phase bus ducts. They are rated as follows:

Rated Current:	9,000 Amps
Voltage:	23 kV class, 3-phase, 60 Hertz
Breaking capacity, symmetrical, amps	150,000

The short circuit rating is tentative and will depend on detailed analysis in the design stage.

(e) 345 kV Oil-Filled Cable

The recommended 345 kV connection is a 345 kV oil-filled cable system between the high voltage terminals of the transformer and the surface switchyard. The cable will be installed in a vertical cable shaft. Cables from two transformers will be installed in a single cable shaft.

The cable will be rated for a continuous maximum current of 800 amps at 345 kV ±5 percent. The maximum conductor temperature at the maximum rating will be 70°C over a maximum ambient of 35°C. This rating will correspond to 115 percent of the generator overload rating. The normal operating rating of the cable will be 87 percent, with a corresponding lower conductor temperature which will improve the overall performance and lower cable aging over its project operating life. Depending on the ambient air temperature, a further overload emergency rating of about 10 to 20 percent will be available during winter conditions.

The cables will be of single-core construction with oil flow through a central oil duct within the copper conductor. Cables will have an aluminum sheath and PVC oversheath. No cable jointing will be required for the 700 to 800 feet length cable installation.

(f) Control Systems

(i) General

A Susitna Area Control Center will be located at Watana to control both the Watana and the Devil Canyon power plants as shown in Plate 34. The control center will be linked through the supervisory system to the Central Dispatch Control Center at Willow as described in Exhibit B, Section (c)(3).

The supervisory control of the entire Alaska Railbelt system will be done at the Central Dispatch Center at Willow. A high level of control automation with the aid of digital computers will be sought but not a complete computerized direct digital control of the Watana and Devil Canyon power plants. Independent operator controlled local-manual and local-auto operations will still be possible at Watana and Devil Canyon power plants for testing/commissioning or during emergencies. The control system will be designed to perform the following functions at both power plants:

- Start/stop and loading of units by operator;
- Load-frequency control of units;
- Reservoir/water flow control;
- Continuous monitoring and data logging;
- Alarm annunciation; and
- Man-machine communication through visual display units (VDU) and console.

In addition, the computer system will be capable of retrieval of technical data, design criteria, equipment characteristics and operating limitations, schematic diagrams, and operating/ maintenance records of the unit.

The Susitna Area Control Center will be capable of completely independent control of the Central Dispatch Center in case of system emergencies. Similarly it will be possible to operate the Susitna units in an emergency situation from the Central Dispatch Center, although this should be an unlikely operation considering the size, complexity, and impact of the Susitna generating plants on the system.

The Watana and Devil Canyon plants will be capable of "black start" operation in the event of a complete black out or collapse of the power system. The control systems of the two plants and the Susitna Area Control Center complex will be supplied by a non-interruptible power supply.

(ii) Unit Control System

The unit control system will permit the operator to initiate an entire sequence of actions by pushing one button at the control console, provided all preliminary plant conditions have been first checked by the operator, and system security and unit commitment have been cleared through the central dispatch control supervisor. Unit control will be designed to:

- Start a unit and synchronize it with the system;
- Load the unit;
- Stop a unit;
- Operate a unit as spinning reserve (runner in air with water blown down in turbine and draft tube); and
- Operate as a synchronous condenser (runner in air as above).

(iii) Computer-Aided Control System

The computer-aided control system at the Susitna Area Control Center at Watana will provide for the following:

- Data acquisition and monitoring of unit (MW, MVAR, speed, gate position, temperatures, etc.);
- Data acquisition and monitoring of reservoir headwater and tailwater levels;
- Data acquisition and monitoring of electrical system voltage and frequency;
- Load-frequency control;
- Unit start/stop control;
- Unit loading;
- Plant operation alarm and trip conditions (audible and visual alarm on control board, full alarm details on VDU on demand);
- General visual plant operation status on VDU and on giant wall mimic diagram;
- Data logging, plant operation records;
- Plant abnormal operation or disturbance automatic recording; and
- Water management (reservoir control).

The block diagram of the computer-aided control system is shown in Plate 34.

(iv) Local Control and Relay Boards

Local boards will be provided at the powerhouse floor equipped with local controls, alarms, and indications for all unit control functions. These boards will be located near each unit and will be utilized mainly during testing, commissioning, and maintenance of the turbines and generators. It will also be utilized as needed during emergencies if there is a total failure of the remote or computer-aided control systems.

(v) Load-Frequency Control

The load-frequency system will provide remote control of the output of the generator at Watana and Devil Canyon from the central dispatch control center through the supervisory and computer-aided control system at Watana. The basic method of load frequency control will use the plant error (differential) signals from the load dispatch center and will allocate these errors to the power plant generators automatically through speed-level motors. Provision will be made in the control system for the more advanced scheme of a closed-loop control system with digital control to control generator power.

The control system will be designed to take into account the digital nature of the controller-timed pulses as well as the inherent time delays caused by the speed-level motor run-up and turbine-generator time-constants.

(g) Station Service Auxiliary AC and DC Systems

(i) Auxiliary AC System

The station service system will be designed to achieve a reliable and economic distribution system for the power plant and switchyard, in order to satisfy the following requirements:

- Station service power at 480 volts will be obtained from two 2,000 kVA auxiliary transformers connected directly to the generator circuit breaker outgoing leads of Units 1 and 3;

- Surface auxiliary power at 34.5 kV will be supplied by two separate 7.5/10 MVA transformers connected to the generator leads of Units 1 and 3;

- Station service power will be maintained even when all the units are shut down and the generator circuit breakers are open;

- 100 percent standby transformer capacity will be available;

- A spare auxiliary transformer will be maintained, connected to Unit 5; and

- "Black start" capability will be provided for the power plant in the event of total failure of the auxiliary supply system, 500 kW emergency diesel generators will be automatically started up to supply the power plant and switchyard with auxiliary power to the essential services to enable startup of the generators.

The main ac auxiliary switchboard will be provided with two bus sections separated by bus-tie circuit breakers. Under normal operating conditions, the station-service load is divided and connected to each of the two end incoming transformers. In the event of failure of one end supply, the tie breakers will close automatically. If both end supplies fail, the emergency diesel generator will be automatically connected to the station service bus.

Each unit will be provided with a unit auxiliary board supplied by separate feeders from the two bus section feeder from the two bus section of the main switchborad interlocked to prevent parallel operation. Separate ac switchboards will furnish the auxiliary power to essential and general services in the power plant.

The unit auxiliary board will supply the auxiliaries necessary for starting, running, and stopping the generating unit. These supplies will include those to the governor and oil pressure system, bearing oil pumps, cooling pumps and fans, generator circuit breaker, excitation system, and miscellaneous pumps and devices connected with unit operation.

The 34.5 kV sypply to the surface facilities will be distributed from a 34.5 kW switchboard located in the surface control and administration building. Power supplies to the switchyard, power intake, and spillway as well as the lighting systems for the access roads and tunnels will be obtained from the 34.5 kV switchboard.

The two 2000 kVA, 15000/480 volt stations service transformers and the spare transformer will be of the 3-phase, dry-type, sealed gas-filled design. The two 7.5/10 MVA, 15/34.5 kV transformers will be of the 3-phase oil-immersed OA/FA type.

Emergency diesel generators, each rated 500 kW, will separately supply the 480 volt and 34.5 kV auxiliary switchboards during emergencies. Both diesel generators will be located in the surface control building.

An uninteruptible high security power supply will be provided for the computer control system.

(ii) DC Auxiliary Station Service System

The dc auxiliary system will supply the protective relaying, supervisory, alarm, control, tripping and indication circuit in the power plant. The generator excitation system will be started with "flashing" power from the dc battery. It will also supply the emergency lighting system at critical plant locations.

(h) Grounding System

The power plant grounding system will consist of one mat under the power plant, one mat under the transformer gallery, risers, and connection ground wires. Grounding grids will also be included in each powerhouse floor.

(i) Lighting System

The lighting system in the powerhouse will be supplied from 480/208-120 volts lighting transformers connected to the general ac auxiliary station service system. An emergency lighting system will be provided at the power plant and at the control room at all critical operating locations.

(j) Communications

The power plant will be furnished with an internal communications system, including an automatic telephone switchboard system. A communication system will be provided at all powerhouse floors and galleries, transformer gallery, access tunnels and cable shafts, and structures at the power intake, draft tube gate area, main spillway, dam, outlet facilities, and emergency release facilities.

5.3 - Switchyard Structures and Equipment

(a) Single Line Diagram

A "breaker-and-a-half" single line arrangement will be provided for reliability and security of the power system. Plate 33 shows the details of the switchyard single line diagram.

(b) Switchyard Equipment

The number of 345 kV circuit breakers is determined by the number of elements to be switched such as lines or in-feeds from the powerhouse. Each breaker will have two disconnect switches to allow safe maintenance.

The auxiliary power for the switchyard will be derived from the generator bus via a 15 - 34.5 kV transformer and 34.5 kV cable. The voltage will then be stepped down to 480 V for use in the switchyard.

(c) Switchyard Structures and Layout

The switchyard layout will be based on a conventional outdoor type design. The design adopted for this project will provide a two level bus arrangement. This design is commonly known as a low station profile.

The two level bus arrangement is desirable because it is less prone to extensive damage in case of an earthquake. It is also easier to maintain low level busses.

6 - PROJECT LANDS

The purpose of this section is to provide an overview of the results obtained through the identification of the general land ownership status within the Upper Susitna River Basin and the Anchorage-Fairbanks Intertie Corridor.

6.1 - Significant Land Policies Affecting the Study Area

The Federal government remains the largest land owner in Alaska. However, this domination of ownership has been eroded with the passage of the Alaska Statehood Act in 1959 and the Alaska Native Claims Settlement Act in 1971. These Acts have placed in question the ultimate land ownership patterns of the State with competition for the land divided among the Federal government, the State of Alaska, and private Native regional and village corporations.

With the enactment of the Statehood Act, the State of Alaska became entitled to a total of 104.5 million acres. Section 6(b) of the Act included 102.5 million acres of general grant lands to be used at the discretion of the State. In addition, certain federal lands were to be held in trust for both public schools and for the University of Alaska. Public Law 84-830, passed in 1956, provided for one million acres of mental health grant lands.

In 1978, the State legislature passed a law designed to convert the 1.2 million acres of land held as special trusts for funding public schools, mental health programs, and the University of Alaska into general grant lands to be treated in the same manner as other State-held land. The plan was to replace the land with an annual income, a percentage of the total receipts from the management of State land, including oil royalties. However, the University of Alaska exercised its option and turned down this trust and retains management over the lands it holds title to.

The State of Alaska has granted land entitlements to the organized Boroughs and Municipalities. As a result of this entitlement, both the Matanuska-Susitna and North Star Boroughs have extensive land holdings. The Municipality of Anchorage has received it entitlement, which is considerably less than that received by the Boroughs.

In response to increasing public pressure and changing laws, the State legislature passed HB66 in 1979, charging the Department of Natural Resources with the responsibility of disposing 100,000 acres of land annually to private ownership. This land is disposed through four methods: direct sale, homesites, remote parcels, and agricultural rights. It is apparent from recent discussions between the Alaska Power Authority and the State Division of Lands that the State Division of Lands is severely encumbered by its requirement to annually dispose of 100,000 acres of land to the public. Consequently, necessary regional and site considerations, e.g. proposed Intertie Corridor, relating to the disposal of these lands are frequently omitted from the State's land disposal selection process.

With the passage of the Alaska Native Claims Settlement Act (ANCSA) in 1971, the State of Alaska was no longer the sole entity selecting federal lands. Under the Act, private Native regional and village corporations were entitled to select lands from the Federal government holdings and from those lands previously selected, but not patented to the State of Alaska. To date, neither the State nor the Native Corporations has received its full entitlement under the Statehood Act and the Alaska Native Claims Settlement Act.

6.2 - Present Land Ownership Trends

(a) Anchorage-Willow

This section contains a complex mixture of land ownership with the extensive private ownership interspersed with large blocks of State and Borough lands. The State has reserved several areas for public recreational use (Nancy Lake State Recreation area, Goose Bay and Susitna Flats Game Refuge, and Chugach State Park). The only large State land disposal within this area is the Pt. MacKenzie Agricultural Project scheduled for spring 1981. The holdings by the Federal government are dominated by military reserves in the Anchorage area.

(b) Willow-Talkeetna

This area is characterized by numerous private holdings along the Parks Highway. Large blocks of State, Native, and Borough lands dominate the remainder of the land in this area. Numerous State land disposals have taken place and are projected for this area.

(c) Talkeetna-Fairbanks

This section represents an area of large blocks of State owned land. Numerous private holdings are concentrated in scattered communities located along the Parks Highway. The most notable of these are Cantwell, Healy, Clear, and Nenana. Cantwell and Nenana are both surrounded by large blocks of Native lands. Both the Denali State Park and the Mt. McKinley National Park are located in this section.

(d) Upper Susitna River Basin

The land status in this area is relatively simple, due to the large amount of public land managed by the Bureau of Land Management. There are large blocks of private Native Village Corporation lands along th Susitna River. Other private holdings consist of widely scattered remote parcels. The State has selected much of the Federal land in this area and is expected to receive patent.

6.3 - Land Status Methodology

The following sources were used to identify the ownership and other interests within the Anchorage-Fairbanks Transmission Line Corridor and Upper Susitna River Basin:

Alaska Department of Natural Resources
Alaska Department of Transportation
Bureau of Land Management
Cook Inlet Region, Inc., Land Records
Matanuska-Susitna Borough Tax Assessor Records
Municipality of Anchorage Tax Assessor Records
North Star Borough Land Management Records

Within all areas researched, four general categories of land ownership; i.e., Federal, State, Borough, and Private, are depicted at a scale of 1 inch=1 mile (1:63,360). However, please note that the land status within the corridor continues to be quite fluid and subject to frequent change. The most immediate change comes with the passage of the D-2 legislation. For example, those areas shown to be under a 204-C Withdrawal classification will be incorporated into the National Park System. While the boundaries of the 204-C Withdrawal areas may vary slightly from that shown on the maps, they will not vary to a degree that would significantly impact the overall land status pattern.

Several areas and designations may cause some confusion and are clarified as follows:

(a) Private Land classification do not distinguish between individual landowners (e.g. native corporations) or numerous landowners (e.g. subdivisions).

(b) Federal Lands in the vicinity of Healy have been leased by the Alaska Railroad to private citizens.

(c) Cantwell Townsite contains a mixed ownership pattern with Federal Land interspersed among numerous private parcels.

(d) Native Allotments are designated as Federal Lands but may become private as claims are approved.

(e) Mineral Leases or Mining Claims are not shown on either State or Federal Lands.

(f) Leased parcels of five or less acres are classified private, as they can be expected to receive patent from the State in the near future.

(g) Lands in the Upper Susitna River Basin have previously been withdrawn for the power project under several PLO's (PLO 5654, 2961, and 3458).

(h) Certain lands in the Susitna River area are shown as State Selection suspended. These lands are also selected by the Village Corporations and CIRI. The selections will likely be approved and transferred to the State if the August 31, 1976 agreement between the Department of Interior, CIRI, and the Village Corporations is implemented. It is also a matter involving litigation.

(i) It should be noted that University lands are managed by the Board of Regents and not under control by the Department of Natural Resources.

7 - PROJECT STRUCTURES - DEVIL CANYON DEVELOPMENT

This section describes the various components of the Devil Canyon development, including diversion facilities, emergency release facilities, main dam, primary outlet facilities, reservoir, main and emergency spillway, saddle dam, the power intake, penstocks, and the powerhouse complex, including turbines, generators, mechanical and electrical equipment, switchyard structures, and equipment and project lands. A summary of project parameters is in Table A.1.

A description of permanent and temporary access and support facilities is also included.

7.1 - General Arrangement

The Devil Canyon reservoir and surrounding area is shown on Plate 40. The site layout in relation to main access facilities and camp facilities is shown on Plate 72. A more detailed arrangement of the various site structures is presented in Plate 41.

The Devil Canyon dam will form a reservoir approximately 26 miles long with a surface area of 7,800 acres and a gross storage capacity of 1,100,000 acre-feet at Elevation 1455, the normal maximum operating level. The operating level of the Devil Canyon reservoir is controlled by the tailwater level of the upstream Watana development. The maximum water surface elevation during flood conditions will be 1465.3. The minimum operating level of the reservoir will be 1405, providing a live storage during normal operation of 200,000 acre-feet.

The dam will be a thin arch concrete structure with a crest elevation of 1463 and maximum height of 646 feet. The dam will be supported by mass concrete thrust blocks on each abutment. On the south bank, the lower bedrock surface will require the construction of a substantial thrust block. Adjacent to this thrust block, an earth- and rockfill saddle dam will provide closure to the south bank. The saddle dam will be a central core type generally similar in cross section to the Watana dam. The dam will have a nominal crest elevation of 1469 with an additional 3 feet of overbuild for potential seismic settlement. The maximum height above foundation level of the dam is approximately 245 feet.

During construction, the river will be diverted by means of a single 30-foot-diameter concrete-lined diversion tunnel on the south bank of the river.

A power intake, located on the north bank, will comprise an approach channel excavated in rock leading to a reinforced concrete gate structure. From the intake structure four 20-foot-diameter concrete-lined penstock tunnels will lead to an underground powerhouse complex housing four 150 MW units with Francis turbines semi-umbrella type generators each rated at 180 MVA. Access to the powerhouse complex will be by means of an unlined access tunnel approximately 3,200 feet long as well as by a 950-foot deep vertical access shaft. Turbine discharge will be conducted to the river by means of a single 38-foot-diameter tailrace tunnel leading from a surge chamber downstream from the powerhouse cavern. Compensation flow pumps at the power plant will ensure suitable flow in the river for environmental makeup requirements between the dam and tailrace tunnel outlet portal. A separate transformer gallery just upstream from the powerhouse cavern will house twelve single-phase 15/345-KV transformers. The transformers will be connected by 345-KV, single phase, oil-filled cable through a cable shaft to the switchyard at the surface.

Outlet facilities consisting of seven individual outlet conduits will be located in the lower part of the main dam. These will be designed to discharge all flood flows of up to 38,500 cfs, the estimated 50-year flood. Each outlet conduit will have a fixed-cone valve similar to those provided at Watana to dissipate energy and minimize undesirable nitrogen supersaturation in the flows downstream. The main spillway will also be located on the north bank. As at Watana, this spillway will consist of an upstream ogee control structure with three vertical fixed-wheel gates and an inclined concrete chute and flip bucket designed to pass a maximum discharge of 125,000 cfs. This spillway, together with the outlet facilities, will thus be capable of discharging the estimated 10,000-year flood. An emergency spillway and fuse plug on the south bank will provide sufficient additional capacity to permit discharge of the PMF without overtopping the dam.

7.2 - Arch Dam

The Devil Canyon Dam will be located at the Devil Canyon gorge, River Mile 152, approximately 32 miles downstream from Watana. The arch dam will be located at the upstream entrance of the canyon.

The dam will be a thin-arch concrete structure 646 feet high, with a crest length-to-height ratio of approximately 2, and designed to withstand dynamic loadings from intense seismic shaking. The proposed height of the dam is well within precedent.

(a) Foundations

Bedrock is well exposed along the canyon walls and the arch dam will be founded on sound bedrock. Approximately 20 to 40 feet of weathered and/or loose rock will be removed beneath the dam foundation. All bedrock irregularities will be smoothed out beneath the foundation to eliminate high stress concentrations within the concrete. During excavation the rock will also be trimmed, as far as is practical, to increase the symmetry of the centerline profile and provide a comparatively uniform bearing stress distribution across the dam. Areas of deteriorated dikes and the local areas of poorer qulaity rock will be excavated and supplemented with dental concrete.

The foundation will be consolidation grouted over its entire area, and a double grout curtain up to 300 feet deep will run beneath the dam and its adjacent structures as shown in Plate 51. Grouting will be done from a system of galleries which will run through the dam and into the rock. Within the rock these galleries will also serve as collectors for drainage holes which will be drilled just downstream of the grout curtain and intercept any seepage passing through the curtain.

(b) Arch Dam Geometry

The canyon is V-shaped below Elevation 1350. Sound bedrock does not exist above this level on the left abutment and an artificial abutment is provided up to the crest Elevation 1463 in the form of a massive concrete thrust block designed to take the thrust from the upper arches of the dam. A corresponding block is formed on the right abutment to provide as symmetrical a profile as possible bordering the dam and giving a symmetrical stress distribution across the faces of the horizontal arches.

Two slight ridges are formed by the rock at both abutments. The arch dam abuts the upstream side of these such that the plane of the contact of the horizontal arches is generally normal to the faces of the dam. An exception is in the lower portion of the dam where the rock in the upstream corners is retained in order to decrease the excavation.

The dam bears directly on the rock foundation over the entire length of the contact surface. The bedrock at the foundation will be excavated to remove all weathered material and further trimmed to provide a smooth line to the foundation, thus avoiding abrupt changes in the dam profile and consequent stress concentrations.

The dam is a double curvature structure with a copola shape of the crown cantilever defined by vertical curves of approximately 1352 feet and 893 feet radius. The horizontal arches are based on a two-center configuration with the arches prescribed by varying radii moving along two pairs of center lines. The shorter radii of the intrados face cause a broadening of the arches at the abutment, thus reducing the contact stresses. The dam reference plane is approximately central to the floor of the canyon and the two-center configuration assigns longer radii to the arches on the wider right side of the valley, thus providing comparable contact areas and central angles on both sides of the arches at the concrete/rock interface. The longer radii will also allow the thrust from the arches to be directed more into the abutment rather than parallel to the river. The net effect of this two-center layout will be to improve the symmetry of the arch stresses across the dam.

The crown cantilever is 643 feet high. It is 20 feet thick at the crest and 90 feet at the base, a base width to height ratio of 0.140. The radii of the dam axis at crest level are 697 feet and 777 feet for the left and right sides of the dam, respectively. The central angles vary between 53° at Elevation 1300 and 10° at the base for the left side of the arch, and 57° to 10° for the right side. The dam crest length is 1260 feet and the ratio of crest length to height for the dam is 1.96 (thrust blocks not included). The volume of concrete in the dam is approximately 1.3 x 10^6 cubic yards.

(c) Thrust Blocks

The thrust blocks are shown on Plate 50. The massive concrete block on the left abutment is 113 feet high and 200 feet long. It will be formed to take the thrust from the upper part of the dam above the existing sound rock level. It will also serve as a transition between the concrete dam and the adjacent rockfill saddle dam. The inclined end face of the block will abut and seal against the impervious saddle dam core and be enveloped by the supporting rock shell.

The 113 foot high, 125 foot long thrust block formed high on the right abutment at the end of the dam, adjacent to the spillway control structure, will transmit thrust from the dam through the intake control structure and into the rock.

7.3 - Saddle Dam

The saddle dam at Devil Canyon, which is of similar configuration as the main Watana dam, will be of earth and rockfill construction and will consist of a central compacted core protected by fine and coarse filters upstream and downstream. The downstream outer shell will consist of two zones: a lower zone of clean pressed rockfill material and an upper zone of unprocessed rockfill material. The upstream outer shell will consist of cleaned and graded rockfill material. A typical cross section is shown on Plate 53 and described below.

(a) Typical Cross Section

The central core slopes are 1H:4V with a top width of 35 feet. The thickness of the core at any section will be slightly more than 0.5 times the head of water at that section. Minimum core-foundation contact will be 50 feet, requiring flaring of the cross section at the abutments.

The upstream and downstream filter zones will increase in thickness from 45 and 30 feet, respectively, near the crest of the dam to a maximum of approximately 60 feet at the filter-foundationc contact. They are sized to provide protection against possible piping through transverse cracks that could occur because of settlement or resulting from internal displacement during a seismic event.

Protection against wave and ice action on the upstream slope will consist of a 10-foot layer of riprap comprising quarried rock up to 36 inches in size.

The estimated volume of material needed to construct the saddle dam are approximately:

- core material:	310,000 cubic yards
- fine filter material:	230,000 cubic yards
- coarse filter material:	180,000 cubic yards
- rockfill material:	1,200,000 cubic yards

The saturated sections of both shells will be constructed of compacted clean rockfill, processed to remove fine material in order to minimize pore pressure generation and ensure rapid dissipation during and after a seismic event. The lower section of the downstream shell, due to a unique combination of bedrock and topographic elevations, may become saturated by natural runoff or dam seepage. During design the cost of a major drainage system to prevent this occurrence will be weighed against the added cost of processing the materials for lower portion of the fill. Since pore pressures cannot develop in the unsatured upper section of the downstream shell, the material in that zone will be unprocessed rockfill from surface or underground excavations.

(b) Crest Details and Freeboard

A 3 foot high parapet will be constructed on the crest of the arch dam to provide a freeboard of 11 feet.

The highest reservoir level will be Elevation 1465.3 under PMF conditions. At this elevation, the fuse plug in the emergency spillway will have been breached and the reservoir level will fall to the spillway sill elevation of 1434. The normal maximum pool elevation is 1455.

The typical crest detail for the saddle dam is shown in Plate 53. Because of the narrowing of the dam crest, the filter zones are reduced in width and the upstream and downstream coarse filters are eliminated. A layer of filter fabric is incorporated to protect the core material from damage by frost penetration and dessication, and to act as a coarse filter where required.

A minimum saddle dam freeboard of three feet will be provided for the PMF: hence, the nominal crest of the saddle dam will be Elevation 1469. In addition, an allowance of one percent of the height of the dam will be made for potential settlement of the rockfill shells under seismic loading. An allowance of one foot has been made for settlement adjacent to the abutments; hence, the constructed crest elevations of the saddle dam will be 1470 at the abutments, rising in proportion to the total height of the dam to Elevation 1472 at the maximum section. Under normal operating conditions, the freeboard will range from 15 feet at the abutments to 17 feet at the center of the dam. Further allowances will be made to compensate for static settlement of the dam after completion due to its own weight and the effect of saturation of the upstream shell, which will tend to produce additional breakdown of the rock fill at point contacts. Therefore, one percent of the dam height will be allowed for such settlement, giving a maximum crest elevation on completion of the construction of 1475 at the maximum height, and 1471 at the abutments.

The allowances for post-construction settlement and seismic slumping will be achieved by steepening both slopes of the dam above Elevation 1400. These allowances are considered conservative,

(c) Grouting and Pressure Relief System

The rock foundation will be improved by consolidation grouting over the core contact area and by a grouted cutoff along the centerline of the core. The cutoff at any location will extend to a depth of a least 0.7 of the water head at that location as shown on Plate 51.

A grouting and drainage tunnel will be excavated in bedrock beneath the dam along the centerline of the core and will connect with a similar tunnel beneath the adjacent concrete arch dam and thrust block. Pressure relief and drainage holes will be drilled from this tunnel and seepage from the drainage system will be discharged through the arch dam drainage system to ultimately exit downstream below tailwater level.

(d) Instrumentation

Instrumentation will be installed within all parts of the dam to provide monitoring during construction as well as during operation. Instruments for measuring internal vertical and horizontal displacements, stresses and strains, and total and fluid pressures, as well as surface monuments and markers similar to those proposed for the Watana dam, will be installed.

7.4 - Diversion

(a) General

Diversion of the river flow during construction will be through a single 30-foot-diameter concrete-lined diversion tunnel on the south bank. The tunnel will have a horseshoe-shaped cross-section and be 1,490 feet in length. The diversion tunnel plan and profile is shown on Plate 54.

The tunnel is designed to pass a flood with a return frequency of 1:25 years routed through the Watana Reservoir. The peak flow that the tunnel will discharge will be 37,800 cfs. The maximum water surface elevation upstream of the cofferdam will be Elevation 944. A rating curve is presented in Figure 13.1.

(b) Cofferdams

The upstream cofferdam will consist of a zoned embankment founded on a closure dam (see Plate 54). The closure dam will be constructed to Elevation 915 based on a low water elevation of 910 and will consist of coarse material on the upstream side grading to finer material on the downstream side. When the closure dam is completed, a grout curtain or slurry wall cut-off will be constructed to minimize seepage into the main dam excavation. Final details of this cut-off will be determined following further investigations to define the type and properties of river alluvium. The abutment areas will be excavated to sound rock prior to placement of any cofferdam material.

The cofferdam, from Elevation 915 to 947, will be a zoned embankment consisting of a central core, fine and coarse upstream and downstream filters, and rock and/or gravel shells with riprap on the upstream face. The downstream cofferdam will be a similar closure dam constructed from Elevation 860 to 895, with a cut-off to bedrock.

The upstream cofferdam crest elevation will have a 3 foot freeboard allowance for settlement and wave runup. Under the proposed schedule, the Watana development will be operational when this cofferdam is constructed. Thermal studies conducted show that discharge from the Watana reservoir will be at 34°F when passing through Devil Canyon. Therefore, an ice cover will not form upstream of the cofferdam, and no freeboard allowance for ice will be necessary.

(c) Tunnel Portals and Gates

A gated concrete intake structure will be located at the upstream end of the tunnel (see Plate 55). The portal and gate will be designed for an external pressure (static) head of 250 feet.

Two 30 feet high by 15 feet wide water passages will be formed in the intake structure, separated by a central concrete pier. Gate guides will be provided within the passages for the operation of 30-foot high by 15-foot wide fixed wheel closure/control gates.

Each gate, which will be operated by a wire rope hoist in an enclosed housing, will be designed to operate with a 75-foot operating head (Elevation 945).

Stoplog guides will be installed in the diversion tunnel to permit dewatering of the diversion tunnel for plugging operations. The stoplogs will be in sections to facilitate relatively easy handling, with a mobile crane using a follower beam.

(d) Final Closure and Reservoir Filling

Upon completion of the Devil Canyon dam to a height sufficient to allow ponding to a level above the outlet facilities, the intake gates will be partially closed, allowing for a discharge of minimum environmental flows while raising the upstream water level. Once the level rises above the lower level of discharge valves, the diversion gates will be permanently closed and discharge will be through the 90-inch-diameter fixed cone valves in the dam. The diversion tunnel will be plugged with concrete and curtain grouting performed around the plug. Construction will take approximately 1 year. During this time the reservoir will not be allowed to rise above Elevation 1135.

The filling of the reservoir from this elevation will take approximately 2 to 3 weeks to operating Elevation 1455.

7.5 - Outlet Facilities

The primary function of the outlet facilities is to provide for discharge through the main dam, in conjunction with the power facilities, of routed floods with up to 1:50 years recurrence period at the Devil Canyon reservoir. This will require a total discharge capacity of 38,500 cfs through the valves. The use of fixed-cone valves will ensure that downstream erosion will be minimal and nitrogen supersaturation of the releases will be reduced to acceptable levels, as in the case of the Watana development. A further function of these releases is to provide an emergency drawdown for the reservoir, should maintenance be necessary on the main dam or low level submerged structures, and also to act as a diversion facility during the latter part of the construction period.

The outlet facilities will be located in the lower portion of the main dam, as shown on Plate 52, and will consist of seven fixed-cone discharge valves set in the lower part of the arch dam.

(a) Outlet

The fixed-cone type discharge valves will be located at two elevations: the upper group, consisting of four 102-inch diameter valves, will be set at Elevation 1050, and the lower group of three 90-inch diameter valves will be set at Elevation 930. The valves will be installed nearly radially (normal to the dam centerline) with the points of impact of the issuing jets staggered as shown in Plate 52.

The fixed-cone valves will be installed on individual conduits passing through the dam, set close to the downstream face, and protected by upstream ring follower gates located in separate chambers within the dam. Provisions will be made for maintenance and removal of the valves and gates. The gates and valves will be linked by a 20-foot-high gallery running across the dam and into the left abutment where access will be provided by means of a vertical shaft exiting through the thrust block. Although secondary access will be provided via a similar shaft from the north abutment, primary access and installation are both from the south side.

The valve and gate assemblies will be protected by individual trashracks installed on the upstream face. The racks will be removable along guides running on the upstream dam face. The racks will be raised by operating at deck level. Guides will be installed for the installation of bulkhead gates, if required, at the upstream face. The bulkhead gates will be handled by a travelling gantry crane located at the top of the dam.

(b) Fixed-Cone Valves

The 102-inch diameter valves operating at a gross head of 420 feet and the 90-inch diameter valves operating at a head of 525 feet have been selected to be within current precedent considering the valve size and the static head on the valve. The valves will be located in individually heated rooms and will be provided with electric jacket heaters installed around the cylindrical sleeve of each valve. The valves will be capable of year round operation, although winter operation is not contemplated. Normally, when the valves are closed, the upstream ring follower gates will also be closed to minimize leakage and freezing of water through the valve seats.

The valves will be operated remotely by two hydraulic operators. Operation of the valves will be from either Watana or by local operation.

(c) Ring Follower Gates

Ring follower gates will be installed upstream of each valve. The ring follower gates will have nominal diameters of 102 and 90 inches and will be of welded or cast steel construction. The gates will be designed to withstand the total static head under full reservoir.

The design and arrangement of the ring follower gates will be as for Watana.

(d) Trashracks

A steel trashrack will be installed at the upstream entrance to each water passage to prevent debris from being drawn into the discharge valves. The bar spacing on the racks will be approximately 9 inches. Provision will be made for monitoring head loss across the racks.

(e) Bulkhead Gates

The bulkhead gates will be installed only under balanced head conditions using the gantry crane. The gates will be 13 feet and 11 feet square for the upper and lower valves, respectively.

Each gate will be designed to withstand full differential head under maximum reservoir water level. One gate for each valve size has been assumed. The gates will be stored at the dam crest level.

A temporary cover will be placed in the bulkhead gate check at trashrack level to prevent debris from getting behind the trashracks.

The bulkhead gates and trashracks will be handled by an electric travelling gantry type crane located on the main dam crest at Elevation 1468. The crane and lifting arrangement will have provision for lowering a gate around the curved face of the dam.

7.6 - Main Spillway

The main spillway at Devil Canyon will be located on the north side of the canyon (see Plate 56). The upstream control structure will be adjacent to the arch dam thrust block and will discharge down an inclined concrete-lined chute constructed on the steep face of the canyon wall. The chute will terminate in a flip bucket which will direct flows downstream and into the river.

The spillway will be designed to pass the 1:10,000 year Watana routed flood in conjunction with the outlet facilities. The spillway will have a design capacity of 125,000 cfs discharged over a total head drop of 550 feet. No surcharge will occur above the normal maximum reservoir operating level of 1,455 feet during passage of this flood.

(a) Approach Channel and Control Structure

The approach channel will be excavated to a depth of approximately 100 feet in the rock with a width of just over 130 feet and an invert elevation of 1375.

The control structure, as shown in Plate 57, will be a three-bay concrete structure set at the end of the channel. Each bay will incorporate a 56-foot-high by 30-foot-wide gate on an ogee-crested weir and, in conjunction with the other gates, will control the flows passing through the spillway. The gates will be fixed wheel gates operated by individual rope hoists.

A gallery is provided within the mass concrete weir from which grouting can be carried out and drain holes can be drilled as a continuation of the grout curtain and drainage beneath the main dam. The main access route will cross the control structure deck upstream of the gate tower and bridge structure.

(b) Spillway Chute

The spillway chute will be excavated in the steep north face of the canyon for a distance of approximately 900 feet, terminating at Elevation 1000. The chute will taper uniformly over its length from 122 feet at the upstream end to 80 feet downstream. The chute will be concrete-lined with invert and wall slabs anchored to the rock.

The velocity at the lower end of the chute will be approximately 150 ft/s. In order to prevent cavitation of the chute surfaces, air will be introduced into the discharges. As at Watana, air will be drawn in along the chute via an underlying aeration gallery and offshoot ducts extending to the downstream side of a raised step running transverse to the chute.

An extensive underdrainage system will be provided, similar to that described for Watana, to ensure adequate underdrainage of the spillway chute and stability of the structure. This system is designed to prevent excessive uplift pressures due to reservoir seepage under the control structure and from ground water and seepage through construction joints from the high velocity flows within the spillway itself.

The dam grout curtain and drainage system will be extended under the spillway control structure utilizing a gallery through the rollway. A system of box drains will be installed for the entire length of the spillway under the concrete slab. To avoid blockage of the system by freezing of the surface drains, a 30-foot deep drainage gallery will also be constructed along the entire length of the spillway. Drain holes from the surface drains will intersect the gallery. To ensure adequate foundation quality for anchorage, consolidation grouting will be undertaken to a depth of 20 feet. Drainage holes drilled into the base of the high rock cuts will ensure increased stability of the excavation.

(c) Flip Bucket

The spillway chute will terminate in a mass concrete flip bucket founded on sound rock at Elevation 970, approximately 100 feet above the river. Detailed geometry of the curve of the flow surface of the bucket will be confirmed by means of hydraulic model tests. A grouting/drainage gallery will be provided within the bucket. The jet issuing from the bucket will be directed downstream and parallel to the river alignment.

(d) Plunge Pool

The impact area of the issuing spillway discharge will be limited to the area of the river surface downstream to prevent excessive erosion of the canyon walls. This will be done by appropriate shaping of the flow surface of the flip bucket on the basis of model studies. Over this impact area the alluvial material in the riverbed will be excavated down to sound rock to provide a plunge pool in which most of the inherent energy of the discharges will be dissipated, although some energy will already have been dissipated by friction in the chute, and in dispersion and friction through the air.

7.7 - Emergency Spillway

The emergency spillway will be located on the south side of the river south of the rockfill saddle dam. It will be excavated within the rock underlying the south side of the saddle and will continue downstream for approximately 2,000 feet.

An erodible fuse plug, consisting of impervious material and fine gravels, will be constructed at the upstream end of the spillway. It will be designed to wash out when overtopped by the reservoir, releasing flows of up to 160,000 cfs in excess of the combined main spillway and outlet capacities and thus preventing overtopping of the main or saddle dams during the passage of the PMF.

(a) Fuse Plug and Approach Channel

The approach channel to the fuse plug will be excavated in the rock and will have a width of 220 feet and an invert elevation of 1434. The channel will be crossed by the main access road to the dam on a bridge consisting of concrete piers, precast beams, and an in situ concrete bridge deck. The fuse plug will fill the approach channel and will have a maximum height of 31.5 feet with a crest elevation of 1465.5. The plug will be located on top of a flatcrested concrete weir placed on an air excavated rock foundation. The plug will be traversed by a pilot channel with an invert elevation of 1464.

(b) Discharge Channel

The channel will narrow downstream, leading into a steep valley tributary above the Susitna River. This channel will rapidly erode under high flows but will serve the purpose of training the initial flows in the direction of the valley and away from the permanent project facilities.

7.8 - Devil Canyon Power Facilities

(a) Intake Structure

The intake structure is located on the south side of the canyon as shown on Plate 64. Separate intakes are provided for each turbine. Reservoir levels will vary between Elevations 1455 and 1405. Each intake will be provided with a single intake gate, a set of steel trashracks, and provision for placing bulkhead gates upstream from the intake gate. A traveling gantry crane on the intake deck at Elevation 1466 will service all four intakes. The mechanical equipment is described in more detail below.

The intake will be located at the end of a 200-foot-long unlined approach channel. The overburden in this area is estimated to be approximately 10 feet deep. The excavation for the intake structure will require four tunnel portals on 60 foot centers. Rock pillars 32 feet wide and 38 feet deep will separate the portals.

(b) Intake Gates

Each of the four power intakes will have a single fixed wheel intake gate with a nominal operating size of 20-feet-wide by 25-feet-high. The gates will have an upstream skinplate and seal and will be operated by hydraulic or wire rope hoists located in heated enclosures immediately below deck level. The gates, which will normally close under balanced head conditions to permit dewatering of the penstock and turbine water passages for turbine inspection and maintenance, will also be capable of closing under their own weight with full flow conditions and maximum reservoir water level in the event of runaway of the turbines. A heated air vent will be provided at the intake deck to satisfy air demand requirements when the intake gate is closed with flowing water conditions.

(c) Intake Bulkhead Gates

One set of intake bulkhead consisting of two gate sections will be provided for closing the intake openings. The gate will be used to permit inspection and maintenance of the intake gate and intake gate guides. The gates will be raised and lowered under balanced water conditions only.

(d) Trashracks

Each of the four intakes will have trashracks at the upstream face. The trashrack will have a bar spacing of about 6 inches and be designed for a maximum differential head of about 20 feet. Each trashrack will be constructed in two sections for removal by means of a follower suspended from the intake gantry crane.

(e) Intake Gantry Crane

A 50-ton capacity (approximately) electrical traveling gantry crane will be provided on the intake deck at Elevation 1466 for handling the trashracks, and intake bulkhead gates and for servicing the intake gate equipment.

7.9 - Penstocks

The power plant will have four penstocks, one for each unit. The maximum static head on each penstock will be 638 feet, as measured from normal maximum operating level (Elevation 1455) to centerline distributor level (Elevation 817). An allowance of 35 percent has been made for pressure rise in the penstock under transient conditions, giving a maximum head of 861 feet. Maximum extreme head (including transient loadings) corresponding to maximum reservoir flood level will be 876 feet.

The penstock tunnels are fully concrete-lined except for a 250-foot section upstream of the powerhouse which is steel-lined. The inclined sections of the concrete-lined penstocks will be at 55° to the horizontal.

(a) Steel Liner

The steel-lined penstock will be 15 feet in diameter. The first 50 feet of steel liner immediately upstream of the powerhouse will be designed to resist the full internal pressure. The remainder of the steel liner, extending another 200 feet upstream, will be designed to partially resist the internal pressure together with the rock. Beyond the steel liner, the hydraulic loads are supported solely by the rock tunnel with a concrete liner.

The steel liner is surrounded by a concrete infill with a minimum thickness of 24 inches. A tapered steel transition will be provided at the junction between the steel liner and the concrete liner to increase the internal diameter from 15 feet to 20 feet.

(b) Concrete Liner

The thickness of the concrete lining will vary with the design head, with the minimum thickness of lining being 12 inches.

The internal diameter of the concrete liner is 20 feet.

(c) Grouting and Pressure Relief System

A comprehensive pressure relief system will be installed to protect the underground caverns against seepage from the high pressure penstocks and reservoirs. The system will consist of small diameter boreholes set out in an array to intercept the jointing in the rock. Grouting round the penstocks will also be undertaken.

7.10 - Powerhouse and Related Structures

The underground powerhouse complex will be constructed in the north side of the canyon. This will require the excavation of three major caverns (powerhouse, transformer gallery and surge chamber), with interconnecting rock tunnels for the draft tubes and isolated phase bus ducts.

An unlined rock tunnel will be constructed for vehicular access to the three main rock caverns. A second unlined rock tunnel will provide access from the powerhouse to the foot of the arch dam.

Vertical shafts will be required for personnel access by elevator to the underground powerhouse; for oil filled cable from the transformer gallery; and for surge chamber venting.

The draft tube gate gallery and cavern will be located in the surge chamber cavern, above maximum design surge level.

The general layout of the powerhouse complex is shown on Plates 65, 66 and 67. The transformer gallery will be located upstream of the powerhouse cavern and the surge chamber located downstream of the powerhouse cavern. The spacing between the underground caverns has been fixed so as to be at least 1.5 times the main span of the larger excavation.

(a) Access Tunnels and Shafts

The 3,000-foot long main access tunnel will connect the powerhouse cavern at Elevation 858 with the canyon access road on the north bank. A secondary access tunnel runs from the main powerhouse access tunnel to the foot of the arch dam, for routine maintenance of the fixed cone valves. Branch tunnels from the secondary access tunnel will provide construction access to the lower section of the penstocks at Elevation 820. Separate branch tunnels from the main access tunnel give vehicle access to the transformer gallery at Elevation 896 and the draft tube gate gallery at Elevation 908. The maximum gradient on the permanent access tunnel is 8 percent; the maximum gradient on the secondary access tunnel is 9 percent.

The cross section of the access tunnels, which is dictated by requirements for construction plant, is modified horseshoe shape 35-feet wide by 28-feet high.

The main access shaft will be located at the north end of the powerhouse cavern, providing personnel access by elevator from the surface. Horizontal tunnels will be provided from this shaft for pedestrian access to the transformer gallery and the draft tube gate gallery. At a higher level, access will also be available to the fire protection head tank.

Access to the upstream grouting gallery will be from the transformer gallery main access tunnel, at a maximum gradient of 13.5 percent.

The cross section of the access tunnels, which is dictated by requirements for construction plant, is a modified horseshoe shape 35-feet wide by 28-feet high.

The main access shaft will be located at the north end of the powerhouse cavern, providing personnel access by elevator from the surface. Horizontal tunnels will be provided from this shaft for pedestrian access to the transformer gallery and the draft tube gate gallery. At a higher level, access will also be available to the fire protection head tank.

Access to the upstream grouting gallery will be from the transformer gallery main access tunnel, at a maximum gradient of 13.5 percent.

(b) Powerhouse Cavern

The main powerhouse cavern is designed to accommodate four vertical shaft Francis turbines, in line, with direct coupling to overhung generators. Each unit is rated at 150 MW at 575-foot net head.

The unit spacing will be 60 feet with an additional 110-foot service bay at the south end of the powerhouse for routine maintenance and construction erection. The control room will be located at the north end of the main powerhouse floor. The width of the cavern will be sufficient for the physical size of the generator plus galleries for piping, air-conditioning ducts, electrical cables, and isolated phase bus. The overall size of the powerhouse cavern will be 74 feet wide, 360 feet long, and 133 feet high.

Compensation flow of 500 cfs will be provided by two 1300 hp vertical shaft mixed flow pumps, installed in a gallery below the service bay. Each pump is rated at 115,000 gpm at 35-foot head. Water will be taken from the base of the surge chamber and pumped 1000 feet to the dam toe through a discharge pipe laid partly in the secondary access tunnel and partly in a separate outlet tunnel.

Multiple stairway access points will be available from the powerhouse main floor to each gallery level. Access to the transformer gallery from the powerhouse will be by a tunnel from the access shaft or by a stairway through each of the four bus tunnels. Access will also be available to the draft tube gate gallery by a tunnel from the main access shaft.

A service elevator will be provided for access from the service bay area on the main floor to the machine shop, and the dewatering and drainage galleries on the lower floors. Hatches will be provided through all main floors for installation and routine maintenance of pumps, valves and other heavy equipment using the main powerhouse crane.

(c) Transformer Gallery

The transformers will be located underground in a separate unlined rock cavern, 120 feet upstream of the powerhouse cavern, with four interconnecting tunnels for the isolated phase bus. There will be 12 single-phase transformers with one group of three transformers for each generating unit. Each transformer is rated at 13/345, 70 MVA. For increased reliability, one spare transformer and one spare HV circuit will be provided. The station service transformers and the surface facilities transformers will be located in the bus tunnels. Generator excitation transformers will be located on the main powerhouse floor. The overall size of the transformer gallery will be 43 feet wide, 40 feet high, and 421 feet long; the bus tunnels will be 14 feet wide and 14 feet high.

High voltage cables will be taken to the surface in two 7.5 foot interval diameter cable shafts, and provision will be made for an inspection hoist in each shaft.

Vehicle access to the transformer gallery will be from the south end via the main powerhouse access tunnel. Personnel access will be from the main access shaft or through each of the four isolated phase bus tunnels.

(d) Surge Chamber

A simple surge chamber will be constructed 120 feet downstream of the powerhouse to control pressure fluctuations in the turbine draft tubes and tailrace tunnel under transient load conditions, and on machine start-up. The chamber will be common to all four draft tubes and the inlet pipe to the compensation flow pumps. The overall size of the chamber will be 75 feet wide, 300 feet long, and 188 feet high.

The draft tube gate gallery and crane will be located in the same cavern, above the maximum anticipated surge level. Access to the draft tube gate gallery will be by a rock tunnel from the main access tunnel. The tunnel will be widened locally for storage of the draft tube gates.

The chamber will be an unlined rock excavation with localized rock support as necessary for stability of the roof arch and walls. The guide blocks for the draft tube gates will be of reinforced concrete anchored to the rock excavation by rock bolts.

(e) Draft Tube Tunnels

The orientation of the draft tube tunnels will be 300°. The tunnels will be 23 feet in diameter and steel and concrete lined, with the concrete having a thickness of about 2 feet.

7.11 - Tailrace Tunnel

The tailrace pressure tunnel will convey power plant discharge from the surge chamber to the river. The tunnel has a modified horseshoe cross section with an internal dimension of 38 feet, and will be concrete lined throughout with a minimum thickness of 12 inches. The length of the tunnel is 6800 feet.

The tailrace portal site will be located at a prominent steep rock face on the right bank of the river. The portal outlet is rectangular in section, which reduces both the maximum outlet velocity (8ft/s) as well as the velocity head losses. Vertical stoplog guides are provided for closure of the tunnel for tunnel inspection and/or maintenance.

7.12 - Access Roads

To be added in October.

7.13 - Site Facilities

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

As described for Watana, a camp and construction village will be constructed and maintained at the project site. The camp/village will provide housing and living facilities for 2,300 people during construction. Other site facilities include contractor's work areas, site power, services, and communications. Items such as power and communications and hospital services will also be required for construction operations independent of camp operations.

Buildings used for the Watana development will be used where possible in the Devil Canyon development. Current planning calls for dismantling and reclaiming the site after construction. Electric power will be provided from the Watana development. The salvaged building modules used from the Watana camp/village will be retrofitted from fuel oil heating to electric heat.

(a) Temporary Camp and Village

The proposed location of the camp/village is on the south bank of the Susitna River between the damsite and Portage Creek, approximately 2.5 miles southwest of the Devil Canyon dam (see Plate 72). The south side of the Susitna was chosen because the main access road in this area will be from the south. South-facing slopes will be used for the camp/village location.

The camp will consist of portable woodframe dormitories for single status workers with modular mess halls, recreational buildings, bank, post office, fire station, warehouses, hospital, offices, etc. The camp will be a single status camp for approximately 1,780 workers.

The village, designed for approximately 170 families, will be grouped around a service core containing a school, gymnasium, stores, and recreation area.

The two areas will be separated by approximately 1/2 mile to provide a buffer zone between areas. The hospital will serve both the main camp and the village.

This camp location will be separated from the work areas by approximately a mile. Travel time to the work area will generally be less than 15 minutes.

The camp/village will be constructed in stages to accommodate the peak work force as presented in Table 13.1. Table 13.1 also presents the camp/village facility design numbers. The facilities have been designed for the peak work force plus 10 percent for "turnover". The "turnover" includes provisions or buffers for overlap of workers and vacations. The conceptual layouts for the camp/village are presented in Plates 73 and 74.

Construction camp buildings will consist largely of trailer-type factory-built modules assembled at site to provide the various facilities required. The modules will be fabricated with heating, lighting, and plumbing services, interior finishes, furnishings, and equipment. Trailer modules will be supported on timber cribbing or blocking approximately two feet above grade.

Larger structures, such as the central utilities building, gym, and warehouses, will be pre-engineered, steel-framed structures with metal cladding.

The various buildings in the camp are identified on Plate 73.

(b) Site Power and Utilities

(i) Power

A 345 kV transmission line from Watana and a substation will be in service during the construction activities. Two transformers will be installed at the substation to reduce the line voltage to the desired voltage levels. One of these transformers will be the same used during the Watana development.

Power will be sold to the contractors by the Power Authority. The peak demand during construction is estimated at 20 MW for the camp/village and 4 MW for construction requirements for a total of 24 MW. The distribution system for the camp/village will be 4.16 kV.

(ii) Water

The water supply system will serve the entire camp/village and selected contractor's work areas. The water supply system will provide for potable water and fire protection. The estimated peak population to be served will be 2,300 (1,780 in the camp and 520 in the village).

The principal source of water will be the Susitna River. The water will be treated in accordance with the Environmental Protection Agency (EPA) primary and secondary requirements.

(iii) Wastewater

One waste water collection and treatment system will serve the camp/village. Gravity flow lines with lift stations will be used to collect the wastewater from all of the camp and village facilities. The "in-camp" and "invillage" collection systems will be run through the permawalks and utilidors so that the collection system will always be protected from the elements.

At the village, an aerated collection basin will be installed to collect the sewage. The sewage will be pumped from this collection basin through a force main to the sewage treatment plant.

Chemical toilets located around the site will be serviced by sewage trucks, which will discharge directly into the sewage treatment plant.

The sewage treatment system will be a biological system with lagoons. The system will be designed to meet Alaskan state water law secondary treatment standards. The lagoons and system will be modular to allow for growth and contraction of the camp/village.

The location of the treatment plant is shown on Plates 72 and 73. The location was selected to avoid unnecessary odors in the camp.

The sewage plant will discharge its treated effluent to the Susitna River. All treated sludge will be disposed of in a solid waste sanitary landfill.

(c) Contractor's Area

The contractors on the site will require office, shop and general work areas. Partial space required by the contractors for fabrication shops, storage or warehouses, and work areas will be located on the south side of the Susitna River near the owner/manager's office. Additional space required by the contractor will be in the area between the access road and the camp.

8 - DEVIL CANYON RESERVOIR

The Devil Canyon reservoir, at a normal operating level of 1455 feet, will be approximately 26 miles long with a maximum width on the order of 1/2 mile. The total surface area at normal operating level is 7800 acres. Immediately upstream of the dam, the maximum water depth will be approximately 580 feet. The minimum reservoir level will be 1405 feet during normal operation, resulting in a maximum drawdown of 50 feet. The reservoir will have a total capacity of 1,090,000 acre-feet of which 350,000 acre-feet will be live storage.

9 - TURBINES AND GENERATORS - DEVIL CANYON

9.1 - Unit Capacity

The Devil Canyon powerhouse will have four generating units with a nominal capacity of 150 MW based on the minimum December reservoir level (Elevation 1405) and a corresponding gross head of 555 feet. The head on the plant will vary from 555 feet to 605 feet.

The rated average operating head for the turbine has been established at 575 feet. Allowing for generator losses, this results in a rated turbine output of 225,000 hp (168 MW) at full gate.

The generator rating has been selected as 180 MVA with a 90 percent power factor. The generators will be capable of continuous operation at 115 percent rated power. Because of the high capacity factor for the Devil Canyon station, the generators will, therefore, be sized on the basis of maximum turbine output at maximum head, allowing for a possible 5 percent addition in power from the turbine. This maximum turbine output (250,000 hp) is within the continuous overload rating of the generator.

9.2 - Turbines

The turbines will be of the vertical shaft Francis type with steel spiral casing and a concrete elbow type draft tube. The draft tube will have a single water passage (no center pier).

Maximum and minimum heads on the unit will be 542 feet and 600 feet, respectively. The full gate output of the turbines will be about 240,000 hp at maximum net head and 205,000 hp at minimum net head. Overgating of the turbines may be possible, providing approximately 5 percent additional power. For preliminary design purposes, the best efficiency (best gate) output of the units has been assumed at 85 percent of the full gate turbine output.

The full gate and best gate efficiencies of the turbines will be about 91 percent and 94 percent, respectively, at rated head. The efficiency will be about 0.2 percent lower at maximum head and 0.5 percent lower at minimum head.

9.3 - Generators

The four generators in the Devil Canyon powerhouse will be of the vertical shaft, overhun semi-umbrella type directly connected to the vertical Francis turbines.

The generators will be similar in construction and design to the Watana generator and the general features described in Section 3.2 for the stator, rotor, excitation system, and other details which apply for the Devil Canyon generators.

The rating and characteristics of the generators are as follows:

Rated Capacity:	180 MVA, 0.9 power factor with overload rating of 115 percent.
Rated Power:	162 MW
Rated Voltage:	15 kV, 3 phase, 60 Hertz
Synchronous Speed:	225 rpm
Inertia Constant:	3.5 MW - Sec/MVA
Short Circuit Ratio:	1.1 (minimum)
Efficiency at Full Load:	98 percent (minimum)

9.4 - Governor System

A governor system with electric hydraulic governor actuators will be provided for each of the Devil Canyon units. The system will be the same as for Watana (see Section 3.4).

10 - TRANSMISSION LINES - DEVIL CANYON

To accommodate the additional power from Devil Canyon, the two initially constructed 345 kV transmission lines from Watana will be augmented by a third line from Devil Canyon to Knik Arm. The section between Knik Arm and University substations is a double circuit line capable of taking the extra capacity. This section will be a single steel pole, double circuit structure. The second stage, or the Devil Canyon addition shown will include the following:

Substation Additions	Line Section	Additional Circuit
Devil Canyon	Devil Canyon to Willow	1
Willow	Willow to Knik Arm	1
Knik Arm	Knik Arm Crossing	1
University (Anchorage)		
Ester (Fairbanks)		

11 - APPURTENANT EQUIPMENT - DEVIL CANYON

11.1 - Miscellaneous Mechanical Equipment

(a) Compensation Flow Pumps

The two pumps for providing minimum discharge into the Susitna River between the dam and the tailrace tunnel outlet portal will be vertical mixed flow type located in the powerhouse service bay below the main erection floor, as shown on Plate 66. Each pump will be rated at 250 cfs (115,000 gal/min) at 35 feet total head, and will be driven by 1,400-hp induction motors.

A single pump intake will be located in the surge chamber with an 8-foot-diameter intake tunnel leading to the powerhouse. The intake tunnel will bifurcate into individual pump intake conduits within the powerhouse. The pump discharges will converge into a single pump discharge line.

Butterfly type valves will be installed in the intake and discharge lines of each pump to permit isolation of a pump for inspection and maintenance. Trash screen guides and a trash screen will be provided in the surge chamber at the pump intake. It will be possible to remove the trash screen using the draft tube gate crane discussed below. The width of the guides will be selected so that one of the turbine draft tube gates may be installed in the intake to permit dewatering the pump intake tunnel for inspection and/or maintenance of the tunnel or the intake butterfly valves. Stoplog guides and a set of stoplogs will also be provided at the downstream end of the pump discharge tunnel to allow the discharge tunnel to be dewatered. The stoplogs will be handled with a mobile crane and a follower.

(b) Powerhouse Cranes

Two overhead type powerhouse cranes will be provided at Devil Canyon as at Watana. The estimated crane capacity will be 200 tons.

(c) Draft Tube Gates

Draft tube gates will be provided to permit dewatering of the turbine water passages for inspection and maintenance of the turbines. The arrangement of the draft tube gates will be the same as for Watana, except that only two sets of gates will be provided, each set with two 21-foot-wide by 10.5-foot-high sections.

(d) Draft Tube Gate Crane

A crane will be installed in the surge chamber for installation and removal of the draft tube gates. The crane will be either a monorail (or twin monorail) crane or a gantry crane of 30-ton capacity. The crane will be pendant-operated and have a two point lift. A follower will be used with the crane for handling the gates. The crane runway will be located along the upstream side of the surge chamber and will extend over the intake for the compensation flow pumps, as well as a gate unloading area at one end of the surge chamber.

(e) Miscellaneous Cranes and Hoists

In addition to the powerhouse cranes and draft tube gate cranes, the following cranes and hoists will be provided in the power plant:

- A 5-ton monorail hoist in the transformer gallery for transformer maintenance;
- Small overhead, jib, or A-frame type hoists in the machine shop for handling material; and
- A-frame or monorail hoists in other powerhouse areas for handling small equipment.

(f) Elevators

Access and service elevators will be provided for the power plant as follows:

- Access elevator from the control building to the powerhouse;
- Service elevator in the powerhouse service bay; and
- Inspection hoists in cable shafts.

(g) Power Plant Mechanical Service Systems

The power plant mechanical service systems for Devil Canyon will be essentially the same as discussed in Section 5.1(f) for Watana, except for the following:

- There will be no main generator breakers in the power plant; therefore, circuit breaker air will not be required. The high-pressure air system will be used only for governor as well as instrument air. The operating pressure will be 600 to 1,000 psig depending on the governor system operating pressure.
- An air-conditioning system will be installed in the powerhouse control room.
- Heating and ventilating will be required for the entrance building to the access shaft in the south abutment.
- For preliminary design purposes, only one drainage and one dewatering sump have been provided in the powerhouse. The dewatering system will also be used to dewater the intake and discharge lines for the compensation flow pumps.

(h) Surface Facilities Mechanical Service Systems

The entrance building above the power plant will have only a heating and ventilation system. The mechanical services in the standby power building will include a heating and ventilation system, a fuel oil system, and a fire protection system, as at Watana.

(i) Machine Shop Facilities

A machine shop and tool room will be located in the powerhouse service bay area to take care of maintenance work at the plant. The facilities will not be as extensive as at Watana. Some of the larger components will be transported to Watana for necessary machinery work.

11.2 - Accessory Electrical Equipment

(a) General

The accessory electrical equipment described below includes the following main electrical equipment:

- Main generator step-up 15/345 kV transformers;
- Isolated phase bus connecting the generator and transformers;
- 345 kV oil-filled cables from the transformer terminals to the switchyard;
- Control systems; and
- Station service auxiliary ac and dc systems.

Other equipment and systems described include grounding, lighting system and communications.

The main equipment and connections in the power plant are shown in the single line diagram, (Plate 70). The arrangement of equipment in the powerhouse, transformer gallery, and cable shafts is shown in Plates 65 to 67.

(b) Transformers and HV Connections

Twelve single-phase transformers and one spare transformer will be located in the transformer gallery. Each bank of the three single-phase transformers will be connected to one generator by isolated phase bus located in bus tunnels. The HV terminals of the transformer will be connected to the 345 kV switchyard by 345 kV single-phase oil-filled cables installed in 800-foot long vertical shafts. There will be two sets of three single-phase 345 kV oil-filled cables installed in each cable shaft. One additional set will be maintained as a spare three-phase cable circuit in the second cable shaft. These cable shafts will also contain the control and power cables between the powerhouse and the surface control room, as well as emergency power cables from the diesel generators at the surface to the underground facilities.

(c) Main Transformers

The transformers will be of the single phase, two-winding, oil-immersed, forced-oil water-cooled (FOW) type. A total of twelve single-phase transformers and one spare transformer will be provided, with rating and characteristics as follows:

Rated capacity:	70 MVA
High Voltage Winding:	345/ 3 kV, grounded Y
Basic Insulation Level (BIL) of HV Winding:	1300 kV
Low Voltage Winding:	15 kV, Delta
Transformer Impedance:	15 percent

(d) Generator Isolated Phase Bus

Isolated phase bus connections will be located between the generator and the main transformer. The bus will be of the self-cooled, welded aluminum tubular type with design and construction details generally similar to the bus at the Watana power plant. The rating of the main bus is as follows:

Rated current:	9,000 amps
Short circuit current momentary:	240,000 amps
Short circuit current symmetrical:	150,000 amps
Basic Insulation Level (BIL):	150 kV

(e) 345 kV Oil-Filled Cable

The cables will be rated for a continuous maximum current of 400 amps at 345 kV ± 5 percent. The cables will be of single-core construction with oil flowing through a central oil duct within the copper conductor. The cables will be installed in the 800-foot cable shafts from the transformer gallery to the surface. No cable jointing will be necessary for this installation length.

(f) Control Systems

The Devil Canyon power plant will be designed to be operated as an unattended plant. The plant will be normally controlled through supervisory control from the Susitna Area Control Center at Watana. The plant will, however, be provided with a control room with sufficient control, indication, and annunciation equipment to enable the plant to be operated during emergencies by one operator in the control room. In addition, for the purpose of testing and commissioning and maintenance of the plant, local control boards will be mounted on the powerhouse floor near each unit.

Automatic load-frequency control of the four units at Devil Canyon will be accomplished through the central computeraided control system located at the Watana Area Control Center.

The power plant will be provided with "black start" capability similar to that provided at Watana, to enable the start of one unit without any power in the powerhouse or at the switchyard, except that provided by one emergency diesel generator. After the start-up of one unit, auxiliary station service power will be established in the power plant and the switchyard; the remaining generators can then be started one after the other to bring the plant into full output within the hour.

As at the Watana power plant, the control system will be designed to permit local-manual or local-automatic starting, voltage adjusting, synchronizing, and loading of the unit from the powerhouse control room at Devil Canyon.

The protective relaying system is shown in the main single line diagram (Plate 70) and is generally similar to that provided for the Watana power plant.

(g) Station Service Auxiliary AC and DC Systems

(i) AC Auxiliary System

The auxiliary system will be similar to that in the Watana power plant except that the switchyard and surface facilities power will be obtained from a 4.16 kV system supplied by two 5/7.5 MVA, OA/FA, oil-immersed transformers connected to generators Nos. 1 and 4, respectively. The 4.16 kV double-ended switchgear will be located in the powerhouse. It will have a normally-open tie breaker which will prevent parallel operation of the two sections. The tie breaker will close on failure of one or the other of the incoming supplies. The 1400 hp compensation flow pumps will be supplied with power directly from the 4.16 kV system. Two 4.16 kV cables installed in the cable shafts will supply power to the surface facilities.

The 480 V station service system will consist of a main 480 V switchgear, separate auxiliary boards for each unit, an essential auxiliaries board, and a general auxiliaries board. The main 480 V switchgear will be supplied by two 2000 kVA, 15,000/480 V grounded wye sealed gas dry-type transformers. A third 2000 kVA transformer will be maintained as a spare.

Two emergency diesel generators, each rated 500 kW, will be connected to the 480 V powerhouse main switchgear and 4.16 kV surface switchboard, respectively. Both diesel generators will be located at the surface.

An uninterruptible high-security power supply will be provided for the supervisory computer-aided plant control systems.

(ii) DC Auxiliary Station Service System

The dc auxiliary system will be similar to that provided at the Watana plant and will consist of two 125 V dc lead-acid batteries. Each battery system will be supplied by a double rectifier charging system. A 48 V dc battery system will be provided for supplying the supervisory and communications systems.

(h) Other Accessory Electrical Systems

The other accessory electrical systems including the grounding system, lighting system, and powerhouse communications system will be similar in general design and construction aspects to the system described in Section 5.2 for the Watana power plant.

11.3 - Switchyard Structures and Equipment

(a) Single Line Diagram

The electric system studies recommended a "breaker-and-a-half" single line arrangement. This arrangement was recommended for reliability and security of the power system. Plate 70 shows the details of the switchyard single line diagram.

Devil Canyon will be the main switching station for the generation and transmission system. Five lines will emanate from this switchyard, with three going to Anchorage and two going to Fairbanks.

(b) Switchyard Equipment

The number of 345 kV circuit breakers is determined by the number of elements to be switched such as lines or in-feeds from the powerhouse. Each breaker will be equipped with two disconnect switches to allow safe maintenance.

The auxiliary power for the switchyard will be obtained from the generator bus via a 15 - 4.16 kV transformer and 4.16 kV cable. The voltage will then be stepped down to 480 V for local use.

(c) Switchyard Structures and Layout

The switchyard layout will be based on a conventional outdoor type design. The design adopted for this project will provide a two level bus arrangement. This design is commonly known as a low station profile.

The two-level bus arrangement is desirable because it is less prone to extensive damage in case of an earthquake. Due to the lower heights, it is also easier to maintain.

LIST OF REFERENCES

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

(2) Barton, et al., Engineering Classification of Rock Masses for the Design of Tunnel Support.

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

TABLE A.1: PRINCIPAL PROJECT PARAMETERS

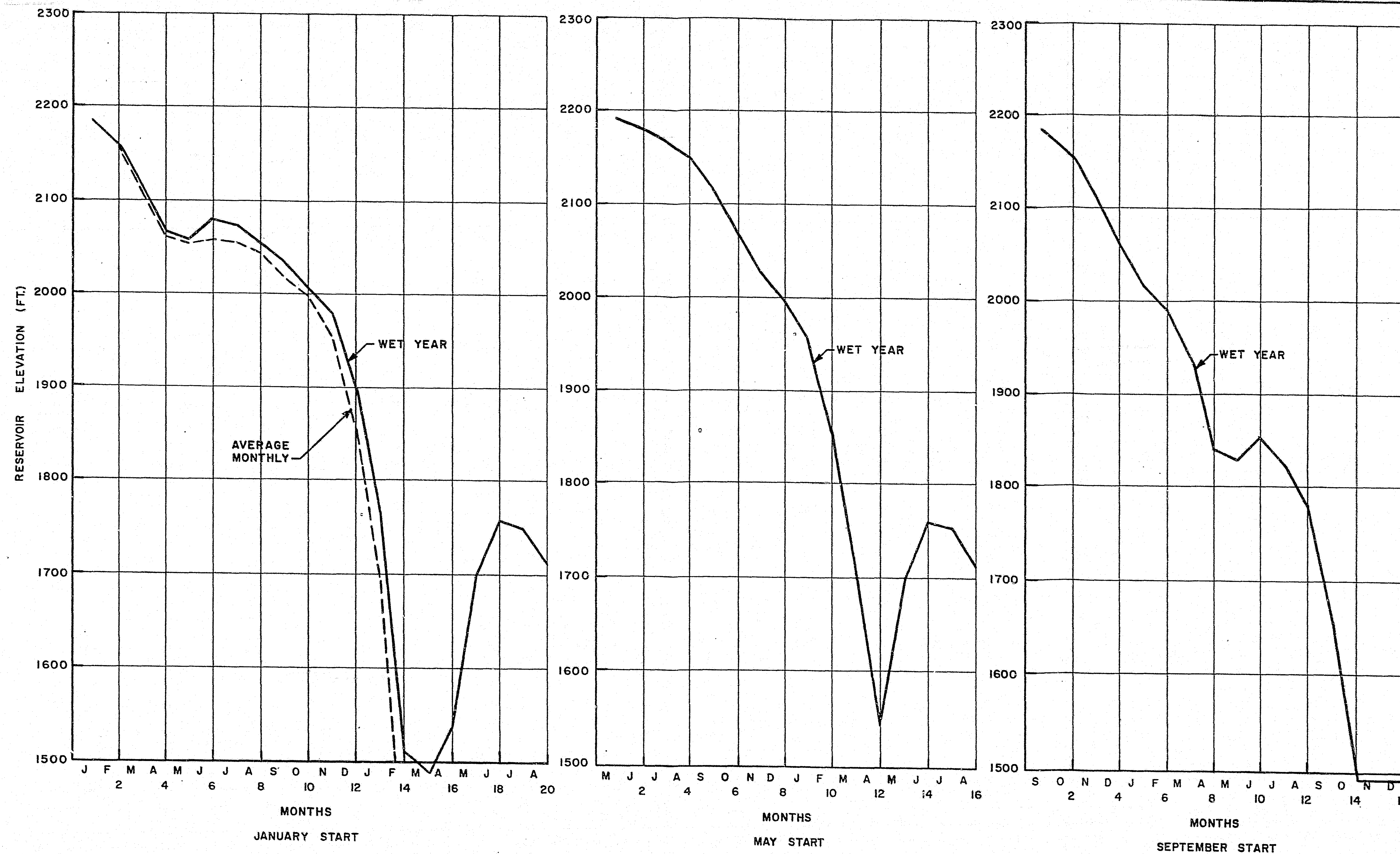
Item	Watana	Devil Canyon
Hydrology		
- Average River Flow (cfs)	7,940	9,040
- Peak Flood Inflows (cfs)		
. PMF	326,000	346,000
. 10,000 year	156,000	165,000
. 100 year	92,000	61,000
Reservoir Characteristics		
- Normal Maximum Operating Level (ft)	2,185	1,445
- Maximum Level, PMF (ft)	2,202	1,466
- Minimum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

TABLE A.1 (Cont'd)

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

TABLE A.1 (Cont'd)

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



WATANA RESERVOIR
EMERGENCY DRAWDOWN

FIGURE A.1