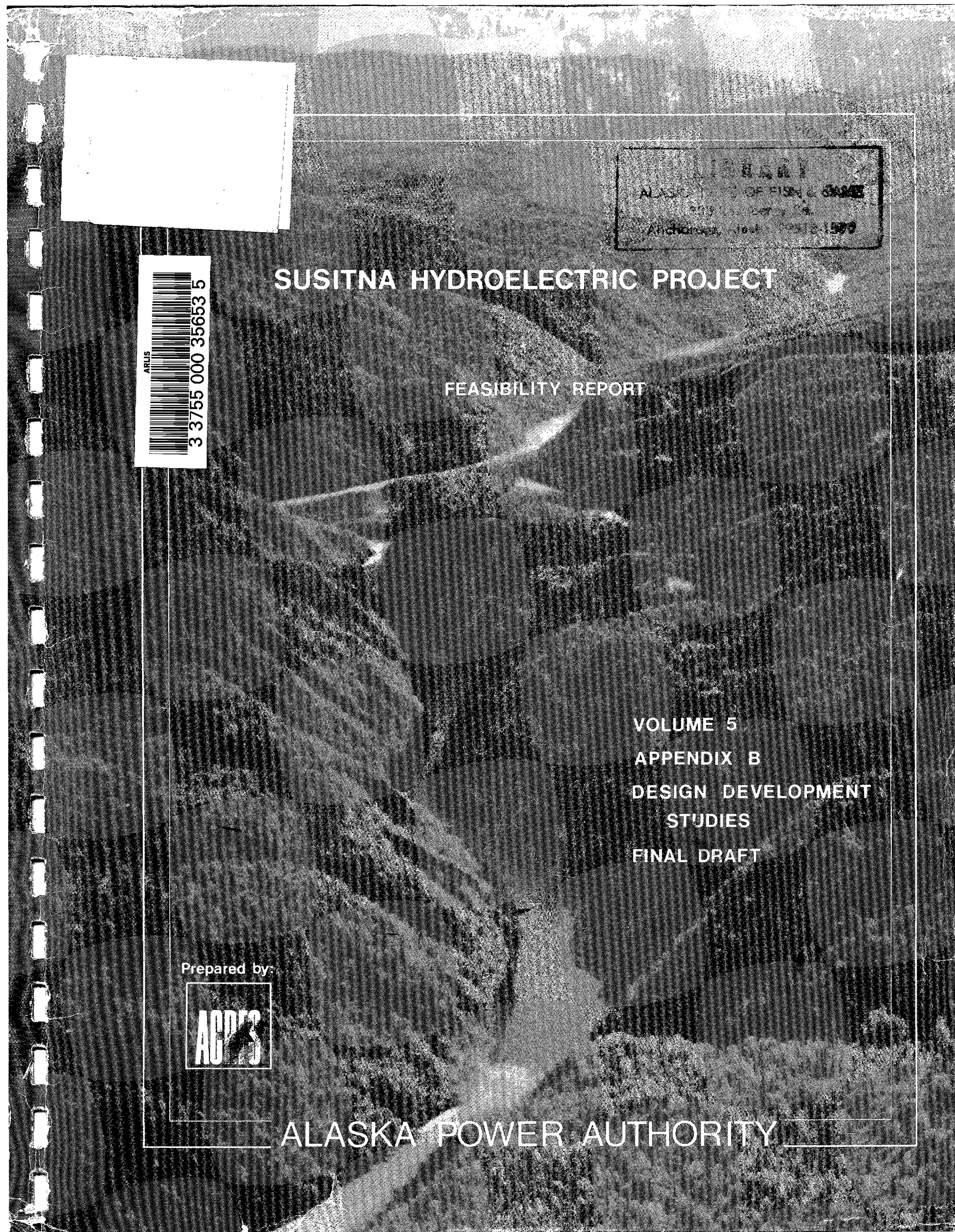

SUSITNA HYDROELECTRIC PROJECT

FEASIBILITY REPORT

VOLUME 5
APPENDIX B
DESIGN DEVELOPMENT STUDIES
FINAL DRAFT

Prepared by:

ACRES

ALASKA POWER AUTHORITY

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APPENDIX B1

DAM SELECTION STUDIES

1 - INTRODUCTION

This Appendix gives an appraisal of alternative dam types considered for the Devil Canyon and Watana sites. The level of study was sufficient to identify the major design features of each alternative, (main dam, diversion, outlet works, spillways and power facilities) as affected by the available data on topography, geology, and seismicity. The dam layouts are conceptual rather than definitive, and are intended only to give a representative design for each alternative to provide an adequate basis for comparison.

Comparison between alternatives was primarily in terms of capital cost, environmental impact, schedule, and construction materials, since each layout was developed to satisfy the same design criteria. Sensitivity to changes during the detailed design phase was also assessed, in view of uncertain data on the properties and availability of construction materials, and the possible increase in the predicted level of seismic activity.

2 - SUMMARY

2.1 - Devil Canyon

Three major types of dam have been considered to assess that most suitable for the Devil Canyon development. These are:

- A concrete arch gravity dam;
- A concrete thin arch dam; and
- A rockfill dam with an impervious clay core.

In each case the overall project layout has been developed in sufficient detail to ensure that the dam itself is technically feasible, and that the layout of other related structures, (diversion tunnels, spillways, outlet works, and power facilities), is compatible. Cost estimates have been developed for the alternative layouts, and schedule impacts assessed.

The cost estimates indicate no significant difference in overall cost between the rockfill dam and the thin arch dam; however, the concrete arch gravity dam is significantly more costly than the other two options.

As a basis for detailed Project layout studies the thin arch dam has been selected at Devil Canyon because:

- The rockfill dam slopes are likely to be reduced in final design;
- There is no proven sources of impervious core material available within reasonable proximity; and
- A schedule delay of approximately 1 year would be involved with a rockfill dam, due to restrictions on placement of fill and access at this site.

2.2 - Watana

Two dam types were considered in detail at Watana:

- A concrete thin arch dam; and
- A rockfill dam with impervious core.

In each case the overall project layout has been developed in sufficient detail to ensure the technical feasibility of the dam, and to provide a compatible layout for all the related structures, (diversion, spillways, outlet works, and power facilities). Cost estimates have been developed for each alternative layout and schedule impacts assessed.

The cost estimates indicate that a rockfill dam with an upstream slope of 2.75:1 is the less expensive option; it was also anticipated that the upstream slope of the rockfill dam might be increased to 2.4:1 in later designs which would further reduce the total cost. (The slope has, in fact, been reduced in later designs). The rockfill dam layout was therefore selected for more detailed layout studies.

3 - SCOPE

The objective of this study was to establish the most suitable types of dam for layout studies at the Devil Canyon and Watana projects. Major factors considered included the preliminary design of each dam type and the associated diversion works, spillways, and power facilities; construction methods, materials and schedule; capital cost estimates; safety of operation; and impact on the environment. Sensitivity to changes in the available data on construction materials and in the level of seismic activity was also considered.

4 - CLIMATOLOGY, GEOLOGY, AND SEISMIC ASPECTS

4.1 - Climate

The climate of the Susitna River Basin is generally characterized by cold, dry winters and warm, moderately moist summers. Mean annual precipitation in the project area is approximately 24 inches; approximately 70 percent of the total precipitation occurs during the warmer months, May through October, while only 30 percent is recorded in the winter months. Average snowfall is approximately 100 inches. Generally, snowfall is restricted to the months of October through April with 80 percent occurring in the period of November to March.

Annual snow accumulations are around 20 to 40 inches, and peak depths occur in late March. Typical average daily minimum temperature in January is approximately -3°F and average daily maximum in July is 64°F.

The Susitna River usually starts to freeze by late October. River ice conditions such as thickness and strength vary according to the river channel shape and slope, and more importantly, with river discharge. Periodic measurements of ice thickness at several locations in the river were carried out during the winters of 1961 through 1972. The maximum thickness observed at selected locations on the river varied between 3 feet and 6 feet. Ice breakup in the river commences by late April or early May, and ice jams occasionally occur at river constrictions resulting in rises in water level of up to 20 feet.

Seasonal variation of flows is extreme and ranges from very low values in winter (October to April) to high summer values (May to September). For the Susitna River downstream from Devil Canyon at Gold Creek, the average winter and summer flows are 2,100 and 20,250 cfs, respectively, i.e., a 1:10 ratio. On average, approximately 88 percent of the streamflow recorded at Gold Creek station occurs during the summer months.

The most common causes of flood peaks in the Susitna River Basin are snowmelt or a combination of snowmelt and rainfall over a large area. Annual maximum peak discharges generally occur between May and October with the majority, approximately 60 percent, occurring in June. Some of the annual maximum flood peaks have also occurred in August or later and are the result of heavy rains over large areas, augmented by significant snowmelt from higher elevations and glacial runoff.

Two flood periods are significant. The first period is the open water period, i.e. after the ice breakup and before freezeup. This period contains the largest floods which must be accommodated by the project. The second period represents that portion of time during which ice conditions occur in the river. These floods, although smaller, can be accompanied by ice jamming and must be considered during the construction phase of the project in planning and design of cofferdams for river diversion.

4.2 - Geology

(a) Devil Canyon

Devil Canyon is a very narrow V-shaped canyon cut through relatively homogeneous argillite and graywacke. This rock was formed by low grade metamorphism of marine shales, mudstones, and clayey sandstones. The bedding strikes about 15° northeast of the river alignment through the canyon and dips at about 65° to the southeast. The rock has been deformed and moderately sheared by the northwest acting regional tectonic forces, causing shearing and jointing parallel to this force. The glaciation of the past few million years apparently preceded the erosion of the canyon by the river. Glacial deposits blanket the valley above the V-shaped canyon, while deposits in the canyon itself are limited to a large gravel bar just upstream of the canyon entrance, and boulder and talus deposits at the base of the canyon walls.

The nature of the rock is such that numerous zones of gouge and fractured rock were caused during the major tectonic events of the past. Consequently, zones of deep weathering can be expected in the foundation rock. Joints and shears are frequently quite open at the surface, but there is a general tightening of such openings with depth. The major joint set strikes northwest across the canyon and is parallel to most shear and fracture zones at the site.

The left bank plateau has a buried river channel paralleling the river. The overburden reaches 90 feet under a small lake in this area. Permafrost has not been detected at the site but, if it does exist, it is not expected to be substantial or widespread.

Construction materials should be available in the terraces upstream of the damsite. The materials in these terraces are estimated to be adequate in quantity for all material needs of the concrete dam. The lakebed and till deposits in Cheechako Creek (approximately 0.25 miles upstream), may be sources of a substantial portion of impervious material for a small earth-fill saddle dam, but would be insufficient for a rockfill main dam at Devil Canyon.

(b) Watana

The diorite pluton that forms the bedrock of the Watana site intruded into sedimentary and volcanic rocks about 65 m.y.b.p. Following intrusion, at intervals that have not yet been determined, volcanic rock erupted into the area. These volcanics form the basalt flows exposed in the canyon near Fog Creek downstream from the site and andesite porphyry flows over the pluton at the damsite. There is no indication of basalt flows within the immediate damsite, but the andesite porphyry is exposed in the western portion of the site.

The surficial material at the damsite is predominantly talus and very thin glacial sediments on the abutments, with limited deposits of river alluvium and lake clay at isolated locations. The river channel is filled with up to 90 feet of alluvial deposits derived from till and talus material. The depth of weathering appears to be between 10 and 40 feet. Bedrock quality below 60 feet is uniform to the maximum depths drilled. The pattern of sound, unweathered rock zones is separated by shear zones, fracture zones, and zones of hydrothermal alteration which are northwest trending. Two major joint sets, northwest and northeast trending, were identified at the site.

Permafrost is present on the left abutment and may also be present under the river channel. The data indicate that this is "warm" permafrost and can be economically thawed for grouting.

Materials for construction of a fill dam and related concrete structures are available within economic distances. Impervious, semipervious core, and filter materials are available within three miles upstream from the site, and a good source of filter material and concrete aggregate is available from a quarry source immediately adjacent to the left abutment of the dam and from structure excavations. Rounded riverbed material for use in the dam shells is also available in adequate quantities in the Tsusena Creek and downstream river channel areas.

4.3 - Seismic Aspects

Regional earthquake activity in the project area is closely related to the plate tectonics of Alaska. The Pacific Plate is underthrusting the North American Plate in this region. The major earthquakes of Alaska, including the Good Friday Earthquake of 1964, have primarily occurred along the boundary between these plates. Four sources of potential earthquakes have been identified at this time. The principal sources are the Denali Fault, located roughly 43 miles north of the site; Castle Mountain Fault, about 65 miles south of the site; and the Benioff Zone, 30 to 40 miles below the surface. A remote possibility also exists that a "Terrain" earthquake event could take place in the crustal zone above the Benioff Zone within 6 miles of the site. No evidence has yet been found to indicate that any of the features and lineaments identified to date in the project vicinity could be regarded as surface expressions of faults that have experienced displacement during recent geologic times.

For preliminary design purposes, the Denali fault has been assigned a preliminary conservative maximum earthquake magnitude of 8.5. This earthquake, when attenuated to the sites, is postulated to generate a mean peak ground acceleration of 0.2g at both Devil Canyon and Watana. The Castle Mountain Fault has been assigned a preliminary conservative maximum earthquake magnitude of 7.5, which would generate a mean peak ground acceleration in the 0.05g to 0.06g range at the two sites. The Benioff Zone has been assigned a conservative maximum earthquake magnitude of 8.5, which would generate mean peak ground accelerations of 0.3g at Devil Canyon and 0.35g at Watana. The duration of potential strong motion earthquakes for both the Denali and Benioff Zones is conservatively estimated to be 45 seconds. It is evident that of these three potential sources the Benioff Zone will govern the design. The Terrain earthquake with a magnitude estimated as 6.25, would cause a mean peak ground acceleration at either site of 0.55g and a duration of about 6 seconds. None of these sources have any potential for causing ground rupture at the sites.

5 - SELECTION METHODOLOGY

5.1 - General

The selection process follows the general methodology previously established for the Susitna Project. The procedure involves five basic work packages or steps, listed in 5.2 below.

5.2 - Methodology

Step 1: - Assemble available data
- Determine design criteria
- Establish evaluation criteria.

Step 2: Develop preliminary layouts, based on the available data and design criteria, for the alternative dam types considered including all related facilities and structures. Produce plans and principal sections for each layout.

Step 3: Develop cost estimates for each layout based on the drawings prepared under Step 2 and the related construction schedule.

Step 4: Review all layouts on the basis of technical feasibility, cost, construction methods and materials, uncertainty of basic data and assumptions, safety, and environmental impacts.

Step 5: Select the most suitable alternative based on the established evaluation criteria.

6 - PROJECT PARAMETERS AND DESIGN CRITERIA

6.1 - General

The principal project parameters and design criteria on which the alternative dam layouts were based are given below. Parts of this criteria will be superseded as more data becomes available. Any assumptions made have been based on the best information available at the time.

6.2 - Devil Canyon

Hydraulic Data

Probable maximum flood:	270,000 cfs
Maximum flood with return period of 1:10,000 years:	135,000 cfs (after routing through Watana)
Maximum flood with return period of 1:50 years:	42,000 cfs (after routing through Watana)
Reservoir normal maximum operating level:	1450 MSL
Reservoir minimum operating level:	1400 MSL

Dam

Crest elevation:	1455 feet MSL
Crest length:	Varies
Height:	635 feet above foundation
Cut-off and foundation treatment:	Founded on rock - grout curtain and downstream drains

Diversion

Cofferdam types:	Rockfill
Upstream cofferdam crest elevation:	960 foot MSL
Downstream cofferdam crest elevation:	900 foot MSL
Water passages:	Low level structure with slide closure gate
Final closure:	Mass concrete plugs in line with dam grout curtain
Releases during impounding:	2,000 cfs minimum via fixed cone valves

Spillway

Design floods:		Passes PMF preserving integrity of dam with no loss of life Passes routed 1:10,000 year flood with no damage to structures
Service spillway	- capacity:	45,000 cfs
	- control structure:	Gated orifice, stilling basin
Main spillway	- capacity:	90,000 cfs
	- control structure:	Gated, ogee crest

Spillway (Cont'd)

Emergency spillway - capacity:	PMF minus routed 1:10,000 year flood
- type:	Fuse plug

Power Facilities

Type of Powerhouse:	Underground
Transformer area:	Separate gallery
Control room and administration:	Underground
Access:	Rock tunnel
Type of turbines:	Francis
Number and ratings:	4 x 150 MW
Rated net head:	550 feet
Design flow:	3,600 cfs
Maximum gross head:	565 feet approximately
Type of generator:	Vertical synchronous
Rated output:	180 MVA
Power factor:	0.9
Frequency:	60 Hz
Transformers:	15/345 kV 70 MVA, single phase

Tailrace

Water passages:	2 concrete lined tunnels
Elevation of water passages:	Pressure tunnel

6.3 - Watana

River Flows

Average flow (over 30 years of record):	7,860 cfs
Probable maximum flood:	235,000 cfs
Maximum design flood (1:10,000 years):	155,000 cfs
Maximum design diversion flood (1:50 years):	87,000 cfs
Reservoir normal maximum operating level:	2200 MSL
Reservoir minimum operating level:	2050 MSL
Area of reservoir at maximum operating level:	40,000 acres
Reservoir live storage:	4.6×10^6 acre-feet
Reservoir full storage:	10×10^6 acre-feet

Dam

Type:	Varies
Crest elevation:	Varies
Crest length and width:	Varies
Height:	Varies
Cut-off and foundation treatment:	Founded on rock, with grout curtain and downstream drains
Upstream slope:	Varies
Downstream slope:	Varies

Diversion

Cofferdam:	Rockfill
Cut-off foundation:	Founded on alluvium with slurry trench to rock
Upstream crest elevation:	1585 MSL
Downstream crest elevation:	1475 MSL
Maximum design pool level during construction:	1580 MSL
Water passages:	Concrete lined
Outlet structures:	Low level structure with slide closure gate
Final closure:	Mass concrete plugs in line with main dam grout curtain
Releases during impounding:	2,000 cfs minimum via fixed cone valves.

Spillway

Design floods:	Passes PMF preserving integrity of dam with no loss of life. Passes routed design flood with no damage to structures
Main Spillway - capacity:	135,000 cfs
- control structure:	Gated ogee crest
- energy dissipation:	Chute and flip bucket to downstream plunge pool
Emergency Spillway - capacity:	PMF minus routed design flood
- type:	Fuse plug

Power Facilities

Type of powerhouse:	Underground
Transformer area:	Separate gallery
Control room and administration:	Surface structure
Access:	Rock tunnel
Type of turbine:	Francis
Number and rating:	4 x 200 MW
Rated net head:	680 feet
Design flow per unit:	3,750 cfs
Maximum gross head:	735 feet
Type of generator:	Vertical synchronous
Rated output:	220 MVA
Power factor:	0.9
Frequency:	60 Hz
	Single phase
	15/345 kV, 130 MVA

Tailrace

2 concrete-lined pressure tunnels

7 - ALTERNATIVE DAM TYPES - DEVIL CANYON

7.1 - General

Three types of dam design have been studied in detail, and these are described below. For the thin arch concrete dam and the concrete arch gravity dam, the location selected is at the entrance to Devil Canyon, where the cross section of the canyon has its minimum area. This location is unsuitable for the rockfill dam, however, with its much flatter slopes, and the axis of the rockfill dam has, therefore, been moved some 625 feet downstream from the crown of the concrete dams (250 feet downstream of the line of the thrust blocks). This site corresponds to the minimum volume for the rockfill dam alternative. The diversion tunnels for the rockfill dam alternative are considerably longer, as a result.

The normal maximum water level is at Elevation 1445; the crest levels of the dams vary with the particular dam type considered.

7.2 - Concrete Arch Gravity Dam

The arch gravity dam arrangement is shown on Plates B1.1 and B1.2. The main dam is a single center arch structure acting partly as a gravity dam with a vertical cylindrical upstream face and a sloping downstream face inclined at 1V:0.4H. The maximum height of the dam is 635 feet and the crest length is 1400 feet. The maximum foundation width is 225 feet. The crest width is 30 feet at Elevation 1455.

The main dam structure terminates in mass concrete thrust blocks set high up on each abutment. The left abutment thrust block is a free standing concrete gravity structure; the right bank thrust block is supported directly by the rock in the right abutment. A low-lying saddle area on the left abutment is closed by means of a rockfill dike founded on bedrock extending from existing rock to the left bank thrust block.

The design floods are controlled by 3 major spillway structures:

- A gated orifice service spillway set in the center of the main dam discharging to a stilling basin in the river channel downstream;
- A main gated spillway constructed in the thrust block on the left abutment discharging into a rock channel which takes water well downstream to an existing side valley; and
- An emergency fuse plug spillway in a separate channel on the left abutment.

The service spillway is used to control flows up to 45,000 cfs. For flows up to 135,000 cfs (the 10,000 year flood), the main spillway and service spillway together have sufficient capacity. The emergency fuse plug spillway is designed to discharge the balance of flow between the PMF flow and the 1-in-10,000 year flood, together with the extra capacity on the other two spillways caused by surcharging the reservoir. The peak reservoir level when passing the PMF is Elevation 1455.

The multi-level intake is integral with the main dam and connected to the powerhouse by 2 vertical steel-lined penstocks. The powerhouse contains 4 x 150 MW units and is located underground beneath the right abutment. Discharge of power flow to the river is from a draft tube manifold and twin tailrace tunnel.

7.3 - Thin Arch Dam (Scheme DC1)

The height and crest length of the thin arch dam is similar to the arch gravity dam described in 7.2, and the dam location is the same. The thrust blocks, the left bank saddle dam, and the depth of excavation to rock are assumed the same. The crest width is 20 feet at an elevation of 1455 and the maximum foundation width is 90 feet. The general arrangement of the thin arch dam is shown on Plates B1.3, and 10.1 (Volume 1).

The spillway design philosophy is similar to the arch gravity dam with three levels of control. The main spillway is on the right abutment comprising a gated control structure, chute, and flip bucket. A service spillway is provided in the main dam comprising four gated orifices discharging to a downstream plunge pool. The saddle dam fuse plug and channel on the left abutment are similar to the scheme described in 7.2 above. The service spillway controls flows up to 45,000 cfs; the combination of the service spillway and the main spillway is designed to control floods up to 135,000 cfs (the flood with a return period of 1:10,000 years). The probable maximum flood (PMF) is handled by the emergency fuse plug spillway and the increased capacity of main and service spillways with the reservoir surcharged to a maximum elevation of 1455.

The powerhouse accommodates 4 x 150 MW units and is located underground in the right abutment. The multi-level power intake is constructed in a rock cut upstream of the dam on the right abutment, with 4 separate penstocks to the powerhouse turbines. Discharge of power flows to the river is from a draft tube manifold and twin tailrace tunnels.

7.4 - Rockfill Dam

The arrangement for the rockfill dam alternative is shown on Plate 8.1, (Volume 1).

For this arrangement the dam axis is some 625 feet downstream of the crown section of the concrete dams. The assumed embankment slopes are 2.25 H:1V on the upstream face and 2H:1V on the downstream face. The main dam is continuous with the left bank saddle dam, and therefore no thrust blocks are required. The crest length is 2200 feet at Elevation 1470; the crest width is 50 feet.

The dam is constructed with a central impervious core, inclined upstream, supported on the downstream side by a semi-pervious zone. These two zones are protected upstream and downstream by filter and transition materials. The shell sections are constructed of rockfill obtained from blasted bedrock. For preliminary design all dam sections are assumed to be founded on rock; external cofferdams are founded on the river alluvium, and are not incorporated into the main dam. The approximate volume of material in the main dam is 20 million cubic yards.

A single spillway is provided on the right abutment to control all flood flows. It consists of a gated control structure and a double stilling basin excavated into rock; the chute sections and stilling basins are concrete lined, with mass concrete gravity retaining walls. The design capacity is sufficient to pass the 1-in-10,000 year flood without damage; excess capacity is provided to pass the PMF, without damage to the main dam, by surcharging the reservoir and spillway.

The powerhouse is located underground in the right abutment. The multi-level power intake is constructed in a rock cut in the right abutment on the dam centerline, with four independent penstocks to the 150 MW Francis turbines. Twin concrete-lined tailrace tunnels connect the powerhouse to the river via an intermediate draft tube manifold.

7.5 - Basis of Dam Design

The analyses for both the arch gravity dam and the thin arch dam were originally carried out using finite element methods. The results indicated significantly lower stresses for the arch gravity dam under hydrostatic and temperature loadings, as would be anticipated. High stresses were found under seismic loading conditions for both dams, with somewhat higher in the case of the arch gravity dam. The finite element model used in these analyses was not sufficiently refined to allow accurate calculation of stresses at the abutments.

In order to model more accurately the stress conditions in the thin arch dam close to the foundation and in the abutments of the thin arch dam, the Trial Load Method was later adopted using the USBR Computer Program Arch Dam Stress Analysis System (ADSAS). Under hydrostatic loading no tension is evident at the dam faces.

Although analysis for seismic loading still had to be finalized, it was considered that the thin arch and the arch gravity dam sections shown on the plates were structurally feasible.

The rockfill dam slopes are considerecd to be representative for the type of material which will be used and for the likely ground movements under seismic shock.

7.6 - Schedule

It is estimated that there would be no significant difference in construction schedule between the two concrete dams; the extra volume of the arch gravity dam would be offset by ease of concrete placement, simpler formwork, and reuse of formwork. Estimated total construction time is about 5 years.

It is estimated that the construction period for the rockfill dam will be at least 5 years and possibly as much as 6 years, in view of the congested nature of the site, seasonal restrictions on placing and compaction of impervious core material, and rockfill placing difficulties within the steep sided canyon.

7.7 - Construction Materials

Sand and gravel for concrete aggregates are believed to be available in sufficient quantities immediately upstream of the Cheechako fan and terraces, and it is anticipated that they will be suitable for the production of concrete aggregates after a screening and washing.

Material for the rockfill dam shells will generally be obtained from local quarry areas; a limited amount will be available from the actual site excavations, (spillways, tunnels and underground caverns). Although a limited amount of impervious material may be available from the till deposits forming the flat elevated areas on the left abutment, no suitable borrow areas are known within a reasonable distance of the site, other than those at Watana, 30 miles upstream. The availability of impervious and semipervious fill will be major factor governing the selection of dam type at Devil Canyon.

8 - ALTERNATIVE DAM TYPES - WATANA

8.1 - General

Two dam types have been considered in detail, a rockfill dam and a concrete thin arch dam as described in 8.2 and 8.3 below. The normal maximum operating level is at Elevation 2200 MSL for both cases; the crest level varies with the type of dam considered.

8.2 - Rockfill Dam

The arrangement of the rockfill dam alternative considered in this comparison is shown on Plate 9.4, (Volume 1). The dam is located between the two major shear zones, (the "Fins" and the "Fingerbuster"), along an alignment similar to that originally proposed by the Corps of Engineers. The side slopes have been conservatively assumed as 1H:2.75V upstream and 1H:2V downstream. The crest width is 80 feet at Elevation 2225 MSL. Total crest length is approximately 4000 feet.

The dam is constructed with a central impervious core, inclined upstream, supported on the downstream side by a semipervious zone. These two zones are protected upstream and downstream by filter and transition materials. The outer shell sections are constructed from rockfill obtained from quarries and bedrock excavation and alluvial gravels. For preliminary design, the core zone is assumed to be founded on sound rock; all other zones are founded on rock. The diversion cofferdams are founded on the river alluvium, and are not therefore incorporated into the main dam. The approximate volume of material in the main dam is 76.5 million cubic yards.

Diversion is provided by two 35 foot diameter concrete-lined tunnels beneath the right abutment.

The main spillway on the right abutment is designed to control flood flows up to the 1-in-1,000 year event. The PMF is controlled by surcharging the reservoir and the main spillway together with the emergency fuse plug spillway on the right abutment.

The powerhouse is located underground in the left abutment. The multi-level power intake is constructed in a rock cut 200 feet upstream of the dam centerline. Individual penstocks are provided for each 200 MW Francis turbine in the powerhouse; twin 30-foot-diameter concrete-lined tailrace tunnels then discharge the power flow to the river.

8.3 - Thin Arch Dam

The alternative thin arch dam arrangement considered in this comparison is shown on Plate 9.1 (Volume 1). The detailed geometry is given on Plates B1.4 and B1.5.

The main dam is a three-center double curvature concrete arch structure with a crest width of 40 feet at Elevation 2215 MSL. The approximate total crest length is 3950 feet. The maximum foundation width is 180 feet at Elevation 1360 MSL. The dam is founded on an extensive concrete pad in the river bed excavation, and the extreme upper section of the dam terminates in massive concrete thrust blocks set high on each abutment. The approximate volume of concrete in the dam and thrust blocks is 8.25 million cubuc yards.

The diversion arrangement is similar to that for the rockfill dam, but the tunnels are much shorter because of the reduced foundation width.

The main spillway on the right abutment is designed to control flows up to the 1-in-10,000 year event. The probable maximum flood is controlled by surcharging the reservoir and the main spillway.

The powerhouse is located underground beneath the right abutment. The multilevel power intake is constructed in a rock cut about 200 feet upstream of the dam centerline. Four individual penstocks deliver water to each 200 MW Francis turbine in the power plant; twin concrete-lined tailrace tunnels then discharge the flow to the river. An alternative powerhouse location on the left bank was considered (as indicated on Plate B1.4) but there was no significant cost savings in any of the major structures, (intake, penstocks, and tailrace tunnels) and the rock conditions slightly favor the right abutment.

8.4 - Basis of Design

The upstream slopes of the dam were conservatively selected to be similar to the Oroville Dam in California which has been analyzed and found to be safe under severe seismic shaking. It is anticipated that the upstream slope may be safely reduced to 1H:2.4V during detailed design.

The thin arch dam design was checked for static loadings only using the USBR Trial Load Method computer program (ADSAS); all stresses were within acceptable limits.

8.5 - Schedule

The estimated construction period for the rockfill dam at Watana is 7 years from the commencement of diversion works to the commissioning of the first generating unit. It is estimated that construction of the concrete arch dam will probably not be significantly faster than for the rockfill.

8.6 - Construction Materials

Impervious core material is available from the glacial tills located approximately 3 miles upstream from the site on the right side of the river valley. Gravels and sands for filter and transition materials are available from the alluvial deposits in Tsusena Creek. Approximately 50 percent of the rockfill for the shell sections is assumed to be obtained from quarries. A small proportion of the rockfill requirements will also be available from the site excavations.

The gravels and sands available from alluvial deposits in Tsusena Creek will be suitable for concrete aggregates, after screening and washing.

9 - COST ESTIMATES

The cost estimate summary for the alternative dam layouts at Devil Canyon is shown in Table B1.1.

The cost estimate summary for the alternative dam layouts at Watana is shown in Table B1.2.

All estimates are based on quantities taken from the drawings using unit rates derived for the Upper Limit Cost Estimate (July 1981). In the absence of a known source, the unit price for impervious material at Devil Canyon was assumed to be similar to that at Watana, and as such is probably underestimated.

10 - SELECTION OF DAM TYPE

10.1 - Evaluation Criteria

The criteria used for evaluation of the alternative dam types are as follows:

- Construction cost estimate;
- Availability of construction materials;
- Schedule;
- Environmental impact;
- Sensitivity to changes in basic data; and
- Operation and safety.

10.2 - Comparison of Alternatives

The comparison of alternative dam layouts at Devil Canyon is summarized in Table B1.3, based on the evaluation criteria in 10.1 above. For each factor considered, the preferred layout or layouts have been selected. The final selection has then been made on the basis of the results of the individual factor assessments.

A similar comparison of alternative dam layouts at Watana is summarized in Table B1.4.

10.3 - Recommended Dam Types

From the detailed comparison of the three alternative dam arrangements, there would not appear to be a significant advantage favoring any particular alternative. Consideration of a concrete face rockfill alternative at this site may overcome the apparent scarcity of impervious material nearby. However, it is not likely that there would be any significant cost advantage using this alternative. Since the height of such a dam would be significantly greater than any currently in existence, consideration of this type of structure would require detailed investigation. On the other hand, the thin arch dam alternative is less expensive than the arch gravity dam and has been shown with a reasonable degree of confidence to be feasible and no more expensive than the rockfill.

There would therefore appear to be no reason to initiate studies of the concrete-faced rockfill alternative.

On the basis of a significant cost advantage, the recommended dam type for further layout studies at Watana is the rockfill dam with impervious core.

TABLE B1.1: COST ESTIMATE SUMMARY - DEVIL CANYON

Item	Capital Cost ($000) Arch Gravity	Thin Arch	Rockfill
Land Acquisition	$ 21,000	$ 21,000	$ 21,000
Reservoir Clearance	10,000	10,000	10,000
Excavation/Preparation	29,975	12,035	74,180
Drainage and Grouting	82,520	81,492	26,665
Thrust Blocks	24,893	20,744	--
Main Dam/Reregulation	358,106	293,573	178,432
Low Level Release	10,000	10,000	20,000
Winterization	12,000	12,000	9,000
Diversion and Cofferdams	30,302	30,302	51,619
Power Facilities	267,895	278,278	332,345
Spillways	108,455	115,254	169,040
Saddle Dam	15,976	15,976	--
Switchyard	6,718	6,718	6,718
Miscellaneous/Roads	36,000	36,000	36,000
Support and Camp	156,500	156,500	156,500
Subtotal	$1,170,340	$1,099,872	$1,091,499
Contingency (20%)	234,068	219,974	218,300
Engineering/administration (12.5%)	175,551	164,981	163,725
TOTAL	$1,579,959	$1,484,827	$1,473,524

NOTE: The above are conceptual cost estimates for comparison purposes only.

TABLE B1.2: COST ESTIMATE SUMMARY - WATANA

Item	Capital Cost ($000) Rockfill	Thin Arch
Land Acquisition	$ 35,000	$ 35,000
Reservoir Clearance	15,000	15,000
Excavation/Preparation	180,435	22,680
Drainage/Grouting	53,415	217,000
Main Dam	940,974	1,237,500*
Low Level Release	25,000	11,500
Saddle Dam	45,538	45,538
Diversion and Cofferdams	101,967	77,939
Power Facilities	262,505	257,626
Spillways	195,440	195,440
Switchyard	7,018	7,018
Miscellaneous/Roads	105,700	105,700
Support and Camp	306,000	306,000
Subtotal	$2,273,992	$2,533,941
Contingency (20%)	454,798	506,788
Engineering/Administration (12.5%)	341,099	380,091
TOTAL	$3,069,889	$3,420,820

*Using concrete rate of $150 per cubic yard

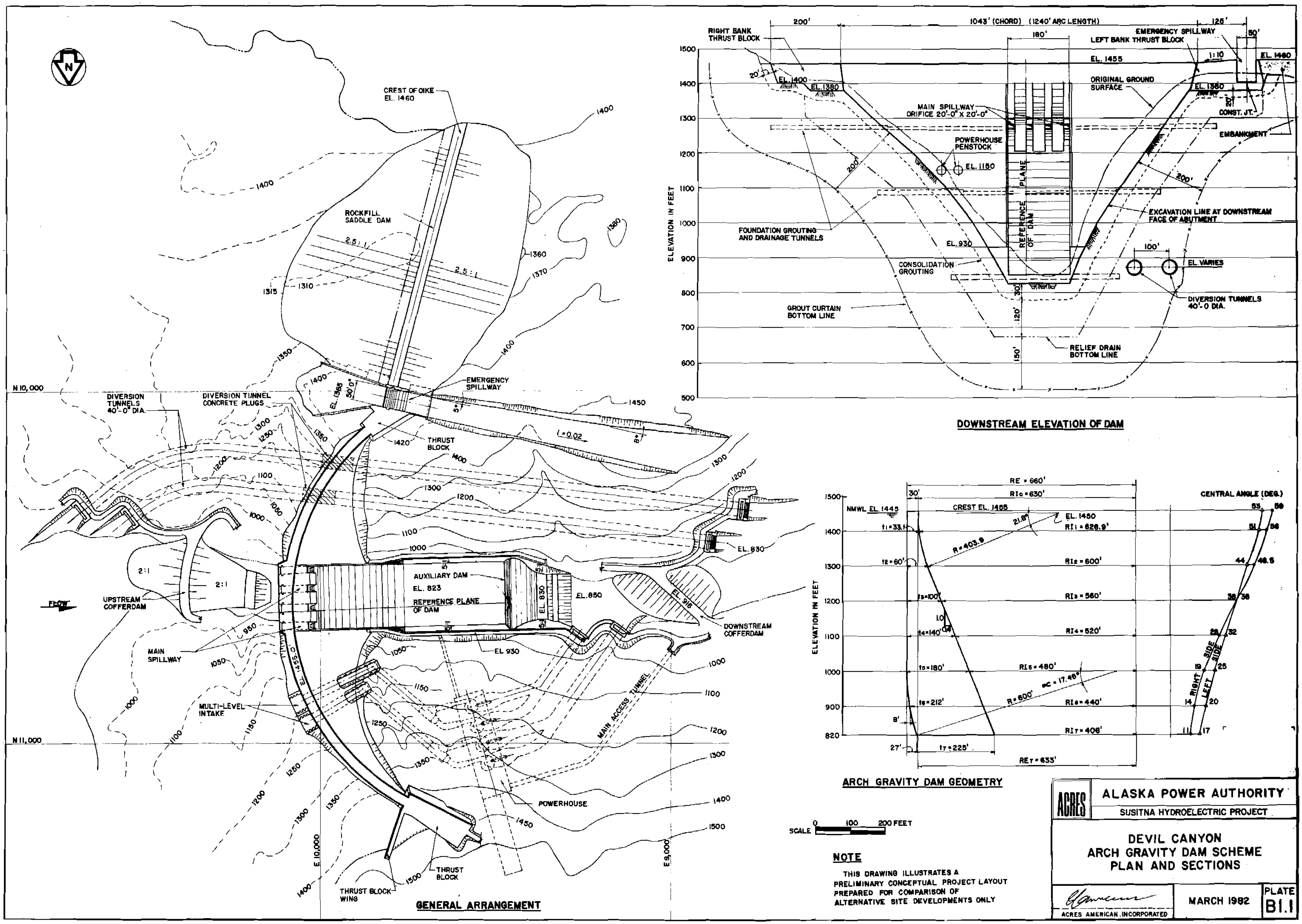
Note: The above are conceptual cost estimates for comparison purposes only.

TABLE B1.3: COMPARISON OF ALTERNATIVE DAM TYPES - DEVIL CANYON

Number	Alternative Item	A Arch Gravity	B Thin Arch	C Rockfill	Recommended	Remarks
1	Cost Estimate ($ million)	1580	1485	1474	B,C	C likely to increase in final design
2	Availability of Materials	Good	Good	Poor	A,B	Impervious core material source not proven
3	Schedule	--	--	--	A,B	--
4	Environmental Impact	--	--	--	A,B,C	No advantage to any scheme
5	Sensitivity to Changes in Base Data	Low	Low	High	A,B	Rockfill dam slopes likely to be flatter in final design
6	Operation/Safety	--	--	--	A,B,C	No advantage to any scheme

TABLE B1.4: COMPARISON OF ALTERNATIVE DAM TYPES - WATANA

No.	Alternative Item	A Rockfill	B Thin Arch	Recommended Layout	Remarks
1	Cost Estimate	3070	3421	A	Cost difference $351 million
2	Availablility of Materials	Good	Good	A,B	--
3	Schedule	--	--	A,B	--
4	Environmental Impact	--	--	A,B	--
5	Sensitivity to Basic Data	--	--	A,B	--
6	Operation/Safety	--	--	A,B	--



NOTE

THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY

ACRES

ALASKA POWER AUTHORITY

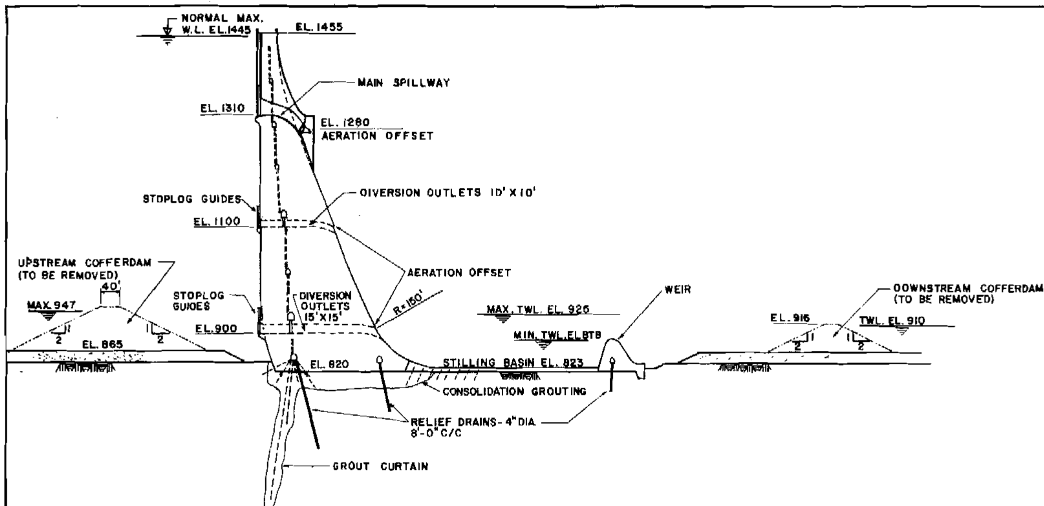
SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON
ARCH GRAVITY DAM SCHEME
PLAN AND SECTIONS

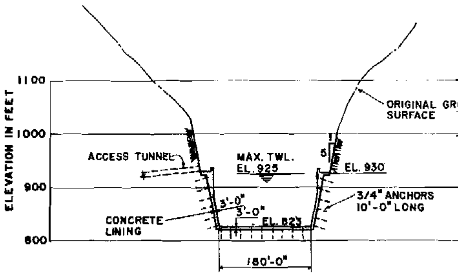
ACRES AMERICAN INCORPORATED

MARCH 1982

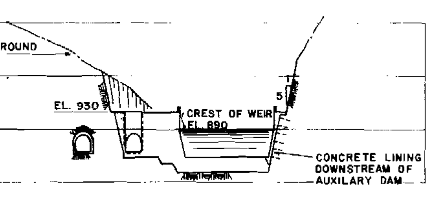
PLATE B1.1



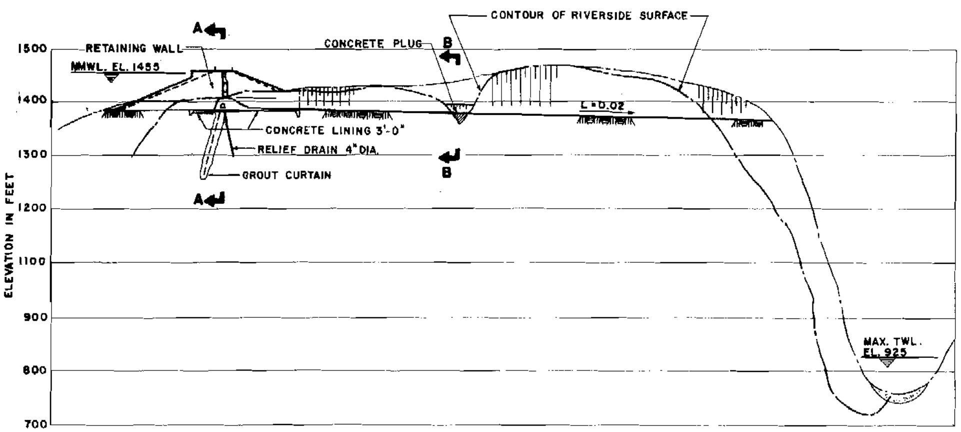
ARCH-GRAVITY DAM LAYOUT



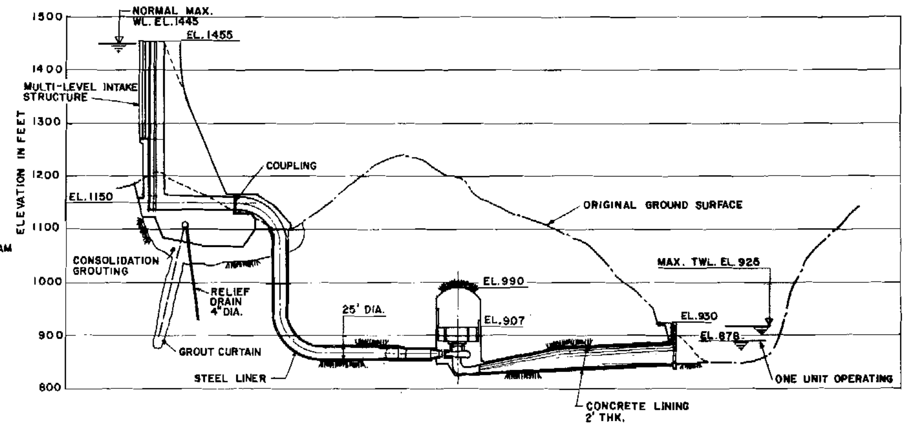
SECTION AT SPILLWAY



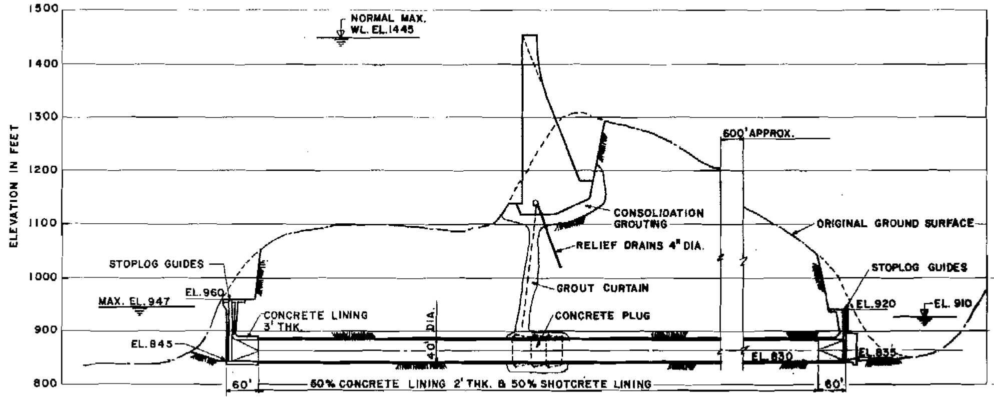
SECTION AT WEIR



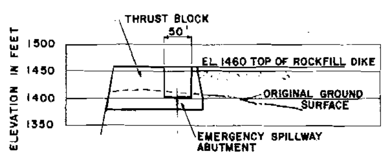
PROFILE OF EMERGENCY SPILLWAY



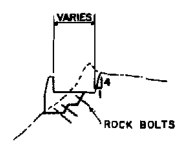
POWER FACILITIES PROFILE



SECTION THRU DIVERSION TUNNEL



SECTION A-A



SECTION B-B

SCALE 0 100 200 FEET

NOTE

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ALASKA POWER AUTHORITY

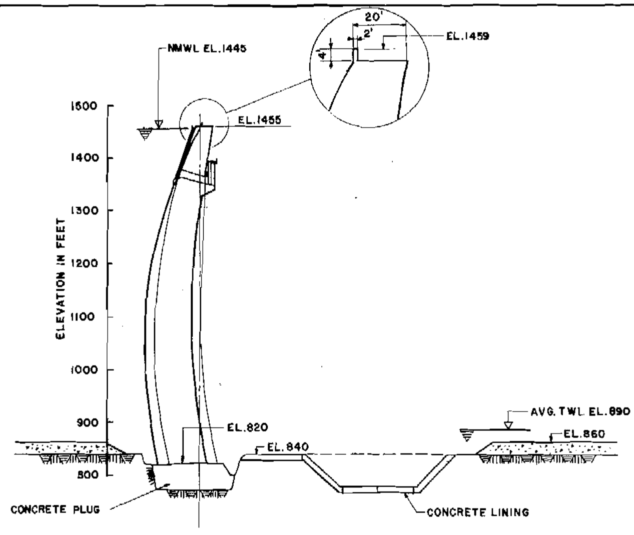
SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON
ARCH GRAVITY DAM SCHEME
SECTIONS

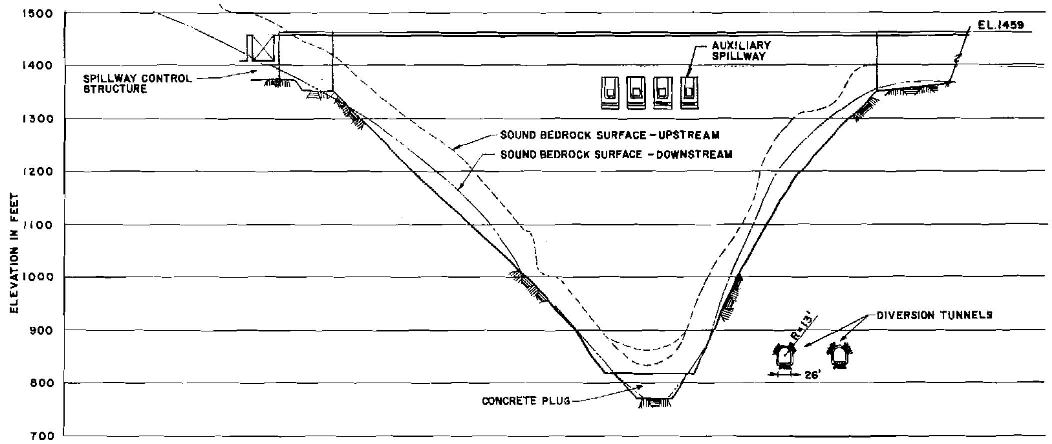
ACRES AMERICAN INCORPORATED

MARCH 1982

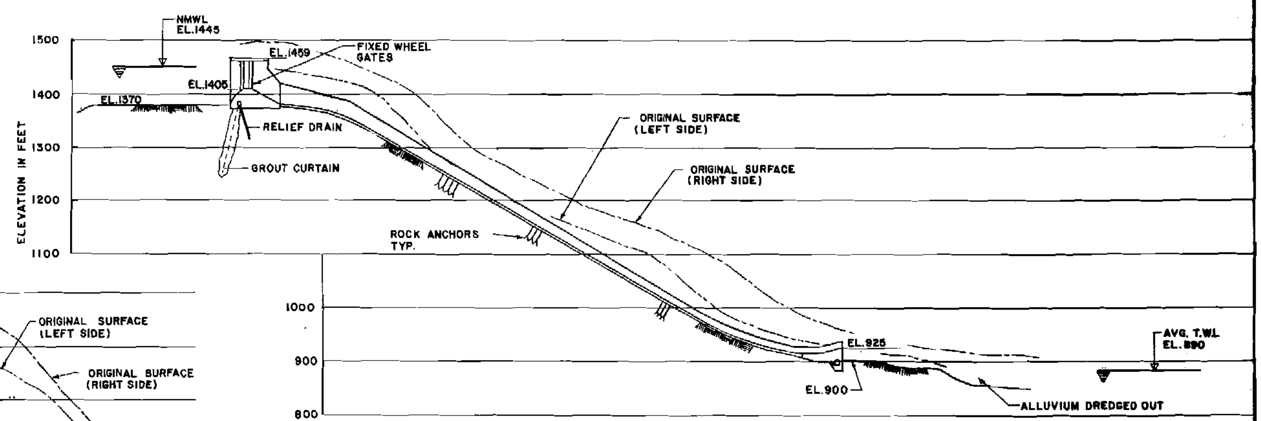
PLATE B1.2



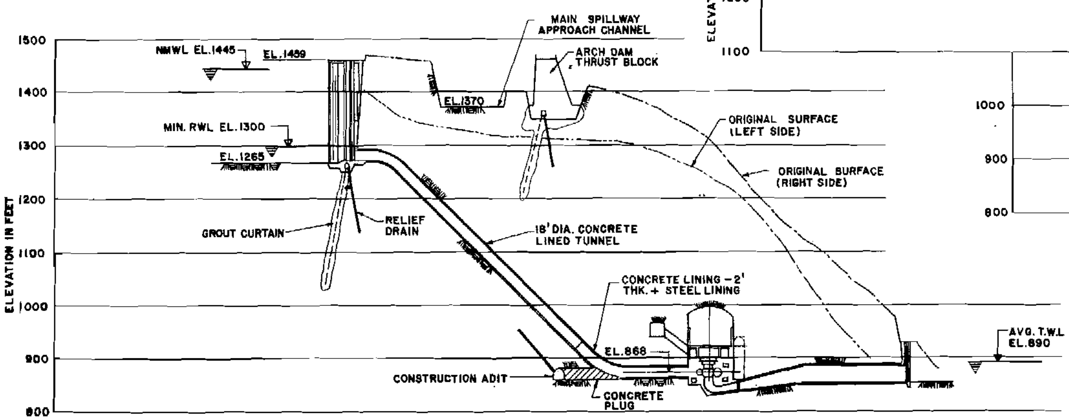
CROWN SECTION



DAM PROFILE



SECTION THRU SPILLWAY



SECTION THRU POWERHOUSE FACILITIES

SCALE 0 100 200 FEET

NOTE

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SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON SCHEME DC1 SECTIONS

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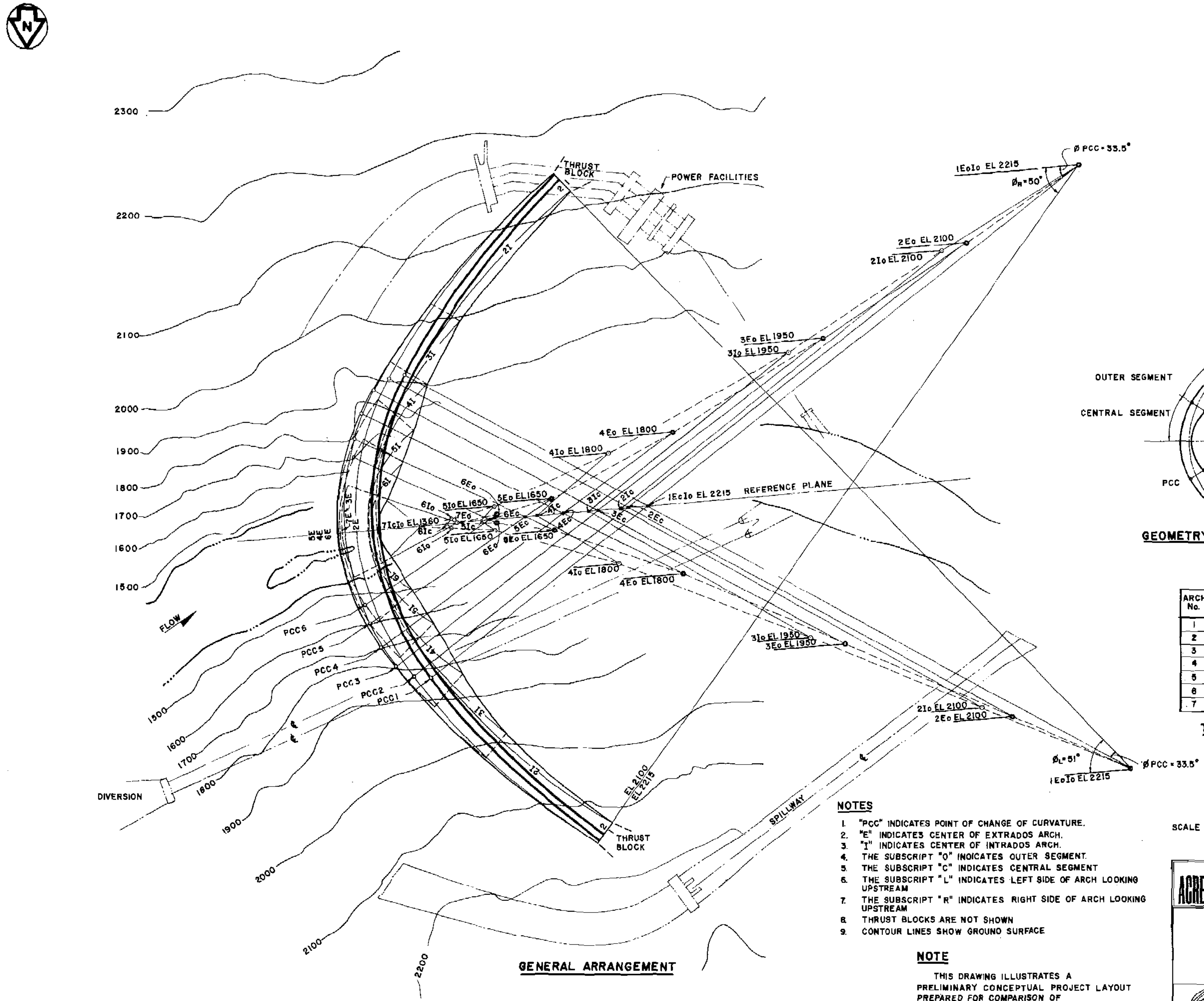
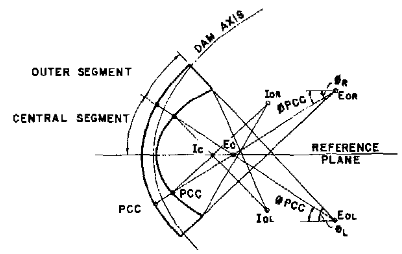
PLATE B1.3



GENERAL ARRANGEMENT



GEOMETRY TYPICAL ARCH SECTION

ARCH No.	ELEV. (FEET)	COMPOUND ANGLE ØPCC (DEG)	CENTER ANGLE (Ø) (DEG) LEFT	RIGHT
1	2215	33.5	51	50
2	2100	33.0	54	54
3	1950	32.5	45	46
4	1800	31.0	41.5	44
5	1650	29.0	40.5	41
6	1500	29.0	37	37
7	1360	0	23	23

TABLE OF ARCH ANGLES

SCALE 0 200 400 FEET

NOTES

1. "PCC" INDICATES POINT OF CHANGE OF CURVATURE.
2. "E" INDICATES CENTER OF EXTRADOS ARCH.
3. "I" INDICATES CENTER OF INTRADOS ARCH.
4. THE SUBSCRIPT "O" INDICATES OUTER SEGMENT.
5. THE SUBSCRIPT "C" INDICATES CENTRAL SEGMENT
6. THE SUBSCRIPT "L" INDICATES LEFT SIDE OF ARCH LOOKING UPSTREAM
7. THE SUBSCRIPT "R" INDICATES RIGHT SIDE OF ARCH LOOKING UPSTREAM
8. THRUST BLOCKS ARE NOT SHOWN
9. CONTOUR LINES SHOW GROUND SURFACE

NOTE

THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY.

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ALASKA POWER AUTHORITY

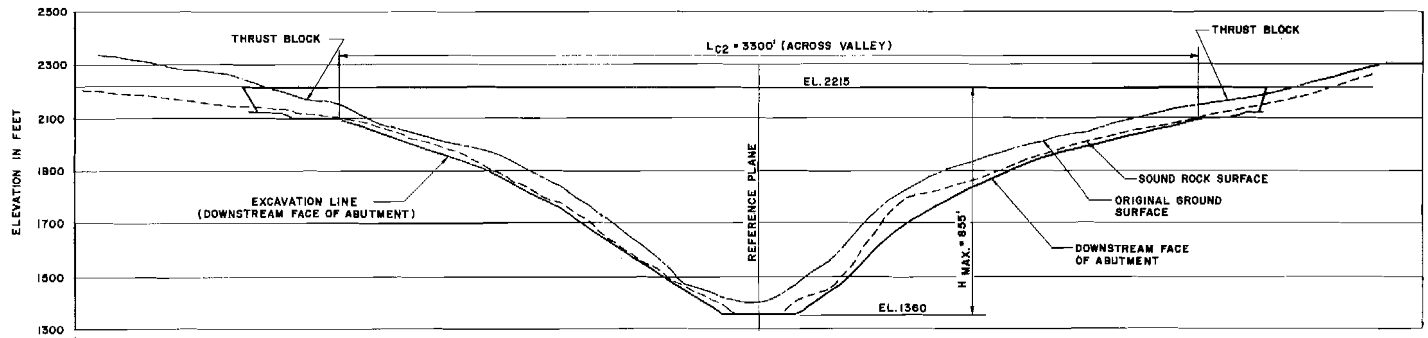
SUSITNA HYDROELECTRIC PROJECT

WATANA
ARCH DAM GEOMETRY

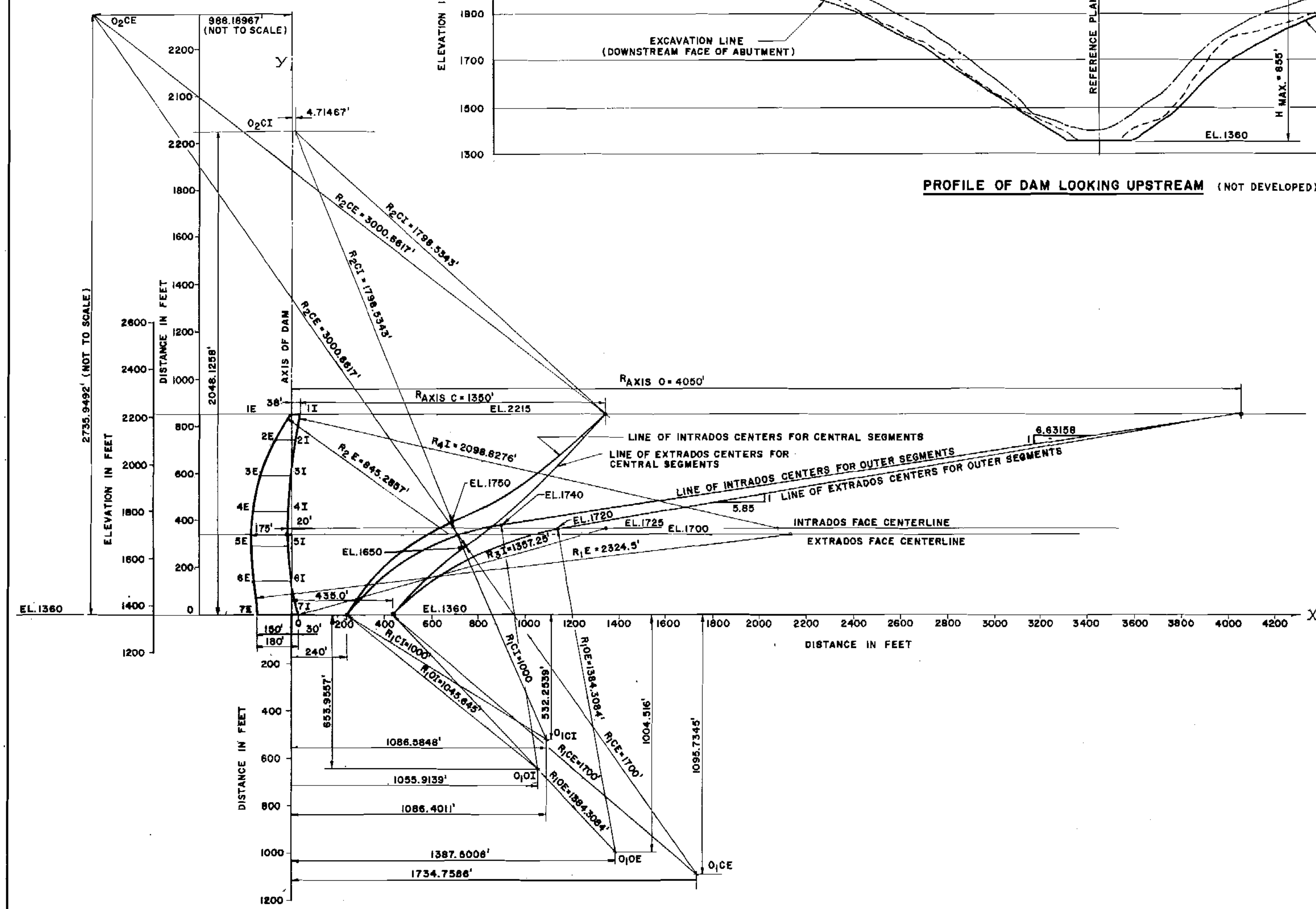
ACRES AMERICAN INCORPORATED

MARCH 1982

PLATE B1.4



PROFILE OF DAM LOOKING UPSTREAM (NOT DEVELOPED)



SECTIONS ALONG PLANES OF CENTERS

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SUSITNA HYDROELECTRIC PROJECT

WATANA
ARCH DAM GEOMETRY

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MARCH 1982

PLATE B1.5

APPENDIX B2

WATANA GENERAL ARRANGEMENT STUDY

1 - INTRODUCTION

Following an economic and technical review of a number of potential hydroelectric sites within the Susitna River Basin and an assessment of their development in different combinations, two sites were selected as being especially suitable for joint development. Details of this selection study are given in the Development Selection Report (DSR).

The upstream and larger site is the prospective Watana Development; and the lower site is Devil Canyon, named after the canyon in which it is located. The locations of the two sites are shown in Figure B2.1. Average flow in the river is 7,940 cfs at Watana and the total gross head developed by the two sites is approximately 1,330 feet. A high degree of regulation is achieved primarily through the Watana reservoir, a factor which contributes greatly to the decision to construct Watana as the first stage of an overall staging concept.

As set out within the DSR certain aspects of the layouts at the selected sites were consistent with certain generalized concepts. Such items as the configuration of power facilities and the type of spillway were developed to be suitable for the majority of schemes within the river basin to reflect, in their conservatism and potential adaptability to different conditions, the general uncertainties of the physical characteristics of each site. Although suitable for this initial selection process, the layouts of the chosen sites were not intended to define the final schemes. They have been reexamined and new layouts developed through more rigorous study based on the site information available from previous investigations by the U.S. Army Corps of Engineers and the Department of the Interior, together with data from Acres' 1980-81 site investigations.

It is the purpose of this report to describe the final general arrangement developed for the Watana site and to delineate the selection process and the comparative layouts which led to this arrangement. The arrangement for the Devil Canyon Development is described separately in another report.

2 - SUMMARY

2.1 - Scope

The objective of this study is to develop the most suitable overall conceptual layout for the major structures at Watana based on technical, economic and environmental considerations and restrictions.

It is not intended that the layout will be definitive but it is the intention to determine the general configuration of the major structures and facilities and the relationship of these facilities within the project layout.

2.2 - Methodology

(a) Preliminary Review of Layouts

Layouts were developed to a preliminary stage. A review of layouts included the considerations of technical feasibility, environmental acceptability, and obvious cost differences.

(b) Intermediate Review

Layouts were selected from the preliminary reviews and further developed. Review of these layouts included technical, cost, and environmental considerations.

(c) Final Review

Two layouts were selected and further developed. The layouts were compared on the basis of technical feasibility, mode of operation, the required maintenance, cost, and environmental considerations.

2.3 - Review Process

Nine layouts were compared, including that proposed in the DSR. These layouts involved involving single and multiple spillways on both sides of the river, with chute and flip bucket, chute and stilling basin, and unlined rock cascade spillways. Different dam locations and surface and underground power facilities on both sides of the river were reviewed.

The following four layouts were selected and further developed.

(a) Scheme WP1

The rockfill dam is constructed within the area bounded by major transverse shear zones. The spillway is a chute and flip bucket on the right bank. The twin tunnel diversion is located on the right bank and an underground powerhouse is constructed on the left side.

(b) Scheme WP2

The main dam is similar to WP1. The diversion tunnel is located on the right bank as is the chute and stilling basin spillway. An emergency rock channel spillway closed by an erodible earthfill plug is also located on this abutment. An underground powerhouse is located on the left bank.

(c) Scheme WP3

This scheme is similar to WP1 except that the main spillway is reduced in size and an emergency spillway is included.

(d) Scheme WP4

The dam location and geometry are similar to the other schemes and the diversion is on the right abutment. A rock cascade spillway is located on the left bank. An underground powerhouse is located on the right bank.

There is little scope for movement of the main dam which is bounded by major shear zones. A flip bucket is the most economical spillway but a cascade configuration gives environmental advantages. The underground powerhouse is more favorably located within the sound rock of the right bank.

A mid-level release for reservoir emergency drawdown can be used as a primary spillway facility.

(e) Final Review

Two schemes were developed from the preceeding comparisons. The first scheme consisted of the main rockfill dam, right bank tunnel diversion, a primary tunnel type spillway with discharge valves, an auxiliary flip bucket spillway, an emergency fuse plug spillway, and a right bank underground powerhouse. The second scheme consisted of a similar dam and diversion to the above. The main spillway was an unlined cascade on the left bank and a further emergency fuse plug spillway was located on the right bank.

The flip bucket scheme was selected for the final layout on the basis of its lower cost. The potential for erosion of the cascade spillway and the poor rock conditions in the vicinity of the cascade led to the rejection of this alternative.

3 - SCOPE

The objective of this study is to develop the most suitable conceptual layout of the facilities and structures for the site at Watana. Major factors considered included production of the maximum firm energy consistent with economic cost, technical feasibility, safety of operation, and impact on the environment. The layout was based on potential ease of construction and the capability of bringing the first generating unit on line within a nine-year construction period.

It was not intended that the layout should be definitive, but it was intended to establish the basis of the final layout of structures by establishing the general configuration of the dam, powerhouse, and diversion and confirming the spillway type and location. There will be future modifications such as minor realignment of structures themselves but the general concept of the scheme will remain unchanged.

4 - BASIN CHARACTERISTICS

A general discussion of climatology, geology, and seismic aspects is presented in Appendix B1, Section 4.

Geologicially, the Upper Susitna Basin lies within what is called the Talkeetna Mountains area. This area is geologically complex and has a history of at least three periods of major tectonic deformation. The oldest rocks (250 to 300 m.y.b.p.)* exposed in the region are volcanic flows and limestones which are overlain by sandstones and shales dated approximately 150 to 200 m.y.b.p. A tectonic event approximately 135 to 180 m.y.b.p. resulted in the intrusion of large diorite and granite plutons, which caused intense thermal metamorphism. This was followed by marine deposition of silts and clays.

Faulting and folding of the Talkeetna Mountains area occurred in the Late Cretaceous period (65 to 100 m.y.b.p.). As a result of this faulting and uplift, the eastern portion of the area was elevated, and the oldest volcanics and sediments were thrust over the younger metamorphics and sediments. The major area of deformation during this period of activity included the Watana area. The Talkeetna Thrust Fault, a well-known tectonic feature, trends northwest through this region and was one of the major mechanisms of this overthrusting from southeast to northwest.

During the Tertiary period (20 to 40 m.y.b.p.) the area surrounding the site was again uplifted by as much as 3,000 feet. Since then, widespread erosion has removed much of the older sedimentary and volcanic rocks. This post glacial uplift has induced downcutting of streams and rivers and is believed to be still occurring.

A deep relict channel exists on the right bank upstream from the dam. The overburden within this relict channel contains a sequence of glacial till and outwash interlayered with silts and clays of glacial origin. The top of rock under the relict channel area will be below the reservoir level. The data collected to date do not indicate that it will have any major impact on the feasibility of the site.

5 - METHODOLOGY

5.1 - General

Preliminary alternative layouts of the Watana site were set out and subjected to a series of review and screening processes. The layouts selected from each screening were developed to a greater degree of detail prior to the next review process and, if necessary, further "hybrid" layouts were included which combined the features of two or more of the alternative arrangements. Assumptions and criteria were evaluated at each stage and where additional data was available, this was incorporated.

The selection process follows the general selection methodology previously established for the Susitna project and is outlined below.

5.2 - Selection Methodology

The determination of the final arrangement was carried out in three distinct stages:

*m.y.b.p.: million years before present.

(1) Preliminary Review of Alternative Layouts

Step 1: (a) Assemble available data
(b) Determine design criteria
(c) Establish evaluation criteria

Step 2: Develop preliminary layouts based on the above data and design criteria including all plausible alternatives for the constituent facilities and structures.

Step 3: Review all layouts on the basis of technical feasibility, practicability, readily apparent cost differences, safety, and environmental impact.

Step 4: Select the layouts that can be identified as most favorable, taking into account the preliminary nature of the work at this stage. Selection is based on the evaluation criteria determined under Step 1c.

Step 5: Review of selected layouts by Acres' Internal Review Panel, followed by the review by Alaska Power Authority.

(2) Intermediate Review of Layouts

Step 1: (a) Review all data, incorporating additional data from other work tasks.
(b) Review and expand design criteria to a greater level of detail.
(c) Review evaluation criteria.

Step 2: Revise selected layouts on basis of Stage 1, Step 5, and the revised criteria and additional data. Produce plans and principal sections of layouts.

Step 3: (a) Produce quantity take-offs for major structures based on drawings prepared under Step 2.
(b) Carry out a preliminary contractor's type estimate and develop a construction schedule to determine unit rates for major quantities consistent with construction methods which will allow completion of the project within the required time frame.
(c) Determine overall cost of the schemes. Where breakdowns of certain work items are not available, costs are to be based on equivalent work carried out elsewhere. All direct costs are to be included.

Step 4: Review all layouts on the basis of technical merit, practicability, cost, impact of possible unknown conditions and uncertainty of assumptions, safety, and environmental impact.

Step 5: Select the two layouts that are most favorable based on the evaluation criteria determined under Step 1c.

From a review of the layouts and their composite structures under Step 4 it may be that the optimum layouts are not completely similar to those considered but would consist of individual facilities extracted from the different layouts. If this is the case then recommendations are to be made under Step 5 as to changes in the configuration of the two layouts to be examined further.

(3) Final Review of Layouts

Step 1: (a) Assemble and review any additional data from other work tasks.
(b) Revise design criteria to accord with additional data.
(c) Finalize overall evaluation criteria.

Step 2: Revise or develop the two layouts on the basis of conclusions from Stage 2. Overall dimensions of structures, water passages, gate sizes, etc., are to be determined.

Step 3: (a) Produce quantity take-offs for all major structures.
(b) Review cost components within a preliminary contractors' type estimate using the most recent data and criteria, and develop a construction schedule.
(c) Determine overall direct cost of schemes.

Step 4: Review all layouts on the basis of practicability, technical merit, cost, impact of possible unknown conditions, safety, and environmental impact.

Step 5: Select the final layout on the basis of the evaluation criteria developed under Step 1c.

6 - PRELIMINARY REVIEW OF ALTERNATIVE LAYOUTS

6.1 - General

An initial layout for the Watana development had already been prepared for comparison of Susitna sites as described in the Development Selection Report. This layout consisted of the main rockfill dam, right bank dual stilling basin spillway, and underground left bank powerhouse.

As a preliminary review of possible layout configurations, eight additional layouts were prepared to a low degree of detail. These layouts included a variety of flood discharge facilities, different main dam slopes, and alternative power facilities and locations.

The purpose of these layouts was to embrace all alternative facility types, configurations and locations and indicate their relationships within the overall developments.

A visual inspection of the alternative schemes allowed the elimination of some of these alternatives on the basis of their obvious expense, their impracticability, and their technical infeasibility.

6.2 - Design Data and Criteria

Sound bedrock contours and major shear zones are shown on Plate B2.1. These are based on drill hole logs and surface features located during recent field investigations to date, and may be subject to change.

Generalized criteria established for the initial layouts were as follows:

Probable maximum flood:	235,000 cfs
Design (1:10,000 year) routed flood:	115,000 cfs
1:50-year construction flood:	87,000 cfs
Maximum normal operating level:	2,200 ft MSL
Minimum normal operating level:	2,000 ft MSL
Surcharge:	5 ft
Average tailrace elevation:	1,465 ft MSL
Dam freeboard:	25 ft
Dam crest elevation:	2,225 ft MSL
Dam slopes upstream:	2.5:1 and 2.25:1
downstream:	2:1
Maximum energy dissipated per feet width at stilling basin:	45,000 hp
Powerhouse capacity:	800 MW
Number of generating units:	4
Maximum power flow:	16,000 cfs

6.3 - Evaluation Criteria

The merits of individual layouts were assessed on the basis of the following criteria:

- Technical feasibility;
- Compatability of layout with known structural features of site;
- Ease of construction;
- Excessive physical size of component structures in certain locations;
- Obvious cost differences of comparative structures;
- Environmental acceptability; and
- Operating characteristics.

6.4 - Description of Layouts

Eight layouts were examined for the Watana development in addition to the double stilling basin layout prepared for the basin development studies and shown on Plate 8.2 (Vol. 1). These layouts are shown on Plate 9.3 (Vol. 1) and briefly described in Table B2.1.

Although it was recognized that provision would have to be made for downstream releases of water during filling of the reservoir, and that some sort of low level release would be required for emergency reservoir drawdown, these features were not incorporated in the layouts. These facilities would either be interconnected with the diversion of be provided for separately. It appeared that whichever systems were selected would be similar for all layouts with minimal cost differences and little impact on other structures. These features were therefore excluded from overall layout assessment at the early stage.

6.5 - Layout Features

The two major shear zones crossing the Susitna River and running roughly parallel in the northwest direction appeared to enclose approximately a 4,500-feet stretch of watercourse (Plate B2.1). It was anticipated that the fracture materials and infill within the actual shear zones would be unable to support standard tunneling methods and would be inadequate for founding of massive concrete structures. The originally proposed dam centerline lay between these shears. Since no major advantage appeared to be gained from large changes in the dam location, layouts generally were kept within the confines of these bounding zones.

A rockfill cofferdam with impervious fill core, as shown on Plate 9.3 (Vol. 1), is used as the basis for all layouts. The downstream slope of the dam is set at 2:1 in all instances but the upstream slope varies between 2.5:1 and 2.25:1 in order to determine whether variance of the dam slope will affect congestion of the layout. In all arrangements, except that prepared for the basin development studies, cofferdams are included in the body of the main dam.

The discharge facilities could consist of more than one spillway. The overall design discharge corresponds to the 1:10,000 recurrence. Floods greater than the routed 1:10,000-year flood and up to the probable maximum flood are passed by surcharging the spillways except in cases where an unlined cascade or stilling basin type spillway serves as the sole discharge facility. In such instances, under large surcharges, the spillways would not act as efficient energy dissipators, but would be drowned out, acting as steep open channels with the possibility of their total destruction. In order to avoid such an occurrence, the design flood was considered as the routed probable maximum flood.

On the basis of existing information, it appeared that an underground powerhouse could be located on either side of the river. A surface powerhouse on the right bank appeared feasible but was precluded from the left bank by the close proximity of the downstream toe of the dam and the broad shear zone. Situating the powerhouse further downstream would necessitate tunneling across the shear zone, which would be expensive, and excavating a talus slope. Furthermore, it was found that a left bank surface powerhouse was generally either in the way of a left bank spillway or directly in line with discharges from a right bank spillway.

The diversion took the form of a two-tunnel scheme in all layouts. A single tunnel would have a diameter of approximately 45 feet, which would be large considering the quality of the bedrock and could require an excessive amount of rock bolting and steel supports. It was also considered that two tunnels would give a greater degree of security.

6.6 - Comparison of Layouts

The original layout as prepared for comparison of site developments in the DSR has a skewed dam centerline, as proposed by the Corps of Engineers, and a right bank double stilling basin spillway. The volume of the dam could be slightly reduced by locating it more nearly square to the river and slightly upstream. The spillway follows the shortest line to the river avoiding interference with

The spillway follows the shortest line to the river avoiding interference with the dam and discharges downstream, almost parallel to the flow, into the center of the river. A substantial amount of excavation is required for the chute and stilling basins, although most of this material could probably be used in the dam. However, a large volume of concrete would be required and the system would be very expensive. The maximum head dissipated within each stilling basin is approximately 450 feet, within world experience. Cavitation and erosion of the chute and basins should not be a problem if the structures are properly designed. Extensive erosion downstream would not be expected. The diversion follows the shortest route, cutting the bend of the river on the right bank, and has inlet portals as far upstream as possible without having to tunnel through the "Fins" shear zone. It is possible that the underground powerhouse is in the area of the "Fingerbuster," but it could be located upstream almost as far as the system of drain holes and galleries backing up the main dam grout curtain.

Alternative 1 is similar to the double stilling basin alternative except that the right side of the dam is rotated clockwise with the center of the dam moved 850 feet upstream and the spillway changed to a chute and ski jump flip bucket. A localized downstream curve is introduced in the dam close to the right abutment in order to reduce the length of the spillway. The alignment of the spillway is almost parallel to the downstream section of the river and it discharges into a pre-excavated plunge pool in the river approximately 800 feet downstream from the flip bucket. This type of spillway should be considerably cheaper than a stilling basin alternative, provided that excessive excavation of bedrock within the plunge pool area is not required. Careful design of the bucket will be required to prevent excessive erosion downstream causing undermining of the valley sides and/or build-up of material downstream which could result in elevation of the tailwater levels.

Alternative 2 consists of a left bank cascade spillway with the main dam curving downstream at the abutments. The cascade spillway would require an extremely large volume of excavation but it is probable that most of this material, with careful scheduling, could be used in the dam. The excavation would cover a large area, but would allow a reduction in the size of the rock quarry. The excavation would cross the "Fingerbuster" and dental concrete would be required. In the upstream portion of the spillway, velocities would be relatively high because of the narrow configuration of the channel and erosion could take place in this area in proximity to the dam. Flow enters the river at right angles to the general flow but unit discharges would be relatively low and should not cause substantial erosion problems. The powerhouse is in the most suitable location for a surface alternative where the bedrock is close to the surface and the overall slope is approximately 2:1.

Alternative 2A is similar to Scheme 2 except that the upper end of the spillway is divided with separate control structures. This division would allow use of one structure while maintenance or remedial work is being performed on the other structure or channels.

Alternative 2B is similar to Scheme 2 except that the cascade spillway is replaced by a double stilling basin type. This is somewhat longer than the similar type of spillway on the right bank in Alternative 1. However, the slope of the ground is less than the rather steep inclination of the right bank and it may be easier to construct, a factor which may partly mitigate the cost of the greater length. The discharge is at a sharp angle to the river and, being more concentrated than the cascade, could cause erosion of the opposite bank.

Alternative 2C is a derivative of 2B with a similar arrangement, except that the double stilling basin spillway is reduced in size and augmented by an additional emergency spillway in the form of an inclined, unlined rock channel. Under this arrangement the stilling basin acts as the service spillway, passing the 1:10,000-year design flood, and greater flows are passed down the unlined channel which is closed at its upstream end by an erodible fuse plug. The problems of erosion of the opposite bank still remain, although these could be overcome by excavation and/or slope protection. Erosion of the chute would be extreme for significant flows, although it is highly unlikely that this emergency spillway would ever be used.

Alternative 2D replaces the cascade of Scheme 2 with a lined chute and flip bucket. Criticism of the flip bucket is the same as for Alternative 1 except that the left bank location in this instance necessitates a longer chute. This is partly offset by cheaper construction costs because of the flatter slope, but it discharges into the river at an angle which may cause erosion of the opposite bank. The underground powerhouse is located on the right bank, an arrangement which gives an overall reduction of the length of the water passages.

Alternative 3 has a dam centerline location slightly upstream from Scheme 2, but retains the downstream curve at the abutments. The service spillway is an unlined rock cascade on the left bank which passes the design flood. Discharges beyond the 1:10,000-year flood, if they should ever occur, would be passed down the concrete-lined chute and flip bucket spillway on the right bank. A gated control structure is provided for this auxiliary spillway which gives it the flexibility to be used as a backup if maintenance should be required on the other spillway. Erosion of the cascade may be a problem, as mentioned previously, but erosion downstream should not be a problem because of the low unit discharge and the spillway's infrequent operation. The diversion is situated beneath the right abutment, as with previous arrangements, and is of similar cost for all these alternatives.

Scheme 4 is based on a downstream movement of the main dam around the bend of the Susitna River and a rotation of the dam to maintain the dam centerline square to the river. The relocation may produce a reduction in the overall dam quantities but would require siting the impervious core of the dam directly over the "Fingerbuster" shear zone at its highest cross section. The left bank spillway, consisting of chute and flip bucket, is reduced in length compared to other left bank locations, as are the power facility water passages. The diversion is situated on the left bank. There is no advantage to a right bank location, since the tunnels are of similar length owing to the overall downstream shift of the dam. Spillways and power facilities would also be lengthened by a right bank location with this dam configuration.

6.7 - Conclusions

If the main dam core is located over major shear zones, assurance of an effective cut-off becomes difficult. Thus, there is very little scope for realigning the main dam apart from a slight rotation to place it more at right angles to the river.

Location of the spillway on the right bank gives a shorter distance to the river and allows discharges almost parallel to the general direction of flow. The original double stilling basin arrangement would be extremely expensive, particularly using a design flow equal to the probable maximum flood. An alternative such as 2C would reduce the design flood but would only be acceptable if a more predictable emergency spillway could be constructed. A flip bucket spillway on the right bank, discharging directly down the river, would appear to be an economic arrangement, although some scour might occur in the plunge pool area. A cascade spillway on the left bank might be an acceptable solution providing most of the excavated material can be used in the dam.

The diversion is shorter if it is located on the right bank and is accessible by a preliminary access road from the north, which is the most likely route. It also avoids the area of the "Fingerbuster" and the steep cliffs, close to the downstream dam toe, which would be encountered on the left side.

The underground configuration presently assumed for the powerhouse allows for location on either side of the river with a minimum of interference with the surface structure.

Four of the preceding layouts, or variations of them, were selected for further study. The layouts are:

(a) A variation of the double stilling basin alternative with a single stilling basin service spillway on the right bank and a rock channel and fuse plug emergency spillway on the left bank, a left bank underground powerhouse and a right bank diversion.

(b) Alternative 2 with right bank flip bucket spillway, left bank underground powerhouse, and right bank diversion.

(c) A variation of Alternative 2 with a reduced capacity service spillway and a right bank rock channel with fuse plug serving as an emergency spillway.

(d) Alternative 4 with a left bank rock cascade spillway, a right bank underground powerhouse, and a right bank diversion.

7 - INTERMEDIATE REVIEW OF LAYOUTS

7.1 - General

The four layouts described in Section 6 were developed in greater detail, taking into account any new data that had become available and based on expanded and updated design criteria. Capital cost estimates of the layouts were prepared and the schemes were evaluated to determine the two arrangements that were the most favorable.

Several variations for each layout were developed and discarded during production of the layouts discussed herein. They were discarded on the basis of technical unsoundness or obvious excessive expense while offering no energy, operating or environmental benefits over the alternatives. They are not described in this report. However, the identifying numbers assigned to the selected schemes studied have been retained.

7.2 - Design Criteria

The principal project parameters and design criteria on which the layouts were based are given below. Parts of this criteria will be superseded as more information becomes available. Where assumptions were made, they were based on the best information available at that time.

River Flows

Average flow (over 30 years of record):	7,860 cfs
Probable maximum flood (routed):	235,000 cfs
Maximum inflow with return period of 1:10,000 years:	155,000 cfs
Maximum 1:10,000-year routed discharge:	115,000 cfs
Maximum flood with return period of 1:500 years:	116,000 cfs
Maximum flood with return period of 1:50 years:	87,000 cfs
Reservoir normal maximum operating level:	2,200 ft MSL
Reservoir minimum operating level:	2,050 ft MSL
Area of reservoir at maximum operating level:	40,000 acres
Reservoir live storage:	4.6×10^6 acre ft
Reservoir full storage:	10.0×10^6 acre ft

Dam

Type:	Rockfill
Crest elevation at center:	2,225 ft MSL
Height:	890 ft above foundation
Cutoff and foundation treatment:	Core founded on rock, grout curtain and downstream drains
Upstream slope:	1V:2.75H
Downstream slope:	1V:2.0H
Crest width:	80 ft

Diversion

Cofferdam types:	Rockfill
Cutoff and foundation:	Slurry trench to bedrock
Upstream cofferdam crest elevation:	1,560 ft MSL
Downstream cofferdam crest elevation:	1,500 ft MSL
Maximum pool level during construction:	1,555 ft MSL
Water passages	Concrete lined
Outlet structures:	Low level structure with high head slide gates to operate under low heads

Final closure:	Mass concrete plugs in line with dam grout curtain
Releases during impounding:	2,000 cfs min. via bypass to outlet structure

Spillway

Design floods:	Passes PMF, preserving integrity of dam with no loss of life Passes routed 1:10,000-year flood with no damage to structures
Main spillway - Capacity:	Routed 1:10,000-year flood (115,000 cfs) with 5 ft surcharge (Passes PMF with surcharge to dam crest if no emergency spillway)
- Control structure:	Gated ogee crests
Emergency spillway (where applicable) - Capacity:	PMF minus 1:10,000-yr flood
- Type:	Fuse plug

Power Intake

Type:	Massive concrete structure embedded in rock
Number of intakes:	4
Draw-off requirements:	Multi-level corresponding to temperature strata
Drawdown:	150 feet

Penstocks

Type:	Concrete-lined tunnels with downstream steel liners
Number of penstocks:	4

Powerhouse

Type:	Underground
Transformer area:	Separate gallery
Control room and administration:	Surface
Access - Vehicle:	Rock tunnel
- Personnel:	Elevator from surface

Power Plant

Type of turbines:	Francis
Number and rating:	4 x 200 MW
Rated net head:	690 ft
Design flow:	5,300 cfs per unit
Normal maximum gross head:	745 ft
Type of generator:	Vertical synchronous
Rated output:	222 MVA
Power factor:	0.9
Frequency:	60 HZ
Transformers:	222 MVA - 13.8-345 kV, 3-phase

Tailrace

Water passages:	2 concrete-lined tunnels
Elevation of water passages:	Below minimum tailwater
Surge:	Separate surge chambers
Average tailwater elevation:	1,475 ft MSL
Main Access:	From the north side
Transmission:	From the north side

7.3 - Evaluation Criteria

The review of layouts was carried out and assessments of the different schemes made on the basis of the following evaluation criteria:

(a) Technical feasibility of the scheme;
(b) Overall cost of the scheme;
(c) Ease of construction of the project. This will partly be reflected in the cost of the scheme and be evaluated under (b);
(d) Impact on construction schedule;
(e) Environmental considerations; and
(f) Operating characteristics.

7.4 - Description of Layouts

The schemes selected from Section 6 were reviewed in more detail and modified. A description of each of the schemes is as follows:

(a) Scheme WP1: This scheme is derived from Alternative 1 and is shown on Plate 9.4 (Vol. 1). The upstream slope of the main dam is reduced to a gradient of 2.75:1. Due to the uncertainty regarding riverbed alluvium, the cofferdams are located outside the body of the dam and the inlets to the right bank diversion tunnels are moved upstream from the "Fins." The spillway takes the form of a chute and flip bucket located on the right bank and is similar in configuration to that shown on Plate 9.6 for Scheme WP3. The underground powerhouse is located on the left side of the river.

(b) Scheme WP2: This scheme is shown on Plates 9.6 and 9.7 (Vol. 1) and is derived from the stilling basin layout. The main dam and diversion are similar to Scheme WP1 except that the lower cofferdam is located downstream from the spillway outlet and the diversion tunnels are correspondingly extended. The service spillway is located on the right bank, but the two stilling basins of the double stilling basin layout are reduced to a single stilling basin down at river level. An emergency spillway is located on the right bank. It consists of a channel excavated in sound rock discharging downstream from the area of the relict channel. The channel is sealed by an impervious fuse plug and is capable of discharging the flow differential between the probable maximum flood and the 1:10,000-year design flood of the service spillway. The underground powerhouse is located on the left bank.

(c) Scheme WP3: This scheme is also shown on Plate 9.6 (Vol. 1) and is similar to Scheme WP1 in all respects, except that the main spillway is reduced in size and an emergency spillway is added, consisting of right bank rock channel and fuse plug.

(d) Scheme WP4: The dam location and geometry for Scheme WP4 are shown on Plates 9.8 and 9.9 and are similar to the other schemes. The diversion is on the right bank and discharges downstream from the powerhouse tailrace outlet. A rock cascade spillway is located on the left bank and is served by two separate control structures with downstream stilling basins. The underground powerhouse is located on the right bank.

7.5 - Layout Features

The main dam is in the same location and has the same configuration for each of the four layouts considered. Typical sections are shown in Plate B2.2, Main Dam. The upstream slope of the dam has been reduced to a slope of 2.75:1. Although this compares conservatively to other high rockfill dams that have been constructed in extremely active seismic areas, the technical feasibility of the dam is assured. The cofferdams have been constructed outside the main dam in order to allow excavation of the alluvial material and ensure a competent rock foundation beneath the complete area of the dam. The overall design of the dam is conservative, and possible savings in both fill and excavation can be made after further study.

The diversion is located on the right bank. The upstream reduction of the dam slope necessitates the location of the diversion inlets upstream from the "Fins" shear zone. This will require extensive excavation and support where the tunnels pass through the zone of sheared rock, and delays in the construction schedule could result.

A low-lying area exists on the right bank above the area of the relict channel, and this is closed by an approximately 50-foot high saddle dam. Treatment proposed for this area comprises a slurry trench cutoff combined with grouting to seal the 200-foot depth of pervious material infilling this channel.

7.6 - Construction

The diversion tunnel will be constructed from both ends. Access to the upstream portal area will be protected by a section of rock left in place across the approach channel to form a temporary cofferdam. Heavy support will be necessary in the area of the "Fins".

Material for the shell of the main dam will be blasted rock from a quarry adjacent to the south abutment. Most of the rock from the structural excavations will also be used in the shell. Impervious material will be available from borrow areas located upstream above the right abutment.

It is anticipated that the great majority of the rock from the cascade spillway excavation in Scheme WP4 will be used in the dam such that the spillway serves as an inexpensive source for the shell material. However, little is known about the rock in this area and if the majority of the excavated material is not usable, the relative cost of this type of spillway will be significantly increased.

The left bank powerhouse is located upstream of the "Fingerbuster" in what is anticipated to be competent rock. However, difficulties could be encountered in the tailrace tunnel excavation where it crosses the shear zone.

7.7 - Scheduling

Construction of the diversion scheme is estimated to take two years provided serious problems are not encountered during tunneling through the "Fins". Scheduling of the diversion and the main dam is on the critical path and construction of the dam is anticipated to require more than eight years, giving a total construction period of nine years with a one-year overlap of diversion and dam construction.

Placing the impervious fill materials for the main dam is expected to take place each year over a five-month period when the temperature is above freezing and the water content of the material will not be frozen. Excavation and concreting of the underground caverns will take place throughout the year.

7.8 - Costs

Capital cost estimates for construction of the alternative schemes are given in Table B2.2, which lists the costs of the main facilities together with indirect costs. Costs are in January 1982 dollars.

Unit rates are based on a preliminary contractor's type estimate developed from anticipated plant and labor content and construction activities. Quantities have been calculated from the drawings or, where structures are similar for all layouts, they have in some instances been developed from comparable structures in other developments. Twenty percent has been added to the costs to cover contingencies, and 12.5 percent has been added to cover engineering and administration.

For all spillway alternatives, sound material from excavation has been assumed to be usable in the main dam. All overburden plus 10 feet of weathered rock have been considered as spoil; 75 percent of the underlying 30 feet of rock after bulking has been assumed usable as dam fill; and 100 percent of the remaining rock, after bulking, has been considered as suitable for fill material. An appropriate credit has been indicated in Table B2.2 for use of excavated rock from the spillways in the main dam.

7.9 - Comparison of Layouts

The single-chute, flip bucket type spillway of Scheme WP1 is less costly than other spillway layouts, with simple operating characteristics and provision for surcharging the control structure to pass the design flood. The probable maximum flood can be passed by additional surcharging up to the crest level of the dam. In Scheme WP3 a similar spillway is provided, except that the control structure is reduced in size and discharges above the routed design flood are passed through the rock channel emergency spillway. The arrangement in WP1 provides no backup to the main spillway, and if downstream erosion in the plunge pool area takes place over a long period, or if maintenance were required on the concrete structures, no alternative discharge facility would be available. Scheme WP3 with the additional spillway gives greater operating flexibility allowing emergency discharge if it is absolutely required under extreme circumstances. It would also reduce the absolute maximum discharges into the river which could cause erosion downstream from the dam.

The stilling basin spillway in Scheme WP2 would reduce the danger of extensive erosion downstream, but high velocities on the lower part of the chute could cause cavitation even with provision for aeration of the discharge. The stilling basin would be designed for the 1:10,000-year routed flood, with additional flows passed through the emergency spillway. This type of spillway would be very expensive, as can be seen from Table B2.2. Furthermore, from a worldwide review of spillways, no operating experience is available for a stilling basin of such high capacity operating under a static head as high as 720 feet, as is the case at Watana. Experience of smaller stilling basins at comparable heads has shown severe damage under operating conditions in several cases.

The feasibility of the rock cascade spillway is entirely dependent on the quality of the rock, which dictates the amount of treatment required for the rock surface and also the percentage of the excavation which can be used in the main dam. For determining the capital cost of the layout, conservative assumptions were made regarding surface treatment and the portion of material that would have to be wasted as discussed in Section 7.8.

The diversion scheme is located on the right bank for all alternatives, but extends downstream from the stilling basin in Scheme WP2, which involves an approximately 800-feet increase in the length of the tunnels. The left bank location of the powerhouse is close to a suspected shear zone, with the tailrace tunnels passing through this shear zone to reach the river. A longer access tunnel is also required, together with an additional 1,000 feet in the length of the tailrace. The left bank location is remote from the main access road, which will probably be on the north side of the river, as will the transmission corridor.

7.10 - Conclusions

There is little scope within the layouts for adjustment of the dam centerline owing to the constraints imposed by the upstream and downstream shear zones (this is confirmed in Section 8). The passage of the diversion tunnels through the upstream zone could result in delays in construction.

From a comparison of costs it can be seen that the flip bucket type spillway is the most economical, but because of the potential for erosion under frequent operation its use as the sole discharge facility is undesirable. A mid-level release will be required for emergency drawdown of the reservoir. Use of this facility for discharge of more frequent floods would allow less frequent use of the main spillway, combining flexibility and safety of operation with reasonable cost. The emergency rock channel spillway would be retained for discharge of flows above the routed 1:10,000-year flood as well as giving additional security should the main spillway become inoperative under such circumstances as jamming of the control gates under severe earthquake conditions.

The stilling basin spillway is expensive. The large amount of energy to be dissipated in the basin has the potential to cause extensive damage to the structure. Previous operating experience of basins with heads in excess of 700 feet, as at Watana, is not available. Erosion downstream should not be a problem but cavitation of the chute could occur. Scheme WP4 was therefore discarded.

The cascade spillway was also not favored for technical and economic reasons. However, this alternative was retained for further consideration because of its lower susceptibility to nitrogen supersaturation in the downstream discharges which could be harmful to the fish population, as discussed in Section 8. The capacity of the cascade was reduced and the emergency rock channel spillway was included for discharge of extreme floods.

The schemes selected for further evaluation were:

- Right bank diversion, mid-level release facilities for discharge of more frequent flood flows, right bank chute and flip bucket main spillway, rock channel as an emergency spillway, and a right bank underground powerhouse; and

- Right bank diversion, left bank rock cascade main spillway, right bank rock channel emergency spillway, and a right bank underground powerhouse.

8 - FINAL REVIEW OF LAYOUTS

8.1 - General

Following the selection of two arrangements described under Section 7, a detailed review of input data and design criteria was carried out based on additional geological investigations and intepretation and ongoing engineering study. Limitations on dissolved nitrogen in the flood discharges had considerable impact on the overall spillway design. Additional information on the location of the "Fingerbuster" shear zone as a result of on-going field explorations was also factored into the study.

At this stage, outlet facilities for low-level releases during reservoir filling and for emergency drawdown of the reservoir were introduced into the conceptual layouts, and the individual power, spillway, and diversion facilities were considered in more detail. On-going generation planning and reservoir simulation studies also led to revised concepts for the size and scheduling of power facilities.

8.2 - Design Data and Criteria

Revisions in the design data from the previous review are given in this section. The orientation of major rock jointing patterns is given in Figure B2.2. The location of major shear zones is given in Plate B2.3.

Revisions to the criteria are as follows:

Maximum 1:10,000-yr routed discharge:	120,000 cfs
Reservoir normal maximum operating level:	2,215 ft
Reservoir minimum operating level:	2,030 ft
Dam crest elevation at center:	2,240 ft
Upstream slope:	1V:2.4H
Crest width:	50 ft
Upstream cofferdam crest elevation:	1,585 ft
Downstream cofferdam crest elevation:	1,500 ft
Maximum pool level during construction:	1,580 ft
Minimum releases during impounding:	6,000 cfs
No. of intakes:	6
Drawdown:	185 ft
No. of penstocks:	6
No. and rating of turbines:	6 x 140 MW
Rated output of generators:	156 MVA
Tailwater elevation:	
-- Full generation at minimum load:	1,458 ft
-- Single generating unit, 60% load:	1,455 ft
-- Spillway passing 1:10,000-yr flood:	1,473 ft

Nitrogen supersaturation is not to occur in flood discharges with a frequency greater than 1:50 years.

8.3 - Layout Objectives and Evaluation Criteria

The layouts were developed and evaluated in greater depth than previous arrangements on the basis of the following evaluation criteria:

(a) Technical Feasibility

The layouts were judged on whether individual structures were practicable on the basis of their physical size, their compatibility in relation to the characteristics of the site, and whether more suitable alternative facilities could be developed. The structures were reviewed to determine that necessary safety requirements could be met in regard to both damage to the structures and the safety of operators and downstream communities.

(b) Mode of Operation

The mode of operation of the spillways was examined as affected by the flood discharge criteria, surcharge restraints, safety requirements, and environmental considerations. Feasibility of operation of the generating units was considered as well as the ability of units to run at close to optimum generating capacity while meeting a varying load demand.

(c) Maintenance

The design and limitation of operation of facilities to reduce wear and damage to the structures requiring heavy maintenance were considered.

(d) Cost

The costs of the individual facilities within the two selected schemes were compared.

(e) Environmental

The environmental impact of the arrangements was considered including their appearance, their effect on downstream discharges, and the temperature and reduction of dissolved nitrogen in those discharges.

8.4 - Location of Main Dam

As a preliminary step to further study of layouts, the effects of slight reorientation of the main dam was examined. A computer program was written to determine the overall volume of the dam together with the volumes of zoned materials for different dam locations. Typical locations of the dam centerline are shown in Plate B2.4. Alignment No. 4 is similar to the locations for the selected layouts apart from the slight curve at the abutments. Upstream slopes of 1:2.4 and downstream slopes of 1:2 were adopted together with a 50-foot crest width. Centerline 0 is approximately that adopted by the Corps of Engineers in previous studies. Total volumes of fill material in the dam are tabulated on Plate B2.4.

From the table it is apparent that relocating the dam 300 feet or more upstream will reduce the overall volume by approximately 3,000,000 to 4,000,000 cubic yards. It is also apparent that slightly skewing the dam will also give a considerable increase in fill material. As the centerline is moved over the 300 foot length of the valley covered by centerline locations 1, 2, 3, and 4, there is a variation of just over 1,000,000 cubic yards in volume indicating that the location of the dam in this area will have little impact on its cost providing it remains approximately normal to the valley.

Centerline 4, adopted for the layouts, sets the dam as far upstream as possible without encroachment of the diversion structures into the area of the "Fins". This allows for the maximum amount of room possible downstream to accommodate the right bank tunnel portals.

8.5 - Description of Layouts

(a) Right Bank Outlet Facilities (Scheme WP3A)

The layout of the scheme is shown in Plates 9.10 (Vol. 1), B2.5 and B2.6. This is a modified version of Scheme WP3 derived in Section 7. Because of scheduling difficulties and cost, it is important to maintain the diversion tunnels downstream of the "Fins" shear zone. It is also important to keep the dam centerline as far upstream as possible to avoid congestion of the downstream structures. For these reasons, the inlet portals to the diversion tunnels have been located in the sound bedrock forming the downstream boundary of the "Fins", and the approach channel is in open cut through the fractured and gouge materials of the fault. The upstream cofferdam and main dam are maintained in their upstream location. As stated previously, additional criteria have necessitated modifications in the spillway configuration, and low-level and emergency drawdown outlets have been introduced.

The main components of the scheme are as follows:

(i) Main Dam

Further investigation and review of world practice suggests that an upstream slope of 1:2.4 or steeper would be acceptable for the rock shell. On this basis a slope of 1:2.4 has been adopted which results not only in a reduction in dam fill volume but also in a reduction in the base width of the dam which maintains the project within the major shear zones.

The dam is founded on sound rock over its complete cross section. The downstream slope gradient is 2:1 and the cofferdams remain outside the dam in order to allow excavation across its complete foundation area. The foundation of the core of the dam is conservatively assumed at approximately 30 feet beneath the original rock surface. A system of galleries with an upstream grout curtain and downstream drain holes is provided beneath the core. The dam is located approximately normal to the river to reduce the fill volume. The axis is curved slightly downstream at the right abutment to better accommodate the main spillway. This is set as far upstream as possible while locating the main project features downstream of the "Fins", to relieve congestion of the downstream structures. This location also corresponds to the least volume of excavation and fill material required in the dam as shown in Plate 8.1. Optimization studies of dam costs relative to firm energy production led to preliminary selection of a reservoir maximum normal operating level of 2,215 feet MSL. The dam crest elevation was therefore raised to 2240 MSL for this phase of layout studies.

(ii) Diversion

Scheduling requirements for construction of the project call for completion of the diversion facilities in a two-year period. In the intermediate arrangement diversion tunnels passed through the broad structure of the "Fins," an intensely sheared area of breccia gouge and infills. Tunneling in this material would be difficult. High costs would be involved, but of greater importance would be the time taken for construction in this area and the possibility of unexpected delays. For this reason, the inlet portals have been located downstream from this zone with the tunnels closer to the river and crossing the main system of jointing at approximately 45°. This arrangement allows straight tunnels, cutting the bend of the river and giving clear lines of inflow and outflow at the portals. It also provides for a shorter length of tunnel.

Two schemes, one based on pressure tunnels and the other on free-flow tunnels, were considered initially for diversion. Incorporated into these schemes was a provision for low-level discharges during filling of the reservoir. The selected scheme is a combined free flow and pressure tunnel arrangement which allows for accommodation of the low-level discharges in the free-flow tunnel. This scheme avoids the difficulty of cofferdam closure resulting from the higher level inlets in the two free-flow tunnel alternatives.

The selected diversion scheme consists of two concrete-lined, 30-feet diameter tunnels, each approximately 4,000 feet long. The upstream cofferdam is a 120-feet high rockfill dam with impervious fill core founded on the alluvial riverbed materials. Cut-off is provided by a slurry trench down to bedrock. Concrete inlet structures are provided, each housing a pair of slide closure gates capable of closing under heads of up to 140 feet and withstanding a static head of 400 feet when closed.

A separate low-level inlet and 30 feet diameter concrete-lined tunnel is provided. The inlet is located in the reservoir at approximate Elevation 1550, and the tunnel discharges downstream of the diversion plug where it merges with the diversion tunnel closest to the river. This low-level tunnel is designed to pass flows in excess of 2,000 cfs as a low-level release during reservoir filling. It will also pass up to 10,000 cfs under 500 feet of head to allow emergency draining of the reservoir. Energy is dissipated in the tunnel at the outlet of hydraulically-designed passages contained within two mass concrete plugs approximately 350 feet apart. The passages are closed by vertical sealed high-pressure slide gates located in underground chambers with access via a tunnel from the main powerhouse access.

Initial closure is made by lowering the gates to the tunnel located closest to the river and constructing a concrete closure plug in the tunnel, approximately within the grout curtain underlying the core of the main dam. On completion of the plug, the low-level release will be opened and controlled discharges passed downstream. The gates within the second portal will be closed and a mass concrete plug constructed also within the grout curtain. After closure of the gates, filling of the reservoir can commence.

(iii) <u>Outlet Facilities</u>

As a provision for drawing down the reservoir in case of emergency, a mid-level outlet is provided. This will consist of a deep intake structure adjoining the power intake facilities, together with a downstream-lined shaft and tunnel. As discussed in the following paragraph, this facility will also be used to release annual floods with a recurrence interval of less than 50 years.

As part of the design criteria for spillways, a restriction was imposed on the allowance of excess dissolved nitrogen in spillway discharges.

Nitrogen supersaturation occurs when aerated flows are subjected to pressures approaching two atmospheres such as and would occur in deep plunge pools or at large hydraulic jumps. The excess nitrogen would not be dissipated within the downstream Devil Canyon reservoir and a buildup of nitrogen concentration could occur throughout the body of water. It would eventually be discharged downstream from Devil Canyon with extremely harmful effects on the fish population. Discharges of nitrogen supersaturated water from Watana were therefore limited to a recurrence period of 1:50 years or more.

For more frequent discharges, a system of Howell-Bunger valves was introduced which would not cause supersaturation. The valves were incorporated into the downstream end of the outlet facilities, fulfilling a secondary function as an emergency reservoir drawdown. The valves are sized to discharge the routed 1:50-year flows in conjunction with the powerhouse, operating at 75 percent capacity. This results in a design flow of 30,000 cfs. A total of six valves are provided with separate steel-lined tunnels from a common manifold, each protected by individual upstream closure gates. The valves are directed downstream and are partly incorporated into the mass concrete block forming the flip bucket of the auxiliary spillway. The rock downstream is protected by a concrete facing slab anchored to sound bedrock.

(iv) Main Spillway

The main spillway is a concrete-lined chute and flip bucket discharging into a plunge pool excavated in the downstream river bed. Releases are controlled by a three-gated ogee structure located adjacent to the outlet facilities and power intake gate structures upstream from the dam centerline. The assumed design discharge is approximately 80,000 cfs corresponding to the routed 1:10,000-year flood (120,000 cfs) reduced by the capacity of the outlet facilities. The plunge pool is formed by excavating the alluvial river deposits down to bedrock. This approaches the limits of the calculated maximum scour hole and it is not anticipated that, given the infrequent discharges, downstream erosion will be a problem.

(v) Emergency Spillway

A rock channel is excavated on the right bank discharging well downstream from the right abutment in the direction of Tsusena Creek. The channel is sealed by an erodible fuse plug of impervious material designed to fail if overtopped by the reservoir, although some preliminary excavation may be necessary. The crest level of the plug will be set at Elevation 2230 MSL, well below that of the main dam. The channel will be capable of passing the excess discharge of floods greater than the 1:10,000-year flood up to the probable maximum flood of 235,000 cfs.

(vi) Power Facilities

The power intake is set slightly upstream of the dam centerline deep within sound bedrock at the downstream end of the approach channel. The intake consists of six units with provision in each unit of drawing flows from a variety of depths covering the maximum possible drawdown of the reservoir of 185 feet. This facility also provides for drawing water from the different temperature strata within the upper part of the reservoir and thus regulating the temperature of the downstream discharges close to the natural temperatures of the river. The facility to draw from the different levels is effected by a series of upstream vertical shutters moving in a single set of guides and operated to form openings at the required level. Downstream from these shutters each unit has a pair of wheel-mounted closure gates which will isolate the individual penstocks.

The six penstocks are 18-feet diameter concrete-lined tunnels inclined at 55° (an optimum angle) immediately downstream from the intake to a nearby horizontal portion leading to the powerhouse. This horizontal portion is steel-lined for 150 feet upstream from the turbine units to extend the seepage path to the powerhouse and contain the flow within the fractured rock area caused by blasting in the adjacent powerhouse cavern.

The six 140 MW turbine/generator units are housed within the major powerhouse cavern and are serviced by a common overhead crane which runs the length of the powerhouse and into the service area adjacent to the units. Switchgear, maintenance room and minor offices are located within the main cavern with the transformers situated downstream in a separate gallery excavated above the tailrace tunnels. Six inclined tunnels run from the main power hall to the transformer gallery carrying the connecting bus ducts. A vertical elevator and vent shaft runs from the power cavern to the main office building and control room located at the surface. Vertical cable shafts, one for each pair of transformers, run from the transformer gallery to the switchyard directly overhead. Downstream from the transformer gallery, the underlying draft tube tunnels merge into two surge chambers, one chamber for three draft tubes. The surge chambers also house the draft tube gates for isolating the units from the tailrace. The gates are operated by an overhead traveling gantry located in the upper part of each of the surge chambers. Emerging from the ends of the chambers two concrete-lined low pressure tailrace tunnels carry the discharges to the river. Because of space restrictions at the river, one of these tunnels merges with the downstream end of the diversion tunnel. The other tunnel emerges in a separate portal with provision for the installation of bulkhead gates.

The orientation of water passages and underground caverns is such as to avoid as far as possible the main alignment of the excavations running parallel to the major joint sets as shown on Figure B2.2.

(vii) Access

Access is assumed to be from the north (right) side of the river. Permanent access to structures close to the river is from the right bank downstream and then via a tunnel passing through the concrete forming the flip bucket. A tunnel from this point to the power cavern provides for vehicular access. A secondary access road runs across the crest of the dam, down the left bank of the valley, and across the lower part of the dam.

(b) Left Bank Cascade Spillway (Scheme WP4A)

This scheme, as shown on Plate 9.11 (Vol. 1), is similar in most respects to the scheme previously discussed; the principal difference is in the spillways.

(i) Main Dam

The main dam axis is similar to that of Scheme WP3A except for a slight downstream curve at the left abutment to accommodate the spillway control structure.

(ii) Diversion

The diversion and low-level releases are exactly similar for the two schemes.

(iii) Outlet Facilities

With a cascade spillway, nitrogen supersaturation is not considered to be a problem and facilities for more frequent flood discharges are not necessary. In the left bank cascade spillway scheme, a low-level gated outlet structure is located upstream. This will function primarily as an emergency release, discharging up to 30,000 cfs into a concrete-lined, free-flow tunnel with a ski jump flip bucket discharging flows well downstream into the river. This facility will also serve as an auxiliary spillway augmenting the main left bank spillway.

(iv) Spillways

The left bank spillway passes a design flow of 90,000 cfs through a series of 50-feet drops into shallow pre-excavated plunge pools. The spillway as reviewed in Section 7 was designed to pass the probable maximum flood. In view of the change in design flood, to passage of the routed 1:10,000 year flood in conjunction with the emergency releases, the width of the cascade has been reduced to 400 feet. Discharges are controlled by a broad multi-gated control structure discharging into a shallow stilling basin. The feasibility of this arrangement is governed by the quality of the rock in the area, requiring both durability to withstand the spillway flows and a high percentage of sound material that can be used in the rock shell of the main dam. Little investigation has been done in this area of the site and properties of the underlying bedrock can be determined at this stage only from extrapolation of drill holes, seismic lines, and surface investigation farther downstream. A broad altered zone of relatively poor quality rock was known to exist in this area. In all layouts for the cascade it was therefore intended that the spillway should cross this zone before descending in a cascade down the side of the valley. From continuing field investigation it became evident that this altered zone exists farther downstream than had previously been determined. This means the position of the spillway would have to be shifted downstream from where it is shown on Plate 9.11 to avoid this shear area at the lower end of the cascade. The layout has been costed as it is shown on the drawing but as it already appears less attractive than the right bank alternative (see Section 8.8), the increased cost of relocation has not been determined.

The emergency spillway consisting of rock channel and fuse plug is similar to that of the right bank spillway scheme.

(v) Power Facilities

The power facilities are similar to those in Scheme WP3A.

8.5 - Operation

Operation of the project during floods is based on passage of routed floods with frequencies up to 1:50 years through a combination of the powerhouse and outlet facilities. At the time of the annual spring flood the reservoir is drawn down and the storage is sufficient to contain the flood, taking into account the powerhouse discharges of 12,000 cfs. At the time of the summer flood, the reservoir is approaching full; and the 1:50-year flood can only be contained by surcharging the reservoir by 4 feet, passing a continuous 12,000 cfs through the powerhouse and a maximum of 30,000 cfs through the outlet facilities. In the case of the right bank spillway scheme, the 30,000 cfs is passed through the Howell-Bunger valves and, in the case of the left bank spillway, it is passed down the cascade. This flow down the cascade will result in a 20-feet depth of water in the plunge pools, which is not great enough to cause problems of nitrogen supersaturation.

Floods greater than the 1:50-year flood are passed via the main spillway in Scheme WP3A or via the cascade in Scheme WP4A. This results in an increase in dissolved nitrogen in the discharges, but it is anticipated that this would be acceptable because of the infrequency of its occurrence. Passage of flows up to a total of 120,000 cfs (the routed 1:10,000-year flood) can be accommodated with an additional 3-foot reservoir surcharge above the 4 feet already required for the 1:50-year floods. Above the 1:10,000-year flood and up to the probable maximum flood discharges will be routed through the emergency rock channel spillway. It is anticipated that overtopping of the fuse plug will cause complete erosion of the fuse plug; however, some initial localized excavation may be necessary at the crest of the plug to start the process.

Spillway discharges will occur almost exclusively in the months of July, August and September.

Winter operation of the service spillway would be very rare due to low inflow at this time and high power demand. Operation of the service spillway during winter months will only occur under extreme flood conditions and would warrant operation of the chute spillway if discharge from the Howell Bunger valves were avoided during the winter because of spray and ice formation.

The six generating units installed in the powerhouse will provide flexibility of operation of individual units allowing them to operate close to their maximum efficiency, corresponding to approximately 90 percent full load, as they follow the demand curve.

8.6 - Costs

An evaluation of the dissimilar features of each arrangement (the main spillways and the discharge arrangements at the downstream end of the outlets) results in savings in capital costs of $197,000,000, excluding contingencies and indirect costs, in favor of the right bank chute spillway scheme. If the credit for the use of excavated spillway material in the main dam is introduced and contingencies, engineering, and administration are included, there is a net overall difference of approximately $111,000,000 (see Table B2.3). The diversion, dam, and spillway facilities are essentially the same for both schemes at this stage and hence have not been evaluated as part of the comparison of general site arrangements. Cost evaluation of these facilities will be completed as part of the final cost estimate. If the cascade spillway is relocated further downstream to avoid the "Fingerbuster", then the cascade spillway will become more expensive and the cost difference will increase.

8.7 - Conclusion

The uncertain quality of the rock on the left bank in the location of the cascade spillway calls into question the ability of the rock to withstand erosion down the spillway and the feasibility of its use within the main embankment. The cost of a cascade spillway is considerably higher than that of a chute alternative, and hence, the overall layout concept for the chute spillway layout has been adopted as shown on Plates B2.4 to B2.6.

TABLE B2.1: DESCRIPTION OF ALTERNATIVE LAYOUTS

Layout Alter.	MAIN DAM		SERVICE SPILLWAY		AUXILIARY SPILLWAY		POWER FACILITIES	
	Slopes	Configuration	Type	Location	Type	Location	Powerhouse Type	Location
As DSR	u/s 2.25:1 d/s 2:1	As Corps of Engineers skew to river	double stilling basin	right bank	--	--	underground	left bank
1	u/s 2.5:1 d/s 2:1	right side curved upstream	flip bucket	right bank	--	--	underground	left bank
2	u/s 2.25:1 d/s 2:1	right and left sides curved upstream	cascade, single control structure	left bank	--	--	surface	right bank
2A	u/s 2.25:1 d/s 2:1	right and left sides curved upstream	cascade, dual control structures	left bank	--	--	surface	right bank
2B	u/s 2.25:1 d/s 2:1	right and left sides	double stilling basin	left bank	--	--	surface	right bank
2C	u/s 2.25:1 d/s 2:1	right and left sides curved upstream	double stilling basin	left bank	inclined unlined channel	left bank	surface	right bank
2D	u/s 2.25:1 d/s 2:1	right and left sides curved upstream	flip bucket	left bank	--	--	underground	right bank
3	u/s 2.5:1 d/s 2:1	right and left sides curved upstream	cascade	left bank	flip bucket	right bank	underground	left bank
4	u/s 2.5:1 d/s 2:1	left bank skewed upstream	flip bucket	left bank	--	--	underground	left bank

TABLE B2.2: SUMMARY OF COMPARATIVE COST ESTIMATES

INTERMEDIATE REVIEW OF ALTERNATIVE ARRANGEMENTS
(January 1982 Dollars $ X 10^6)

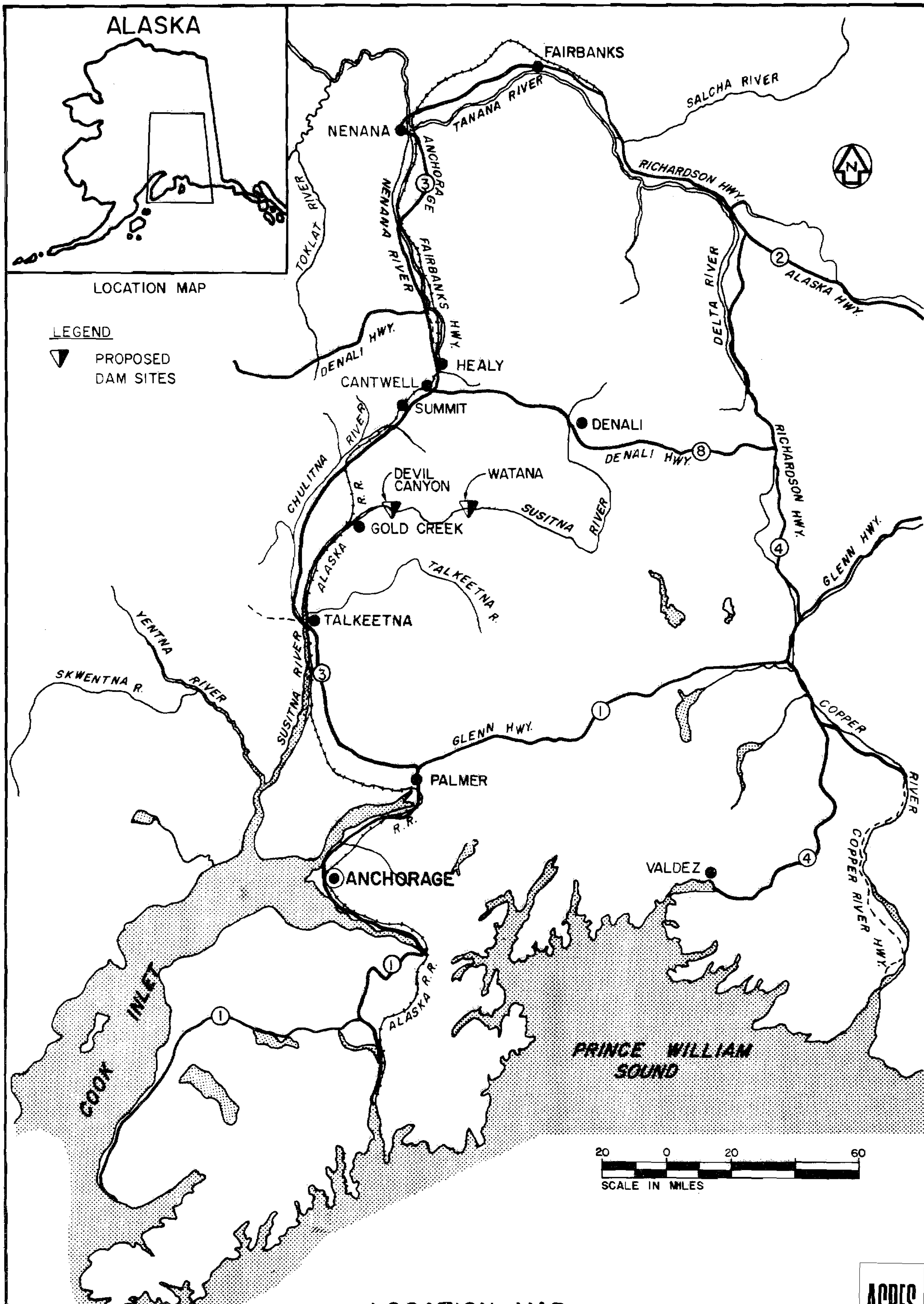
	WP1	WP2	WP3	WP4
Diversion	101.4	112.6	101.4	103.1
Service Spillway	128.2	208.3	122.4	267.2
Emergency Spillway	--	46.9	46.9	--
Tailrace Tunnel	13.1	13.1	13.1	8.0
Credit for Use of Rock in Dam	(11.7)	(31.2)	(18.8)	(72.4)
Total Non-Common Items	231.0	349.7	265.0	305.9
Common Items	1643.0	1643.0	1643.0	1643.0
Subtotal	1874.0	1992.7	1908.0	1948.9
Camp and Support Costs (16%)	299.8	318.8	305.3	311.8
Subtotal	2173.8	2311.5	2213.3	2260.7
Contingency (20%)	434.8	462.3	442.7	452.1
Subtotal	2608.6	1773.8	2656.0	2712.8
Engineering & Administration (12.5%)	326.1	346.7	332.0	339.1
TOTAL	2934.7	3120.5	2988.0	3051.9

TABLE B2.3: SUMMARY OF COST DIFFERENCES FOR SCHEMES WP3A and WP4A

(January 1982 Dollars $ X 10^6)

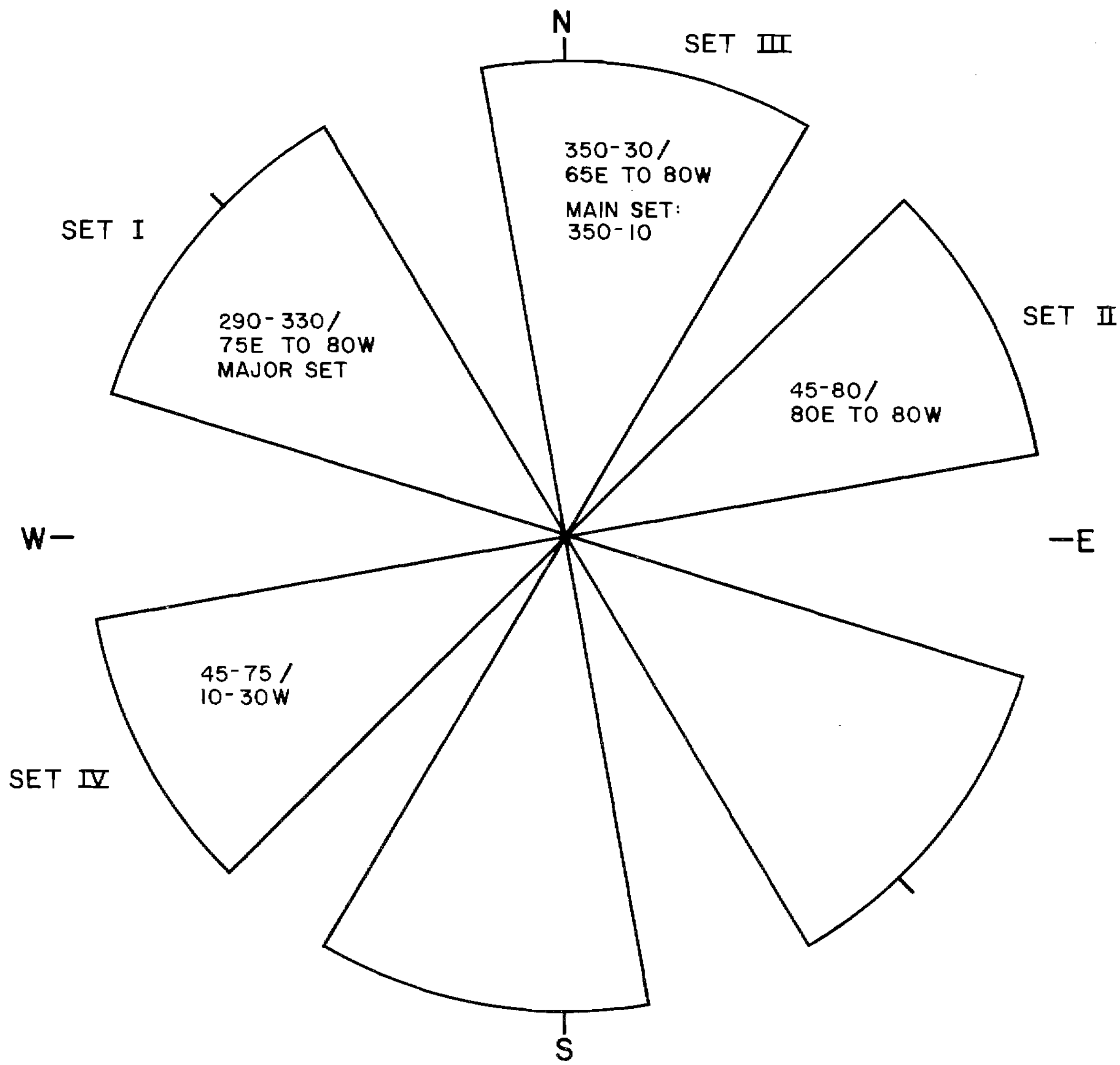
	WP3A	WP4A
Spillway	196.8	393.9
Credit for use of rock in dam	-	126.0
Net cost of spillway	196.8	267.9
Camp and support costs (16%)*	31.5	42.9
Subtotal	228.3	310.8
Contingency (20%)*	45.7	62.2
Subtotal	274.0	373.0
Engineering & Administration (12.5%)*	34.2	46.6
TOTAL	308.2	419.6

*These costs are associated only with the cost of construction of the spillways.



LOCATION MAP

FIGURE B2.1



MAJOR SHEARS PARALLEL TO JOINT SET I
MINOR SHEARS PARALLEL TO JOINT SETS I AND III

WATANA PRIMARY JOINT SETS

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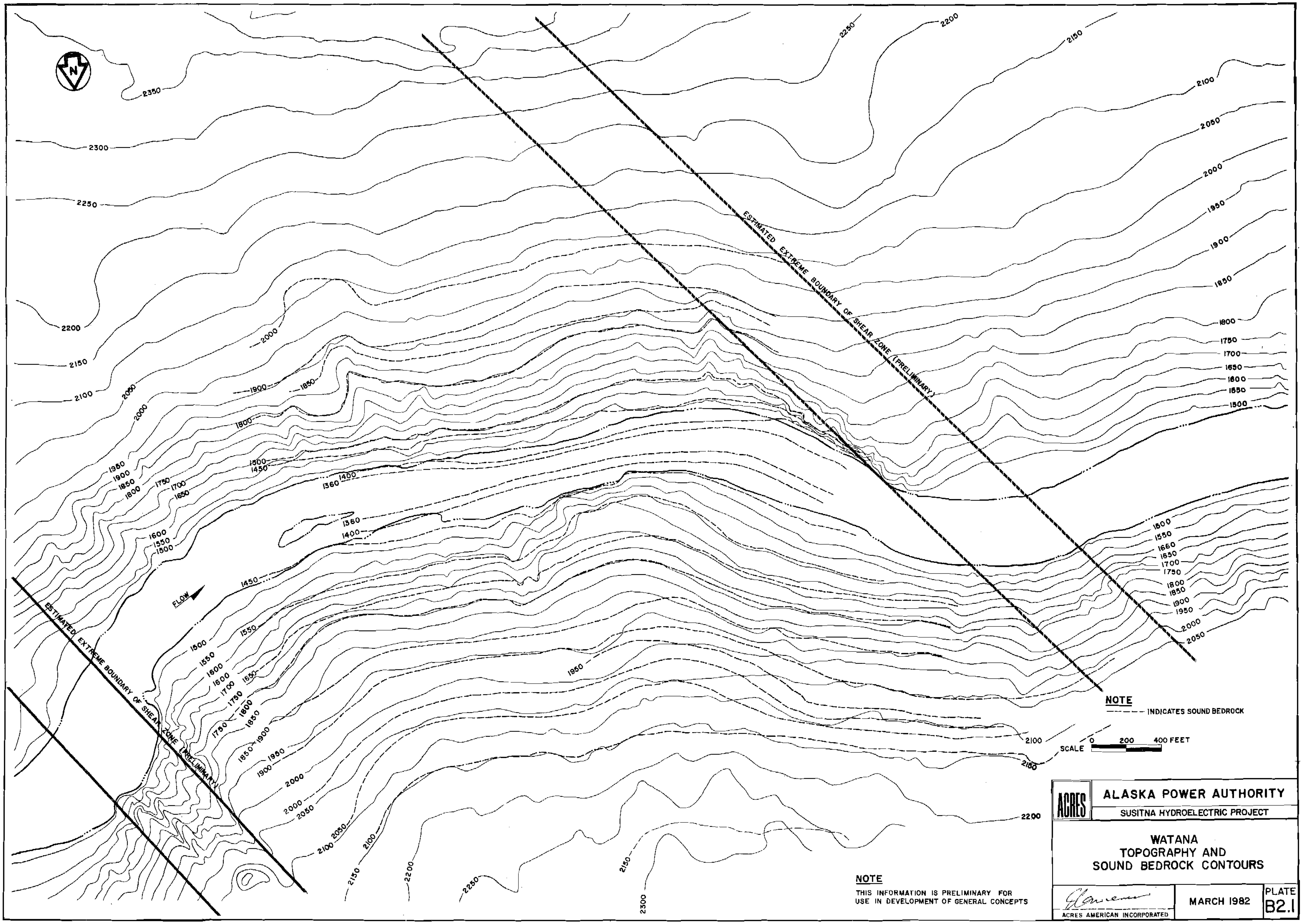
FIGURE B 2.2



NOTE
THIS INFORMATION IS PRELIMINARY FOR USE IN DEVELOPMENT OF GENERAL CONCEPTS

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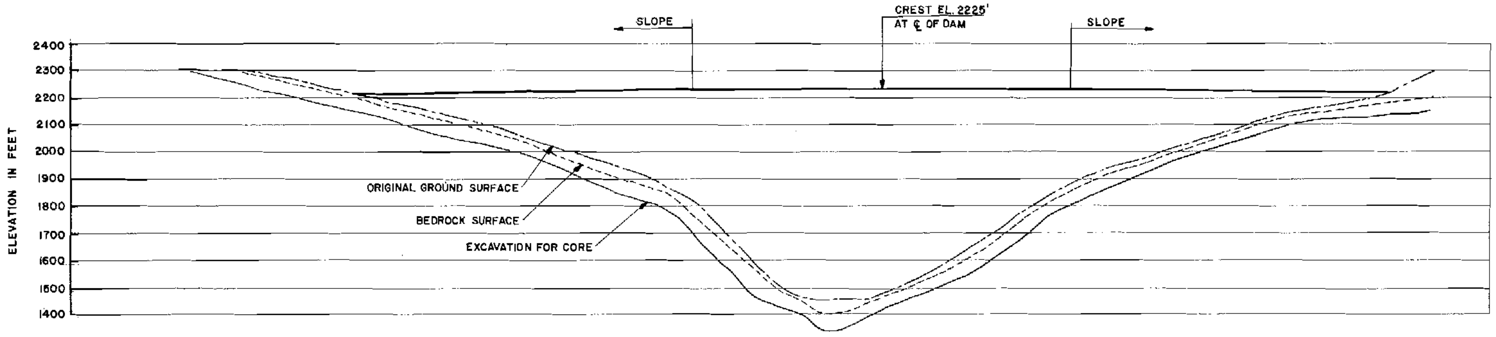
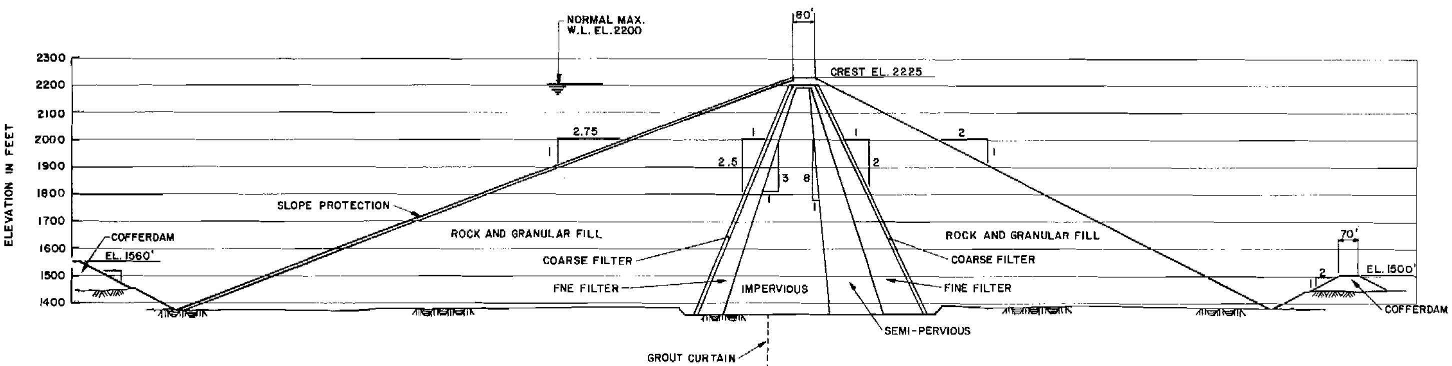
WATANA
TOPOGRAPHY AND
SOUND BEDROCK CONTOURS

ACRES AMERICAN INCORPORATED | MARCH 1982 | PLATE B2.1



SECTION A-A



SECTION B-B

SCALE 0 200 400 FEET

NOTE

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SUSITNA HYDROELECTRIC PROJECT

WATANA

MAIN DAM (ALL SCHEMES)

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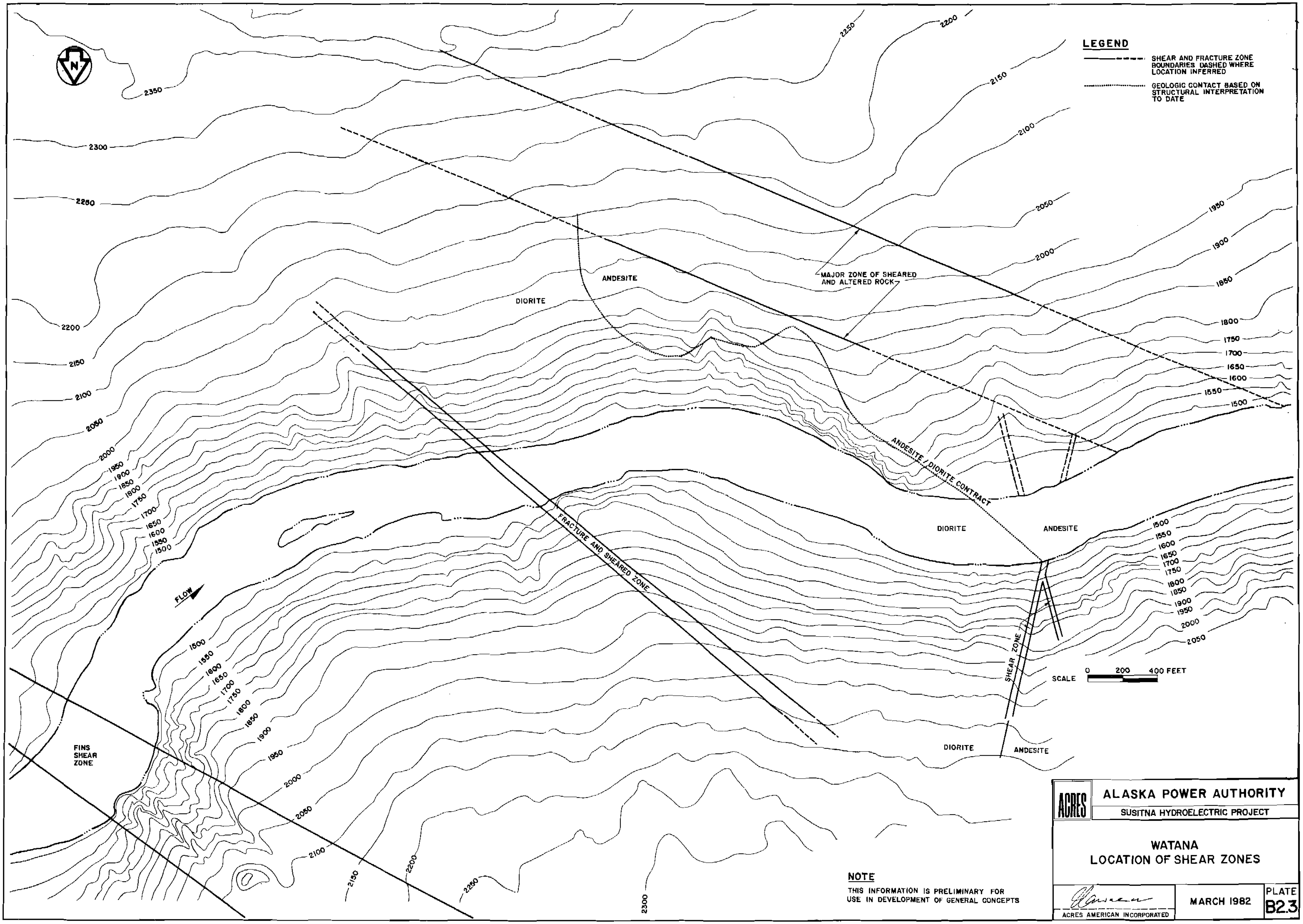
PLATE B2.2



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SUSITNA HYDROELECTRIC PROJECT

WATANA
LOCATION OF SHEAR ZONES

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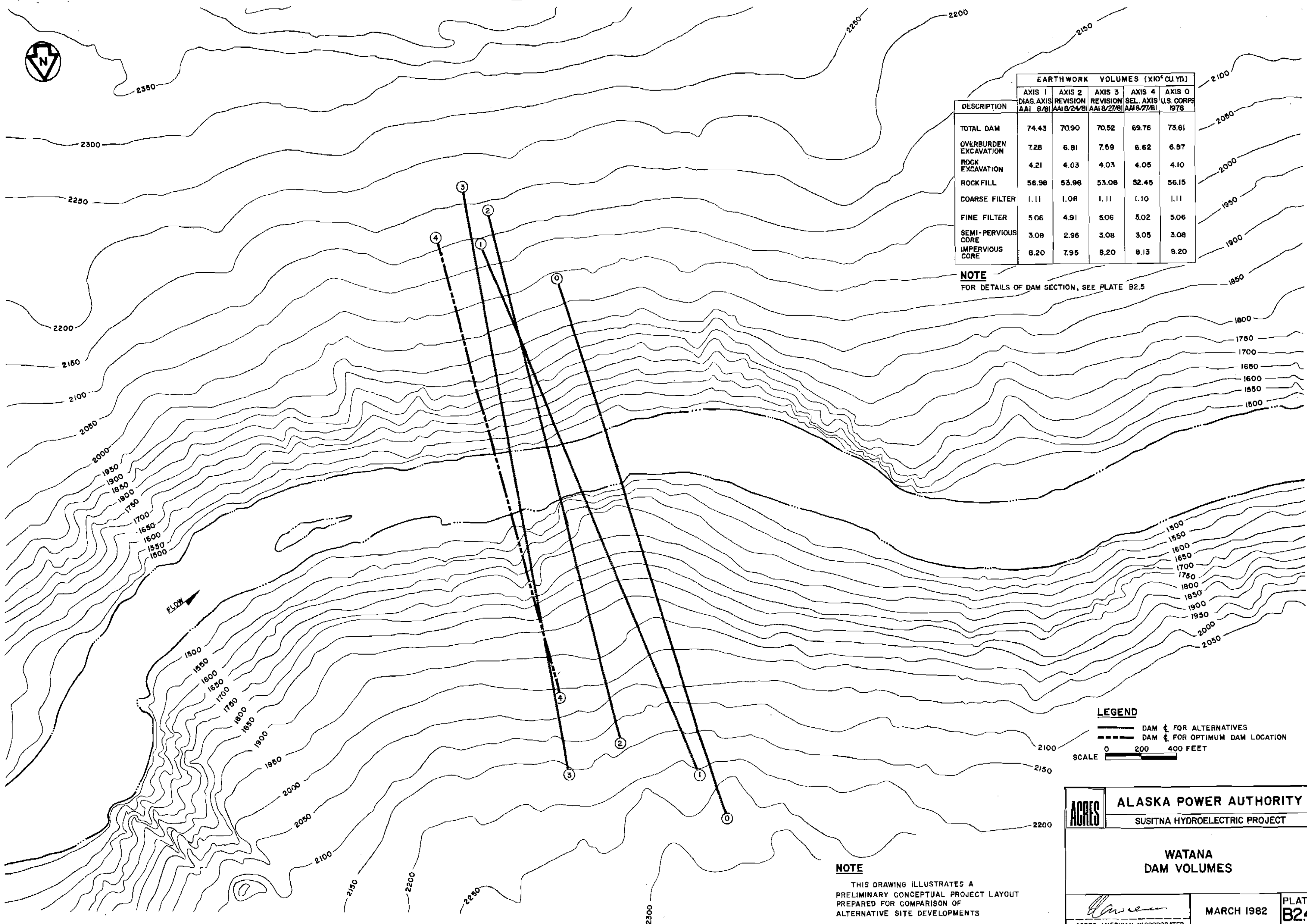
PLATE B2.3



DESCRIPTION	AXIS 1 DIAG. AXIS AAI 8/81	AXIS 2 REVISION AAI 8/24/81	AXIS 3 REVISION AAI 8/27/81	AXIS 4 SEL. AXIS AAI 8/27/81	AXIS 0 U.S. CORPS 1978
	EARTHWORK VOLUMES ($X10^6$ CU.YD.)				
TOTAL DAM	74.43	70.90	70.52	69.76	73.61
OVERBURDEN EXCAVATION	7.28	6.81	7.59	6.62	6.87
ROCK EXCAVATION	4.21	4.03	4.03	4.05	4.10
ROCKFILL	56.98	53.98	53.08	52.45	56.15
COARSE FILTER	1.11	1.08	1.11	1.10	1.11
FINE FILTER	5.06	4.91	5.06	5.02	5.06
SEMI-PERVIOUS CORE	3.08	2.96	3.08	3.05	3.08
IMPERVIOUS CORE	8.20	7.95	8.20	8.13	8.20

NOTE

FOR DETAILS OF DAM SECTION, SEE PLATE B2.5

LEGEND

DAM ℄ FOR ALTERNATIVES
DAM ℄ FOR OPTIMUM DAM LOCATION

SCALE 0 200 400 FEET

NOTE

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WATANA
DAM VOLUMES

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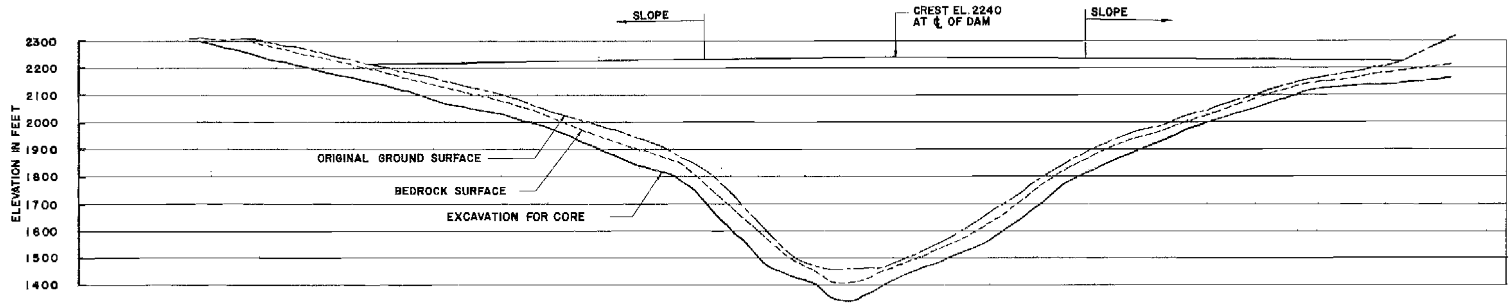
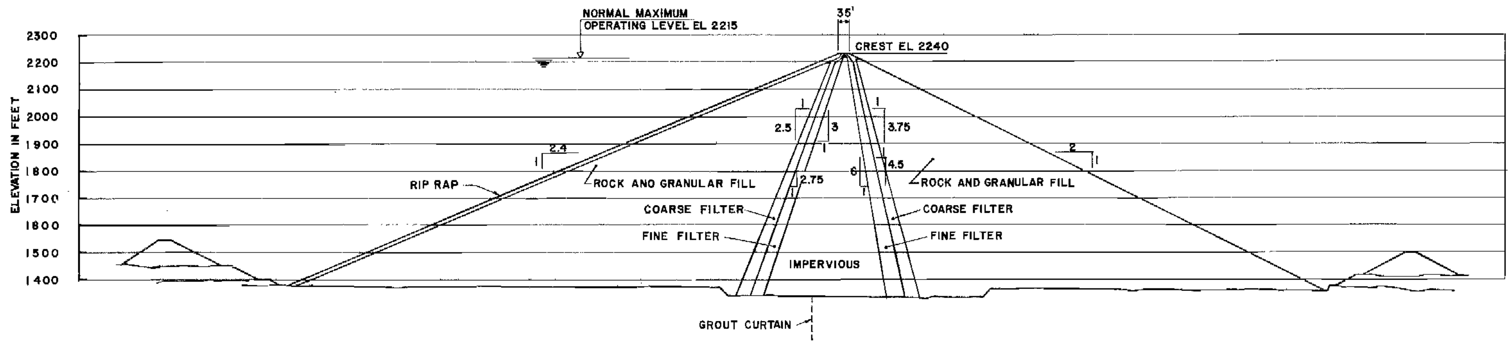
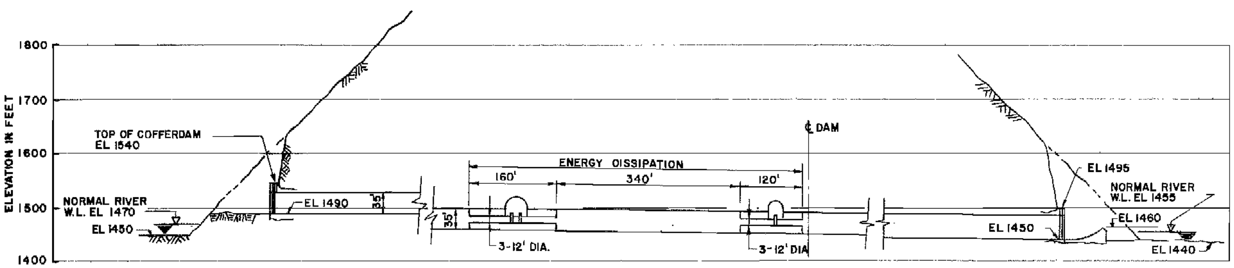
PLATE B2.4



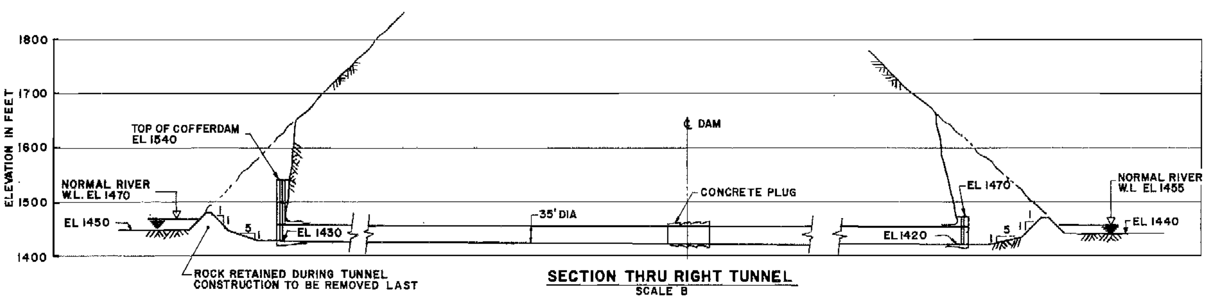
MAIN DAM PROFILE
SCALE A



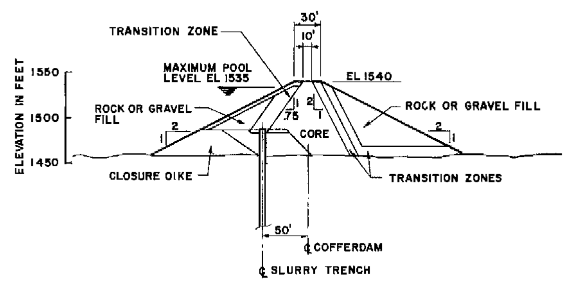
MAIN DAM SECTION AT MAXIMUM HEIGHT
SCALE A



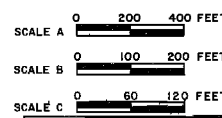
SECTION THRU LEFT TUNNEL
SCALE B



SECTION THRU RIGHT TUNNEL
SCALE B



UPSTREAM COFFERDAM SECTION
SCALE C



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SUSITNA HYDROELECTRIC PROJECT

WATANA
SCHEME WP3A
MAIN DAM AND DIVERSION

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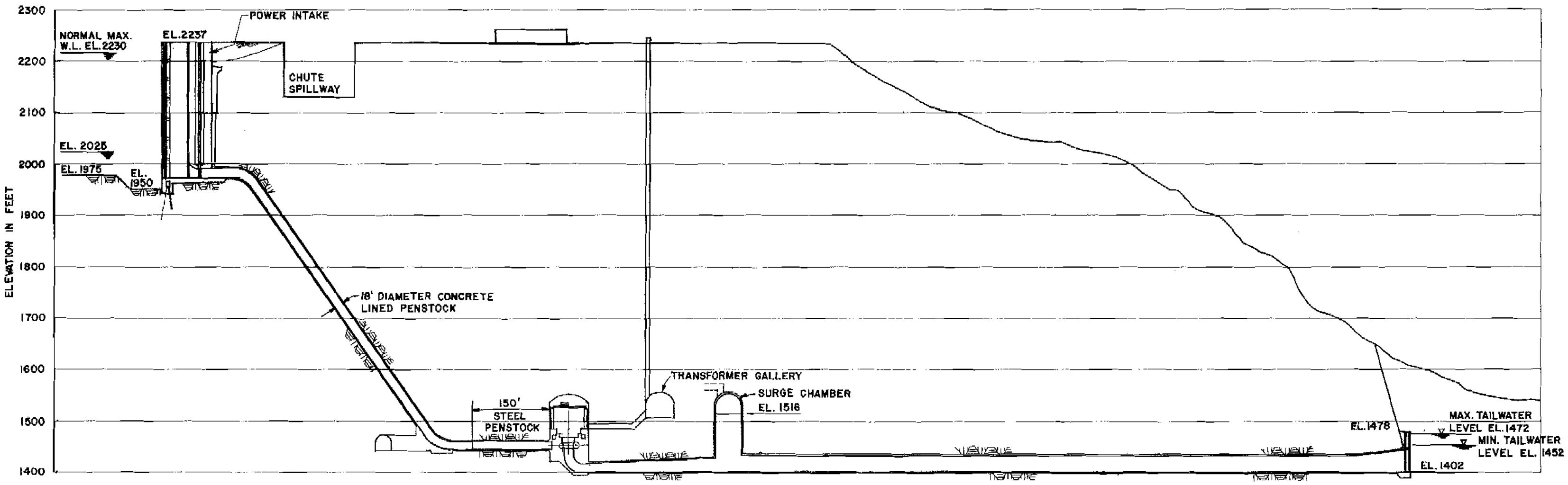
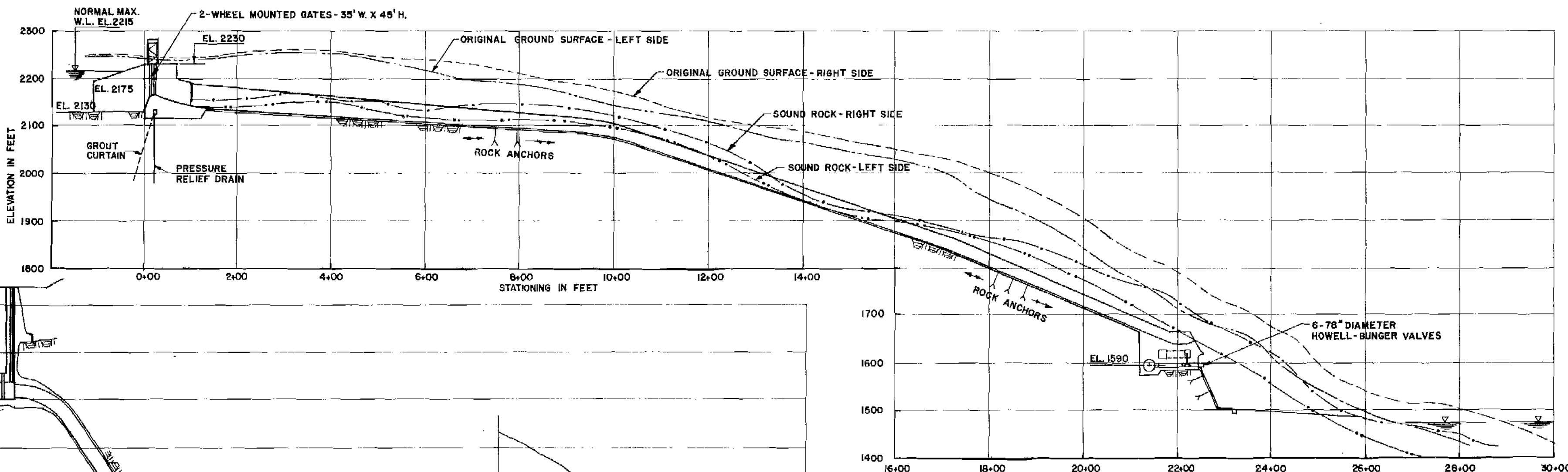
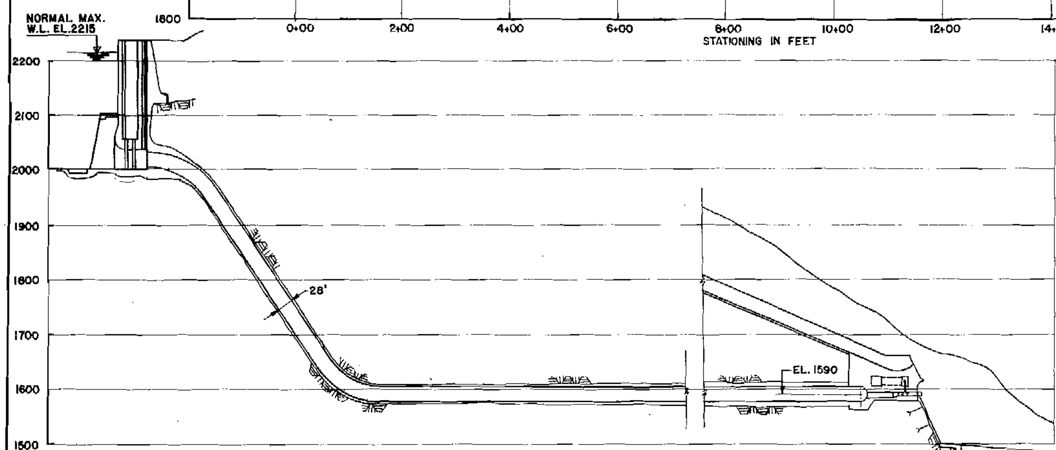
PLATE B2.5



POWER FACILITIES-PROFILE



MAIN SPILLWAY-PROFILE



OUTLET FACILITIES-PROFILE

SCALE 0 100 200 FEET

NOTE

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SUSITNA HYDROELECTRIC PROJECT

WATANA
SCHEME WP3A
POWER FACILITIES AND SPILLWAYS

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PLATE B2.6

APPENDIX B3

DEVIL CANYON GENERAL ARRANGEMENT STUDY

1 - INTRODUCTION

As discussed in Appendix B2, studies described in the DSR led to selection of the Watana and Devil Canyon sites for further study.

The location of the Devil Canyon site is shown in Figure B2.1. Average flow in the river is approximately 9040 cfs at Devil Canyon and the total gross head developed at this site is approximately 600 feet. A high degree of regulation is achieved, primarily through the Watana reservoir, a factor which contributes greatly to the benefit to be gained by construction of Devil Canyon as the second stage of an overall staging concept.

Some features of the layouts of the selected sites compared in the DSR were consistent with certain generalized concepts. These include the configuration of power facilities and the type of spillway, which would be suitable for the majority of schemes within the river basin. These concepts also would reflect in their conservatism and potential adaptability to different conditions, the general uncertainties of the physical characteristics of each site. Although suitable for this initial selection process, the layouts of the chosen sites were not intended to define the final schemes. They have been re-examined and new layouts developed through more rigorous study based on the site information available from previous investigations by the U.S. Army Corps of Engineers and the Department of the Interior, together with data from Acres' 1980-81 site investigations.

It is the purpose of this report to describe the final general arrangement developed for the Devil Canyon site and to delineate the selection process and the comparative layouts which led to this arrangement.

2 - SUMMARY

2.1 - Scope

The objective of this study is to develop the most suitable overall conceptual layout for the major structures at Devil Canyon based on technical, economic, and environmental considerations and restrictions.

It is not intended that the layout will be definitive, but it is the intention to determine the general configuration of the major structures and facilities and the interaction of these facilities within the project layout.

2.2 - Methodology

Preliminary review of alternative layouts were developed and compared on the basis of technical feasibility, cost, and environmental impact. A basic conceptual layout was selected. The selected layout was further developed on the basis of the latest data and criteria to formulate a final layout concept.

2.3 - Development of Layouts

Three basic schemes were developed, costed, and reviewed. All schemes were based on a concrete arch dam within the canyon. The dam terminates in mass concrete thrust blocks and abuts a rockfill saddle dam across the low-lying area on the left abutment. A left bank tunnel diversion is adopted for all schemes and an auxiliary submerged orifice spillway is incorporated in the main dam.

(a) Scheme DC1

This scheme has a right bank chute and flip bucket main spillway discharging into the river downstream. An emergency fuse plug spillway is located on the left bank beyond the saddle dam and the underground powerhouse is constructed within the rock on the right side of the canyon.

(b) Scheme DC2

The layout is similar to Scheme DC1 except that the flip bucket type spillway is constructed on the left bank.

(c) Scheme DC3

The layout for Scheme DC3 is also similar to DC1 except that the right bank spillway is replaced by a tunnel and flip bucket spillway on the right side of the river.

(d) Scheme DC4

The Scheme DC4 layout has a right bank chute spillway with a downstream stilling basin for energy dissipation.

On the basis of the least cost and security of operation, a layout based on Scheme DC1 was selected.

2.4 - Selected Layout Development

On the basis of additional data and updated criteria, the selected layout was further developed into the final layout concept.

The right bank flip bucket spillway was retained, but the submerged spillway high in the dam was eliminated because of the dangers of downstream erosion near the dam. A low level outlet with downstream discharge valves was included close to the base of the dam. The right bank powerhouse was retained as was the tunnel diversion on the left bank.

3 - SCOPE

The scope of this study was based on the overall objective of developing the most suitable layout of facilities and structures for the hydroelectric site at Devil Canyon. Major factors considered included production of the maximum firm energy consistent with economic cost, technical feasibility, safety of operation, and impact on the environment. The layout was based on potential ease of construction and the capability of bringing generating units on-line within a reasonable construction period.

It was not intended that the layout should be definitive, but it was intended to establish the basis of the final layout of structures by establishing the general configuration of the dam, powerhouse, and diversion and confirming the spillway type and location. There will be future modifications such as minor realignment of structures themselves but the general concept of the scheme will remain unchanged.

4 - BASIN CHARACTERISTICS

A general discussion of climatology, geology, and seismic aspects is presented in Appendix B1, Section 4.

5 - METHODOLOGY

5.1 - General

Preliminary layouts of the Devil Canyon site were subjected to a review and screening process. The layout selected from the screening was further reviewed and modifications were introduced to provide the basic conceptual layout for the scheme as described in Section 9.

The selection process follows the general selection methodology previously established for the Susitna project and is outlined below.

5.2 - Selection Methodology

The determination of the final arrangement was carried out in two stages:

(a) Preliminary Review of Alternative Layouts

(i) Step 1

- Assemble available data;
- Determine design criteria; and
- Establish evaluation criteria.

(ii) Step 2

Develop preliminary layouts based on the above data and design criteria including all plausible alternatives for the constituent facilities and structures. Produce plans and principal sections of layouts.

(iii) Step 3

- Produce quantity take-offs for major structures based on drawings prepared under Step 2.

- Carry out a preliminary contractor's type estimate and develop a construction schedule to determine unit rates for major quantities consistent with construction methods which will allow completion of the project within the required time frame.

- Determine overall cost of the schemes. Where breakdowns of certain work items are not available, costs are to be based on equivalent work carried out elsewhere. All direct costs are to be included.

(iv) Step 4

Review all layouts on the basis of technical feasibility, practicability, cost, impact of possible unknown conditions and uncertainty of assumptions, safety, and environmental impact.

(v) Step 5

- Select the layout that can be identified as most favorable based on the evaluation criteria determined under Step 1.

(b) Development of Selected Conceptual Layout

(i) Step 1

- Assemble and review any additional data from other work tasks.
- Revise design criteria to accord with additional data.
- Finalize overall evaluation criteria.

(ii) Step 2

Revise or develop the layout on the basis of conclusions from Stage 1. Overall dimensions of structures, water passages, gate sizes, etc., are to be determined.

(iii) Step 3

- Produce quantity take-offs for major structures.

- Review cost components within a preliminary contractors' type estimate using the most recent data and criteria, and develop a construction schedule.

- Determine overall direct cost of scheme.

(iv) Step 4

Review of modified layout by Acres' Internal Review Panel followed by review by Alaska Power Authority.

6 - PROJECT PARAMETERS AND DESIGN CRITERIA

The principal project parameters and design criteria on which the layouts were based are given below. Parts of this criteria will be superseded as more material becomes available. Any assumptions made have been based on the best information available at the time. The topography and sound bedrock contours are shown in Plate B3.1.

River Flows

Average flow (over 30 years of record):	8,960 cfs
Probable maximum flood:	270,000 cfs
Maximum flood with return period of 1:10,000 years:	135,000 cfs (after routing through Watana)
Maximum flood with return period of 1:50 years:	42,000 cfs (after routing through Watana)
Reservoir normal maximum operating level:	1,445 ft MSL
Reservoir minimum operating level:	1,300 ft MSL
Area of reservoir at maximum operating level:	21,000 acres
Reservoir live storage:	0.75×10^6 acre ft
Reservoir total storage:	1.1×10^6 acre ft

Dam

Type:	Concrete arch
Crest elevation:	1,455 ft MSL
Height:	635 ft above concrete plug
Cut-off and foundation treatment:	Founded on rock, grout curtain and downsteam drains

Saddle Dam

Type:	Earthfill/rockfill
Upstream slope:	1V:3H
Downstream slope:	1V:2.25H
Crest width:	20 ft

Diversion

Cofferdam types:	Rockfill
Cut-off and foundation:	Founded on alluvium with slurry trench to rock
Upstream cofferdam crest elevation:	960 ft MSL
Downstream cofferdam crest elevation:	900 ft MSL
Maximum pool level during construction:	955 ft MSL
Water passages:	Concrete lined
Outlet structures:	Low level structures with slide closure gates
Final closure:	Mass concrete plugs in line with dam grout curtain
Releases during impounding:	2000 cfs min. via Howell Bunger valves

Spillway

Design floods:	Passes pmf preserving integrity of dam with no loss of life
	Passes routed 1:10,000 year flood with no damage to structures
Service spillway - capacity:	45,000 cfs
- control structure:	Howell Bunger valves
- energy dissipation:	5-108 inch diameter Howell Bunger valves
Secondary spillway - capacity:	90,000 cfs
- control structure:	Gated, ogee crests
- energy dissipation:	Stilling basin or plunge pool
Emergency spillway - capacity:	Pmf minus routed 1:10,000 year flood
- type:	Fuse plug

Power Facilities

Type:	Underground powerhouse
Transformer area:	Separate gallery
Control room and administration:	In main power cavern
Access:	Rock tunnel
Type of turbines:	Francis
Number and rating:	4 x 140 MW
Maximum gross head:	565 ft approx.
Type of generator:	Vertical synchronous
Rated output:	156 MVA
Power factor:	0.9

Tailrace

Water passages:	2 concrete-lined tunnels
Elevation of water passages:	Pressure tunnels
Average tailwater elevations:	890 ft

7 - REVIEW OF ALTERNATIVE LAYOUTS

7.1 - General

During formulation of the layouts for the Devil Canyon Development described herein, many arrangements and minor variations of these arrangements were developed to various degrees of detail. They were discarded on the basis either of technical infeasibility or of excessive cost over the selected alternatives while offering no safety, environmental or operating advantages. Four schemes were carried through to full development of the individual structures and facilities within the overall general arrangement concept, and these were considered to cover all the general concepts for the dams, power facilities, spillways and diversions that might be included in the final scheme.

7.2 - Major Features

The general layout of the Devil Canyon Development is governed by the location and configuration of the concrete arch dam. The location of the dam has previously been studied by the United States Bureau of Reclamation (USBR) and the U.S. Corps of Engineers, and this investigation has been directed at the narrow entrance of the canyon. The shape of the canyon at this point is eminently more favorable for an arch dam than the broader reaches downstream and the dam has been fixed in this location, with the configuration described in Appendix B1 - Dam Selection Studies, for all layout alternatives.

A rockfill saddle-dam is located on the lower ground adjacent to the left abutment, and although its alignment is varied slightly for the different layouts, essentially any one of these alignments could be used for the alternative schemes. Hence, although minor variations in cost are incurred, these differences do not influence the overall choice of the arrangement of the main concrete structures at the site.

In Appendix B1, different dam alternatives were investigated, including a gravity arch dam with a chute spillway on its inclined downstream face, discharging into a stilling basin founded on the bedrock underlying the riverbed. The shape of the thin arch dam is not suitable for this type of arrangement and flows have to be discharged either through or over the top of the dam in the form of a plunging jet or in separate spillway facilities built into the abutments.

In all schemes, the power facilities have been located within the sound bedrock forming the right abutment and, in order to avoid interference with the power tunnels, the diversion has been situated on the opposite bank.

7.3 - Description of Layouts

The four schemes for the layout of the project were as follows:

(a) Scheme DC1

(i) Main Dam

The scheme is shown on Plates 10.1 (Volume 1) and B1.3 (Appendix B1). The main dam is a thin concrete arch structure as described in Appendix B1. The dam is founded on a mass concrete plug, constructed on the sound bedrock underlying the riverbed. The structure is 635 feet high, has a crest length of 1,250 feet, a crest width of 20 feet, and a maximum base width of 90 feet. The crest elevation of the dam is 1455 and is extended to 1459 by a concrete parapet wall running the length of the upstream face. The volume of concrete within the dam is approximately 1.4 x 10^6 cubic yards. Mass concrete thrust blocks are founded high on the abutments, the left block extending approximately 100 feet above the existing bedrock surface and supporting the upper part of the dam, as well as sealing against the core of the saddle dam and acting as a transition block. The matching block on the right abutment makes the cross-river profile of the dam more symetrical and helps towards a more uniform stress distribution within the arch dam. A grout curtain cut-off is constructed across the valley beneath the dam and is backed up by a system of drain holes and galleries.

(ii) Diversion

Diversion during construction is made via cofferdams and twin tunnels driven through the rock beneath the left abutment. The left or south bank location for the diversion is more immediately accessible than the right bank which requires a long and expensive access road down the steep north face upstream from the canyon. It is also likely that the main site access road will be on the left side. The inlet portal can be constructed on the outside of the river with flows straight into the inlet and there will be no conflict with the power tunnel. The two tunnels are 24-feet in diameter and concrete-lined, and run just upstream from the cofferdam to downstream of the powerhouse outlets. Temporary closure is made by vertical slide gates within the inlet structures and permanent closure by mass concrete plugs within the diversion tunnels located in line with a grout curtain cut-off beneath the main dam.

(iii) Saddle Dam

The rockfill saddle dam occupies the lower lying area beyond the left abutment running from the thrust block to the higher ground beyond. The impervious fill cut-off for the saddle dam is founded on the sound bedrock approximately 80 feet beneath the existing ground surface. The crest elevation of the dam is 1461, the maximum height above the foundation is approximately 200 feet, and the upstream and downstream slopes are 1:3 and 1:2.25, respectively. The centerline of the rockfill dam is either straight or follows an arch shape curving in an upstream direction, whichever arrangement as adopted will make little difference to the volume of fill materials.

(iv) Spillways

The routed 1:10,000-year design flood of 135,000 cfs is passed by two spillways. The main service spillway is located on the right abutment. It has a design discharge of 90,000 cfs and flows are controlled by a three-gated ogee control structure which discharges down a 1,250-foot-long concrete-lined chute and over a ski-jump type flip bucket which ejects the water in a diverging jet into a pre-excavated plunge pool in the riverbed. The flip bucket is set at Elevation 925, approximately 35 feet above the river level. An auxiliary spillway, discharging a total of 33,000 cfs, is located in the center of the dam. It is located 100 feet below the dam crest and is controlled by three 15-foot-high by 15-foot-wide wheel-mounted gates. The orifices are bell-mouth shaped at their entrances with shaped lips downstream to direct the flow into a concrete-lined plunge pool approximately 2,000 feet downstream from the dam. The remaining 12,000 cfs of the 10,000-year discharge is considered to pass through the powerhouse.

An emergency spillway is located in the sound rock beyond the saddle dam. It is designed to pass excess discharges beyond the 1:10,000-year flood up to a probable maximum flood of 270,000 cfs, if such an event should ever occur. The spillway is an unlined rock channel which discharges into a valley approximately 2,000 feet downstream, running into the Susitna River.

The upstream end of the channel is closed by an earthfill fuse plug with a crest elevation of 1457. The plug is designed to be eroded if overtopped by the reservoir and hence, as the crest is lower than either the main or saddle dams, the plug would be washed out prior to overtopping of either of these structures.

(v) Power Facilities

The power facilities are located on the right side of the river, within the bedrock forming the dam abutment. The rock within this abutment is interpreted from the site investigation and coupled with data from previous studies, as being of better quality with fewer shear zones and a lesser degree of jointing than the rock on the other side of the canyon. Also, any problems which might arise from features associated with the left bank buried river channel are available. Hence, it would appear more conducive to underground excavation. On the right side of the canyon it is possible to set the intake deep in the sound rock, eliminating any problems of stability and allowing a smaller structure. On the left side the bedrock is low and a massive gravity structure would be necessary to overcome the inherent stability problems. The intake would be set in the location of the thrust block, adjacent to the dam. A transition block would be required beyond the intake and making with the earth/rock-fill saddle dam. The length of these two concrete structures would extend into the area of the adjacent low lying area where the rock surface is dropping away with sound bedrock exceeding a depth of 200 feet below water surface at the southern end of the structures. This is exceedingly deep for a gravity structure in such a highly seismic area but a right back power intake location does not give this difficulty.

The intake is located just upstream of the bend in the valley before it veers to the right into Devil Canyon. It is set deep into the rock at the downstream end of the approach channel and consists of four inlets, each serving a single downstream turbine. Drawdown in the reservoir is about 145 feet. Trashracks are located at the face of each draw-off with provision for the insertion of bulkhead gates downstream within the structure. Each inlet passage contains a 20-foot-high by 18-foot-wide wheel-mounted upstream sealing closure gate with separate hydraulic hoists for operation.

The tunnels downstream of the intake are circular in cross-section and concrete-lined with a finished diameter of 18 feet. On leaving the intake they dip at an angle of 55° to the horizontal, an angle which gives an approximate optimum balance between inclined shaft and tunnel lengths from a cost point of view as well as allowing for self-mucking of the tunnel during construction when driving from below. The inclined shafts run into horizontal tunnel lengths which are steel lined for approximately 150 feet upstream of the powerhouse.

The powerhouse contains four 140 MW turbine/generator units. The turbines are Francis-type units coupled to overhead umbrella-type generators. The units are serviced by an overhead crane running the length of the powerhouse and into the end service bay. Offices, the control room, switchgear room, maintenance room, etc., are located beyond the service bay. The transformers are housed in a separate, upstream gallery located above the lower horizontal section of the penstocks. Two vertical cable shafts run from the gallery to the surface. The draft tube gates are housed above the draft tubes in separate annexes off the main powerhall. The draft tubes converge in two bifurcations at the tailrace tunnels which run, under free flow conditions, to the river. Access to the powerhouse is via an unlined tunnel leading from an access portal low down on the right side of the canyon.

The switchyard is located on the left bank of the river downstream from the saddle dam, and the power cables from the transformers are carried to it across the top of the dam.

(b) Scheme DC2

The general arrangement for Scheme DC2 is shown on Plate 10.2 (Volume 1). The layout is generally similar to Scheme DC1 except that the chute spillway is located on the left side of the canyon. The concrete-lined chute is approximately 1,400 feet long terminating in a ski-jump flip bucket high on the left side of the canyon, which discharges into the river below. The design flow is 90,000 cfs and discharges are controlled by a 3-gated ogee crested control structure, similar to that for Scheme DC1, which abuts the left side thrust block.

The saddle dam centerline is straight, following the shortest route between the control structure at one end and the rising ground beyond the low lying area at the other.

(c) Scheme DC3

The general arrangement for Scheme DC3 is shown on Plate 10.4 (Volume 1). The layout is similar to Scheme DC1, except that the right side main spillway takes the form of a single tunnel rather than an open chute. A 2-gated ogee control structure is located at the head of the tunnel and discharges into an inclined shaft 45 feet in diameter at its upper end. The structure will discharge up to a maximum of 90,000 cfs.

The concrete-lined tunnel narrows down to 35 foot diameter and discharges into a flip bucket which directs the flows in a jet into the river below as in Scheme DC1.

An auxiliary spillway is located in the center of the dam and an emergency spillway is excavated on the left abutment.

The layout of dams and power facilities are as in Scheme DC1.

(d) Scheme DC4

The layout for Scheme DC4 is shown on Plate 10.4 (Volume 1). The dam, power facilities, and saddle dam for this scheme are the same as those for Scheme DC1. The major difference is the substitution of a stilling basin type spillway on the right bank for the chute and flip bucket. A 3-gated ogee-control structure is located at the end of the dam thrust block and controls the discharges, up to a maximum of 90,000 cfs.

The concrete-lined chute is built into the face of the canyon and discharges into a 500-foot-long by 115-foot-wide by 100-foot-high concrete stilling basin formed below river level and deep within the right side of the canyon. This arrangement forms the service spillway with central orifices in the dam and the left bank rock channel and fuse plug forming the auxiliary and emergency spillways, respectively, as in the alternative schemes.

The downstream cofferdam is located beyond the spillway, and the diversion tunnel outlets are located further downstream to enable construction of the stilling basin.

7.4 - Construction

Construction of the diversion will be a problem similar to all layouts. It is envisaged that because of the difficulty of access within the canyon the tunnels will be driven entirely from the upper end with immediate access down the south side tributary valley just upstream from the canyon. Impervious material rockfill for the cofferdams will be obtained from the area of the emergency spillway.

Excavation for the arch dam foundations will require low-level access on both sides of the canyon. Roads can be constructed during the period of diversion construction. The concrete for the dam will be placed by high-lines strung across the canyon between the abutments. Concrete aggregates will be available within the upstream river terraces.

It is assumed that construction materials for the saddle dam will be found in the local area. Impervious materials will be obtained from local overburden excavation with the rockfill coming from the emergency spillway excavation.

The powerhouse is founded deep within competent rock. Construction access will be via the main access tunnel and by the tailrace tunnels which will be driven from downstream. Excavation of the penstocks will be from below via a branch adit driven behind the lower bends of the penstocks.

Excavation slopes and support for the right bank open cut spillways will be governed by the inclined bedding planes dipping towards the river. Excavation of a left bank main spillway could also give difficulties because of highly fissured loose rock on this side of the canyon.

Excavation of the right bank tunnel would tend to parallel the bedding planes and heavy support would probably be required.

7.5 - Scheduling

Scheduling for construction of Devil Canyon need not be as tight as for the Watana Project. Construction of the diversion could be scheduled well in advance of construction of the permanent structures. Construction of the tunnels could take place over a two-year period commencing in early summer with cofferdam closure taking place over an approximately 6-month period during the winter when flows are low.

Excavation of the main dam foundation could commence prior to completion of the diversion. The total construction period for the arch dam is estimated at 4.5 years. The arch dam and diversion will be on the critical construction path and as they are similar for all layouts total construction period will be the same for all the schemes.

The main spillways and powerhouse facility construction periods are estimated at 3 and 4 years, respectively for all schemes.

7.6 - Costs

Capital cost estimates for the construction of the schemes are given in Table B3.1, which gives individual costs of the main structures together with indirect costs.

Unit rates are based on a preliminary contractor's type estimate developed from anticipated plant and labor content and construction activities. Quantities have been calculated from the drawings, except in the case of the powerhouse where they have been developed from comparable powerhosues in projects constructed elsewhere. Twenty percent has been added to the costs to cover contingencies and 12.5 percent has been added to cover engineering and administration.

7.7 - Comparison of Layouts

The arch dam, saddle dam, power facilities and diversion vary only in a minor degree between the alternatives. A comparison of schemes, therefore, rests solely with a comparison of the spillway facilities.

As can be seen from a comparison of the costs in Table B3.1, the flip bucket spillways are substantially less expensive to construct than the stilling basin type of Scheme DC4. The left bank spillway of Scheme DC2 is inclined sharply to the river and ejects the discharge jet from high on the canyon face towards the opposite side of the canyon. Over a long period of operation, scour of the heavily jointed rock could be a considerable problem causing undermining of the canyon sides and their consequent instability. The possibility of a build-up of material downstream with a corresponding elevation of the tailrace must also be considered. Construction of a spillway on the steep left side of the river could be more difficult than on the right side because of the presence of deep fissures and large unstable blocks of rock which are present on the left side close to the top of the canyon. Instability of the overlying bedding planes could be a problem with the open cut spillways on the right bank. It could also give problems with the right bank tunnel spillway which trends nearly parallel to the bedding.

The two right side flip bucket spillway schemes based on either an open chute or a tunnel take advantage of a downstream bend in the river to eject discharges parallel to the course of the river. This will reduce the effects of erosion but it could still be a problem as can be seen from the outline of the estimated maximum possible scour hole which would occur over a period of time.

The tunnel type spillway could prove difficult to construct because of the large diameter of inclined shaft and tunnel paralleling the bedding planes. The high velocities, encountered in all spillways, could particularly cause troubles in the tunnel with the possibility of spiralling flows and severe cavitation.

The stilling basin type spillway of Scheme DC4 reduces downstream erosion problems within the canyon. However, cavitation could be a problem under the high flow velocities experienced at the base of the chute. This would be somewhat alleviated by aeration of the flows, introducing air into the water/concrete contact area at offsets along the chute invert. There is, however, little precedent for stilling basin operation at heads of over 550 feet and even where floods of much less than the design capacity have been discharged, severe damage has occurred.

7.8 - Conclusions

The chute and flip bucket spillways of Schemes DC1 and DC2 pose downstream erosion problems which could, in the case of Scheme DC2, cause considerable maintenance costs and reduced efficiency in operation of the project at a future date. Scheme DC3 causes hydraulic problems and cavitation could be severe. There is no cost advantage with this type of spillway over the open chute in Scheme DC4. The operating characteristics of a high head stilling basin are little known and there are few examples of successful operation.

All spillways at the heads and discharges involved will eventually cause some erosion. However, with predicted operational frequency of only 1:50 years it is not anticipated that erosion will be severe. The cost of the flip bucket type spillway in the scheme is considerably less than that of the stilling basin in Scheme DC4. The stilling basin offers no relative operational advantages and hence Scheme DC4 has been selected for future study.

8 - REVISED DATA AND CRITERIA

8.1 - General

Further to the information and criteria forming the basis of Step 7, additional studies have been undertaken on the basis of more recent data which has been made available. This includes a remapping of the ground surface contours at the site, which necessitates changes in the criteria and layout. On the basis of these changes the selected layout from Section 7 has been further developed. The changes from the previous criteria which effect this additional development are set out as follows.

8.2 - Revised Criteria

Nitrogen supersaturation in downstream releases (occurring when aerated water is pressurized to 2 atmospheres or more) should be avoided in discharges occurring more frequently than 1:100 years:

Routed 1:50-year flood:	50,000 cfs
Routed 1:50-year diversion flood:	53,200 cfs
Reservoir normal maximum operating level:	1,455 ft MSL
Reservoir normal minimum operating level:	1,430 ft MSL
Area of reservoir at maximum operating level:	7,800 acres
Reservoir live storage:	350,000 acre ft

9 - SELECTED LAYOUT

9.1 - General

The general concept of the overall layout selected in Section 7 has been further developed to accord with updated engineering study and criteria. The major change is in the central spillway configuration but other lesser changes are necessitated as described in this section.

It is anticipated that other minor changes will occur during the ongoing feasibility study but the general concept of the scheme as established herein will remain unchanged.

9.2 - Layout Description

The revised layout is shown on Plates 10.5 (Volume 1) and B3.2. A description of the structures is as follows:

(a) Main Dam

The maximum operating level of the reservoir has been raised to Elevation 1455 to accord with information received from site which establishes the average water surface of the Watana tailrace at this level. This requires raising the dam crest to Elevation 1465 with the concrete parapet wall set at 1,469 feet. The saddle dam is raised to Elevation 1470. The rock contours at river level are shallower and the mass concrete plug at the foot of the dam is consequently eliminated.

(b) Spillways

To accord with restrictions on nitrogen supersaturation, it is necessary to restrict supersaturated flow to an average recurrence period of not less than 50 years. In order to pass floods of greater frequency, an alternative facility has to be found. This requirement would be satisfied by a number of Howell Bunger valves discharging greatly dispersed jets of water downstream thus avoiding the plunging action of alternative spillways.

It is considered possible that heavy maintenance would be required in the concrete-lined plunge pool beneath the central orifice spillways and just downstream from the dam if this spillway operated for extended periods. This is a critical area because of the proximity and importance of the latter and hence for two reasons, additional security and reduction of nitrogen supersaturation, the orifice spillways have been replaced by five 108-inch diameter centrally located Howell Bunger valves of similar total capacity (45,000 cfs).

The flip bucket spillway remains on the right embankment but the chute is shortened and the bucket is raised further above the river than in Scheme DC1.

The area of ground in the vicinity of the paddle dam appears lower on the updated topography than previously indicated and to accommodate the emergency spillway is relocated slightly further from the river than previously in order to maintain it in sound rock.

(c) Diversion

The previous twin diversion tunnels are replaced by a single tunnel scheme which it is determined will give all necessary security but will be slightly lower in cost than the two-tunnel alternative. The tunnel diameter of 36 feet (39 feet unlined) will be acceptable, from a construction viewpoint, within the rock at the site.

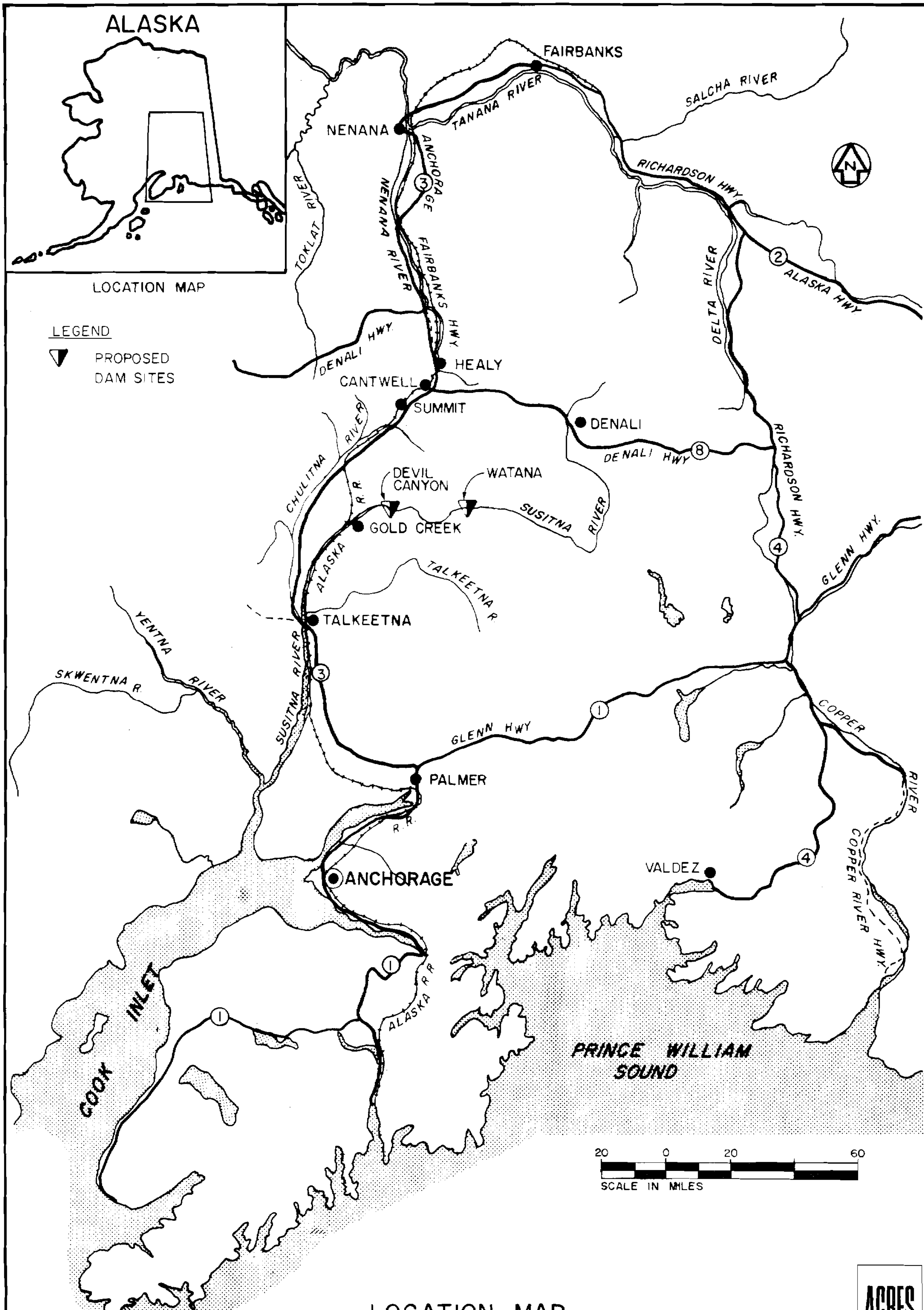
(d) Power Facilities

The drawdown of the reservoir has been reduced and hence the depth of the intake has been reduced accordingly. In order to maintain the intake within the solid rock, it has been moved closer into the side of the valley, and this has necessitated a slight rotation of the water passages, powerhouse and caverns comprising the power facilities.

TABLE B3.1: SUMMARY OF COMPARATIVE COST ESTIMATES

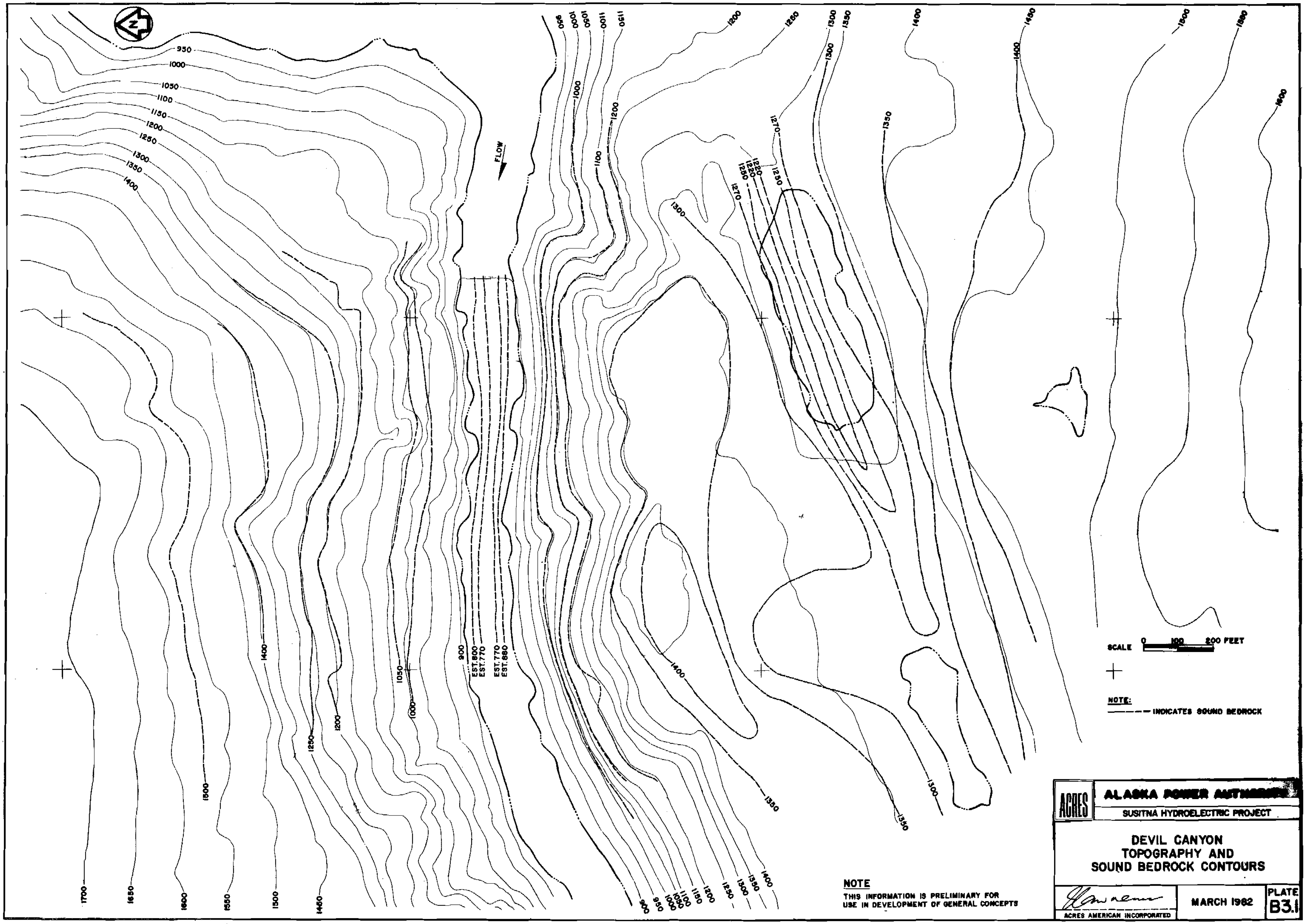
PRELIMINARY REVIEW OF ALTERNATIVE ARRANGEMENTS
(January 1982 $ X 10^6)

Item	DC1	DC2	DC3	DC4
Land Acquisition	22.1	22.1	22.1	22.1
Reservoir	10.5	10.5	10.5	10.5
Main Dam	468.7	468.7	468.7	468.7
Emergency Spillway	25.2	25.2	25.2	25.2
Power Facilities	211.7	211.7	211.7	211.7
Switchyard	7.1	7.1	7.1	7.1
Miscellaneous Structures	9.5	9.5	9.5	9.5
Access Roads & Site Facilities	28.4	28.4	28.4	28.4
Common Items - Subtotal	783.2	783.2	783.2	783.2
Diversion	32.1	32.1	32.1	34.9
Service Spillway	46.8	53.3	50.1	85.2
Saddle Dam	19.9	18.6	18.6	19.9
Non-Common/Items Subtotal	98.8	104.0	100.8	140.0
Total	882.0	887.2	884.0	923.2
Camp & Support Costs (16%)	141.1	141.9	141.4	147.7
Subtotal	1023.1	1029.1	1025.4	1070.9
Contingency (20%)	204.6	205.8	205.1	214.2
Subtotal	1227.7	1234.9	1230.5	1285.1
Engineering & Administration (12.5%)	153.5	154.3	153.8	160.6
Total	1381.2	1389.2	1384.3	1445.7



LOCATION MAP

FIGURE B3.1



NOTE

THIS INFORMATION IS PRELIMINARY FOR USE IN DEVELOPMENT OF GENERAL CONCEPTS

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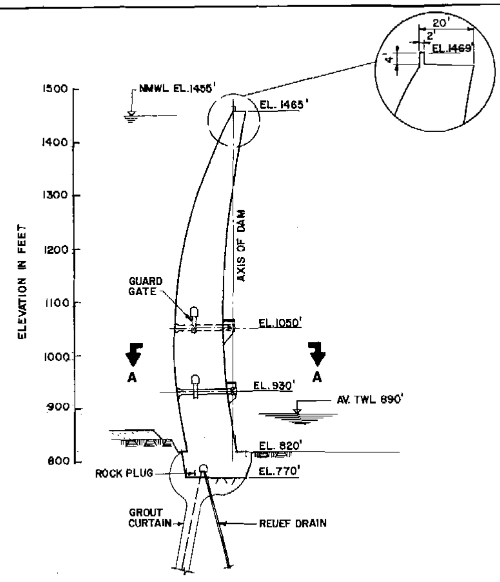
SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON
TOPOGRAPHY AND
SOUND BEDROCK CONTOURS

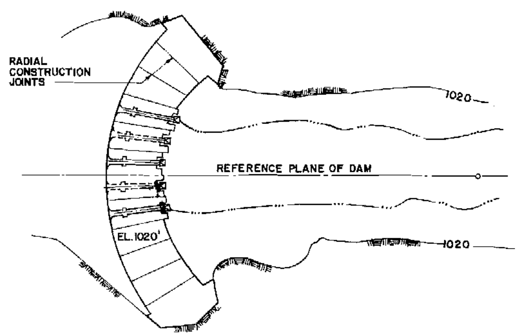
ACRES AMERICAN INCORPORATED

MARCH 1982

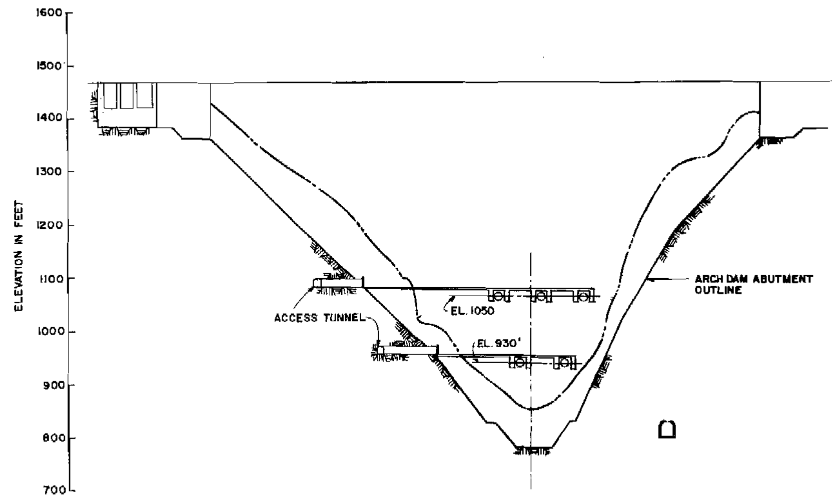
PLATE B3.1



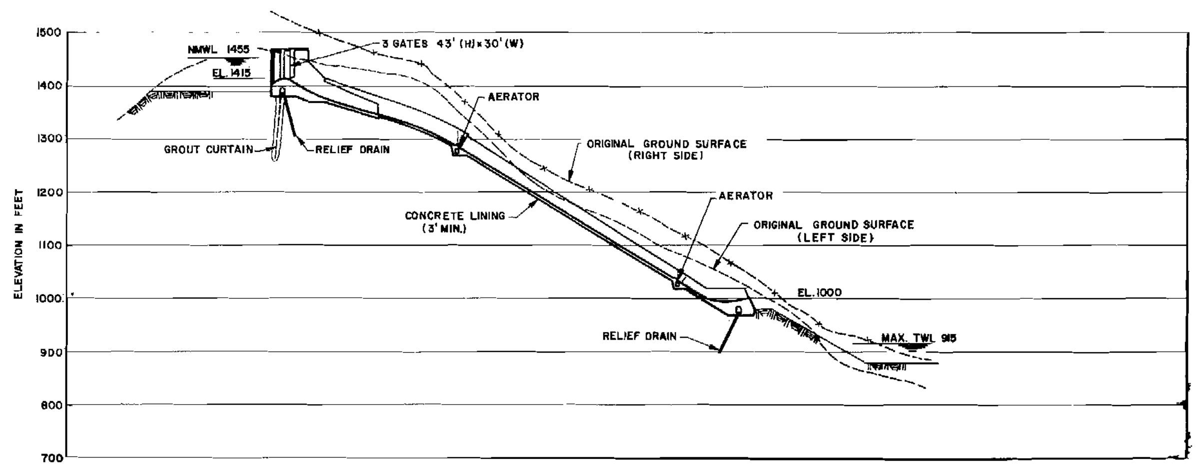
CROWN SECTION



SECTION A–A



DAM PROFILE (LOOKING UPSTREAM)



SPILLWAY PROFILE

SCALE 0 100 200 FEET

NOTE

THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY

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ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON
SCHEME I
SECTIONS

ACRES AMERICAN INCORPORATED

MARCH 1982

PLATE B32

APPENDIX B4

POWER FACILITIES ALTERNATIVES

1 - INSTALLED CAPACITY

A computer simulation of reservoir operation over 32 years of hydrological record was used to predict firm (dependable) and average energy available from Watana and Devil Canyon reservoirs on a monthly basis. As discussed in Appendix A1, four alternative reservoir operating rules were assumed, varying from a maximum power generation scenario (Case A) through to a complete commitment to provide guaranteed minimum summer releases for fisheries (Case D). For the preliminary design, Case A predicted energies have been used to assess the required plant capacity.

The computer simulation gives an estimate of the monthly energy available from each reservoir, but the sizing of the plant capacity must take into account the variation of demand load throughout each month on an hourly basis. Load forecast studies have been undertaken to predict the hourly variation of load through each month of the year, and also the growth in peak load (MW) and annual energy demand (GWh) through to the end of the planning horizon, 2010 (Volume 1, Section 5).

The economic analysis for the proposed development (Volume 1, Section 18) assumes that the average energy from each reservoir is available every year. The hydrological record, however, is such that this average energy is available only from a series of wetter and drier years. In order to utilize the average energy, capacity must be available to generate the energy available in the wet years up to the maximum requirement dictated by the system energy demand, less any energy available from other committed hydro plant.

Watana has been designed to operate as a peaking station, if required. Tables B4.1 and B4.2 show the estimated maximum capacity required in the peak demand month (December) at Watana to fully utilize the energy available from the flows of record. If no thermal energy is needed (i.e. in wetter years), the maximum requirement is controlled only by the shape of the demand curve. If thermal energy is required (in average to dry years), the maximum capacity required at Watana will depend on whether the thermal energy is provided by high merit order plant at base load (Option 1, Table B4.1); or by low merit order peaking plant (Option 2, Table B4.2).

Table B4.3 shows a similar assessment of maximum plant capacity required at Devil Canyon in the peak demand month (December). The Devil Canyon capacity is the same for either Option 1 or Option 2, since Devil Canyon will not operate as a peaking station.

The maximum values from Tables B4.1, B4.2 and B4.3 were used to assess the required installed capacity at Watana and Devil Canyon (Volume 1, Sections 9.6 and 10.6).

2 - ALTERNATIVE LAYOUTS

Alternative layouts for the power facilities at Watana and Devil Canyon were required for an economic comparison of the following features:

- Type of powerhouse (surface or underground);
- Number of units for a given installed capacity; and
- Number and size of penstocks and tailrace tunnels.

The initial layout studies were carried out for Watana with a total installed capacity of 840 MW.* At a later date, the selected capacity was increased to 1020 MW (Section 1 above). The sizes of powerhouse, machines, penstocks and tailrace were increased, but the basic conclusions regarding the optimum layout of the power facilities remain unchanged. These conclusions are summarized below:

- An underground powerhouse arrangement is marginally less costly than an equivalent surface powerhouse and has distinct operational advantages;

- Six units at Watana and four units at Devil Canyon give a reasonable compromise between initial capital cost and overall station efficiency. They also allow for phased unit installation to match actual growth in demand; and

- Individual penstocks to each generating unit should be provided.

Studies on the optimum arrangement and sizing of penstocks and tailrace tunnels are described in Volume 1, Sections 9.11 and 10.11.

3 - LAYOUT STUDIES

Two alternative powerhouse types were studied in detail at Watana. For the first arrangement, the powerhouse was located above ground on the right bank, downstream of the toe of the dam; for the second arrangement, the powerhouse was located underground in the right abutment. For the comparative studies, the station installed capacity (840 MW)* and number of units (4) were common to both arrangements and the same intake and outlet portals were used. The alignment of the water passages was slightly different but the overall length was similar.

The significant advantages and disadvantages of the two types of powerhouses are summarized below:

- The surface powerhouse is more severely affected by river flooding and must be protected against maximum anticipated flood level;

- The underground powerhouse is better suited to operation in the harsh arctic environment;

- The high pressure conduits (penstocks) for the surface powerhouse alternative are significantly longer and require extensive steel lining where there is inadequate rock cover; and

- The underground alternative requires a tailrace tunnel with upstream surge chamber protection.

* 840 MW at minimum December reservoir level; 992 MW at rated head.

The alternative layouts for surface and underground powerhouse arrangements are shown on Plates B4.1 and B4.4. Details of the powerhouse layouts are shown on Plates B4.2, B4.3, B4.5, and B4.6.

A third layout was also developed with an underground powerhouse to accommodate six units of 140 MW. This was used to assess the extra cost of using six smaller units as compared with four larger units. The layout is shown on Plate B4.7 and is similar to that of the four-unit powerhouse, except that six penstocks are used in conjunction with a larger intake structure. Powerhouse details are shown on Plates B4.8 and B4.9.

The comparative cost estimates for these three alternative layouts are given in Table B4.4.

The cost estimates show an advantage in favor of the underground powerhouse of about $16.3 million for the common four-unit layout. The underground powerhouse layout requires a tailrace tunnel and surge chamber, but the surface powerhouse layout penstocks are significantly more expensive and require full steel lining over the length where the rock cover is less than 450 feet. Since the underground powerhouse is also more suitable for operation in an arctic environment, this arrangement was adopted for the Watana layout.

The same conclusion was assumed for the selection of powerhouse types at Devil Canyon. The costs of surface and underground powerhouses are comparable; the underground powerhouse layout was therefore selected since it is more suitable in an arctic environment.

4 - NUMBER OF UNITS

The cost estimates for an underground powerhouse at Watana with four units or six units are summarized in Table B4.4. The six-unit option involves an extra cost of $31 million, predominantly in the cost of intake and penstocks; the increases in cost of the powerhouse and electrical and mechanical equipment are marginal. A separate study for the extra cost of eight units over six units gave a similar extra cost (about $27 million).

Estimated peaking load on Watana in a wet year varies from 900 MW to about 1000 MW. The least cost powerhouse arrangement would utilize a small number of large units, but this would have several disadvantages in normal operation:

- The unit size would be a large proportion of system load with consequent severe disruption on forced or planned outage;

- Station part load efficiency would be relatively low, particularly in the years immediately after commissioning when demand is low;

- Station minimum output (50 percent unit rated output) would be relatively high, thus reducing flexibility of operation;

- Reserve capacity would be high to offset possible machine outages; and

- Phasing of unit installation to match demand would be difficult with a small number of large units.

The four-unit installation is considered to be the minimum number of machines consistent with the above limitations. A study was carried out to assess the increased energy output from the Watana station of using either 6 or 8 units as a result of improved station efficiency. The approximate variation of station efficiency with load is shown on Figure B4.1, assuming all units are equally loaded and assuming a peak turbine efficiency of 92 percent. The overall station efficiency increases as the number of units is increased. Also the minimum load at which output can be maintained is improved as the number of units is increased. The relative cost-benefit is illustrated in the following table using a capitalized value of annual energy of approximately $1 million per GWh (Volume 1, Section 9.5).

Number of Units	Incremental* Capital Cost ($ x 10^6)	Incremental* Energy Value ($ x 10^6)	Incremental B/C Ratio
4	--	--	--
6	31	40	1.29
8	27	10	0.37

*Incremental over preceeding line

Intermediate cases of five and seven units would give intermediate values of cost and benefit, but they were not considered in detail because of difficulties with the arrangement of the electrical facilities (transformers, isolated phase bus, etc.) with an odd number of units. For preliminary design, the six-unit powerhouse layout is the preferred option at Watana.

At Devil Canyon, the position is slightly different since the station will be operated primarily for base load generation. The load on the station would vary between about 500 MW in a wet year to about 150 MW in a dry year.

For this range of operation, the four-unit powerhouse arrangement has been adopted at Devil Canyon. This also gives a unit size comparable with the unit size at Watana.

TABLE B4.1: WATANA - MAXIMUM CAPACITY REQUIRED (MW)
OPTION 1 - THERMAL AS BASE

Hydrological Year	CAPACITY (MW)		
	1995	2000	2010***
1	799	818	886*
2	609	628	723
3	817	836	886*
4	804	823	886*
5	800	819	886*
6	818	837	886*
7	792	811	886*
8	826	845	886*
9	839**	874**	886*
10	796	815	908**
11	825	844	886*
12	839*	859	886*
13	829	848	886*
14	826	845	886*
15	800	819	886*
16	793	812	886*
17	800	819	886*
18	798	817	900*
19	826	845	886*
20	777	796	886*
21	609	628	723
22	609	628	723
23	839*	858	899*
24	803	822	886*
25	786	806	898
26	609	628	723
27	784	803	886*
28	674	693	786
29	839*	859	886*
30	608	628	723
31	839*	862	886*
32	810	829	886*

*Restricted by peak demand
**Maximum value
***Including Devil Canyon

TABLE B4.2: WATANA - MAXIMUM CAPACITY REQUIRED (MW)
OPTION 2 - THERMAL AS PEAK

Hydrological Year	CAPACITY (MW)		
	1995	2000	2010***
1	704	652	886*
2	441	441	443
3	748	678	886*
4	716	660	886*
5	707	654	886*
6	752	680	886*
7	689	643	886*
8	778	693	886*
9	839*	742**	886*
10	698	648	751
11	774	691	886*
12	839**	715	886*
13	788	697	886*
14	778	693	886*
15	707	654	886*
16	692	645	886*
17	707	654	886*
18	700	650	900**
19	778	693	886*
20	662	625	886*
21	441	441	443
22	441	441	443
23	832	713	899*
24	713	658	886*
25	678	635	678
26	441	441	443
27	672	632	886*
28	512	507	519
29	839*	715	886*
30	441	441	443
31	839*	720	886*
32	730	668	886*

*Restricted by peak demand
**Maximum value
***Including Devil Canyon

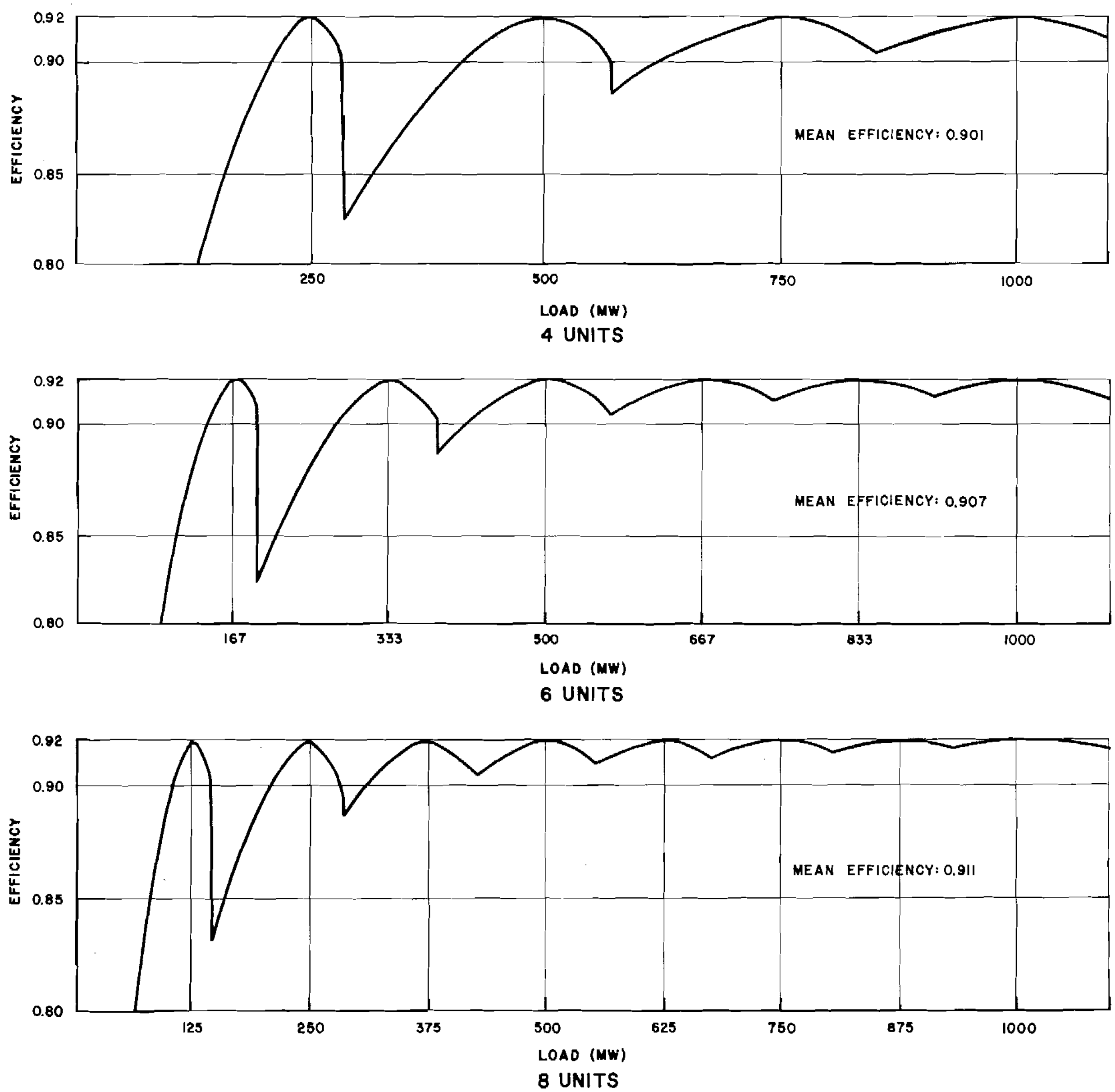
TABLE B4.3: DEVIL CANYON - MAXIMUM CAPACITY REQUIRED (MW)

Hydrological Year	Capacity (MW) 2010 (Option 1 and 2)
1	507**
2	375
3	507
4	507
5	507
6	507
7	507
8	507
9	507
10	431
11	507
12	507
13	507
14	507
15	507
16	507
17	507
18	493
19	507
20	507
21	377
22	377
23	494
24	507
25	378
26	375
27	507
28	380
29	507
30	377
31	507
32	507

**Maximum Value

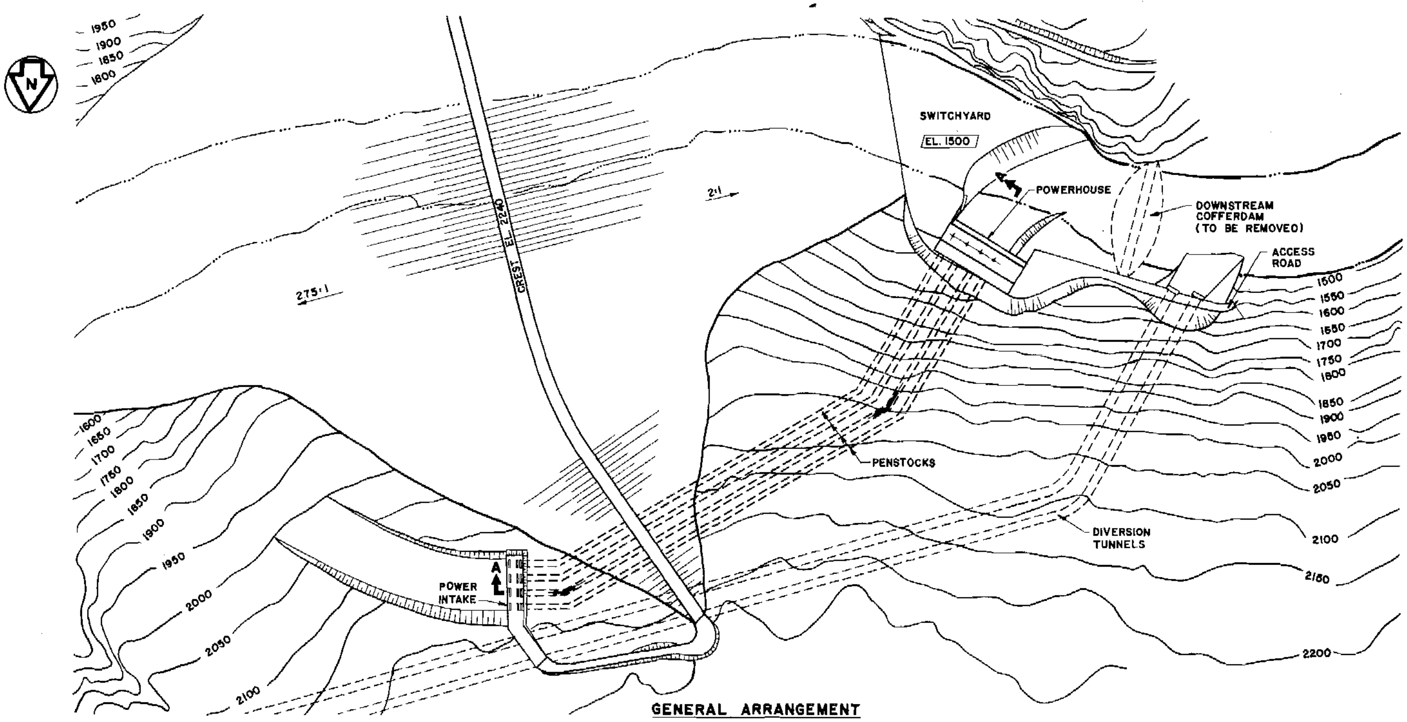
TABLE B4.4: SUMMARY COMPARISON OF POWERHOUSES AT WATANA

Item	SURFACE ($000) 4 x 210 MW	UNDERGROUND ($000) 4 x 210 MW	UNDERGROUND ($000) 6 x 140 MW
Civil Works:			
Intakes	54,000	54,000	70,400
Penstocks	72,000	22,700	28,600
Powerhouse/Draft Tube	29,600	26,300	28,100
Surge Chamber	NA	4,300	4,800
Transformer Gallery	NA	2,700	3,400
Tailrace Tunnel	NA	11,000	11,000
Tailrace Portal	NA	1,600	1,600
Main Access Tunnels	NA	8,100	8,100
Secondary Access Tunnels	NA	300	300
Main Access Shaft	NA	4,200	4,200
Access Tunnel Portal	NA	100	100
Cable Shaft	NA	1,500	1,500
Bus Tunnel/Shafts	NA	1,000	1,200
Fire Protection Head Tank	NA	400	400
Mechanical - For Above Items	54,600	55,500	57,200
Electrical - For Above Items	37,400	37,600	41,200
Switchyard - All Work	14,900	14,900	14,900
TOTAL	262,500	246,200	277,000



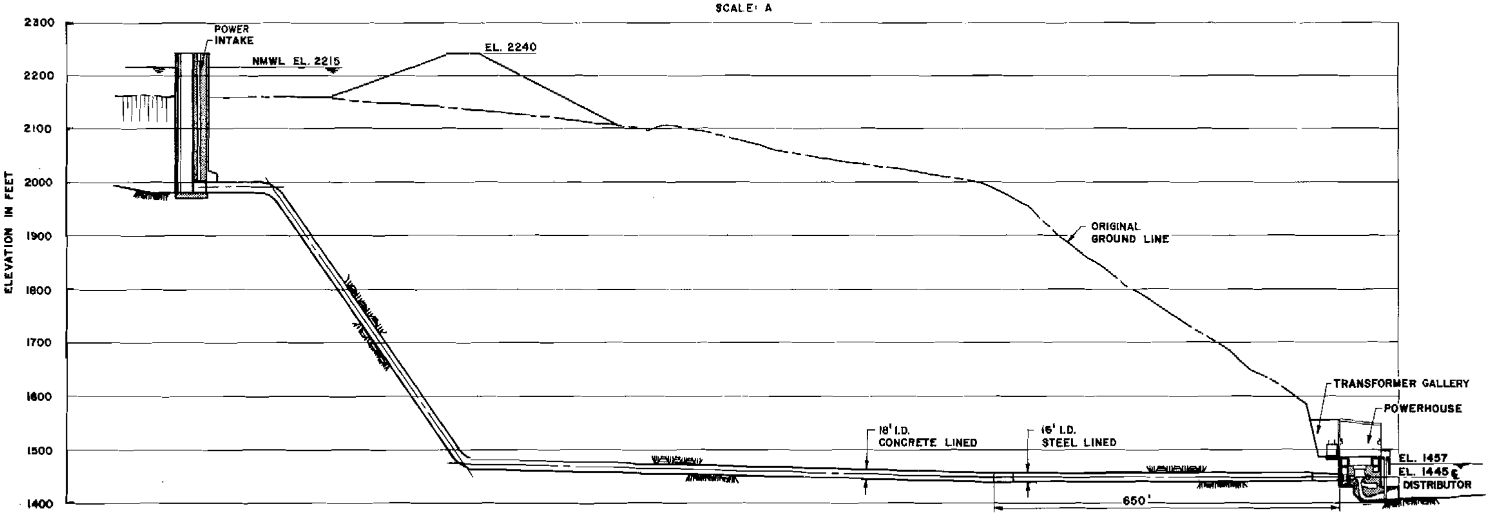
WATANA - STATION EFFICIENCY AT PARTIAL LOAD

FIGURE B 4.1



GENERAL ARRANGEMENT

SCALE: A



SECTION A-A

SCALE: B

SCALE B 0 200 400 FEET

SCALE A 0 100 200 FEET

NOTE

THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY

ACRES

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

WATANA
SURFACE POWERHOUSE
4-210 MW UNITS
GENERAL ARRANGEMENT & SECTION

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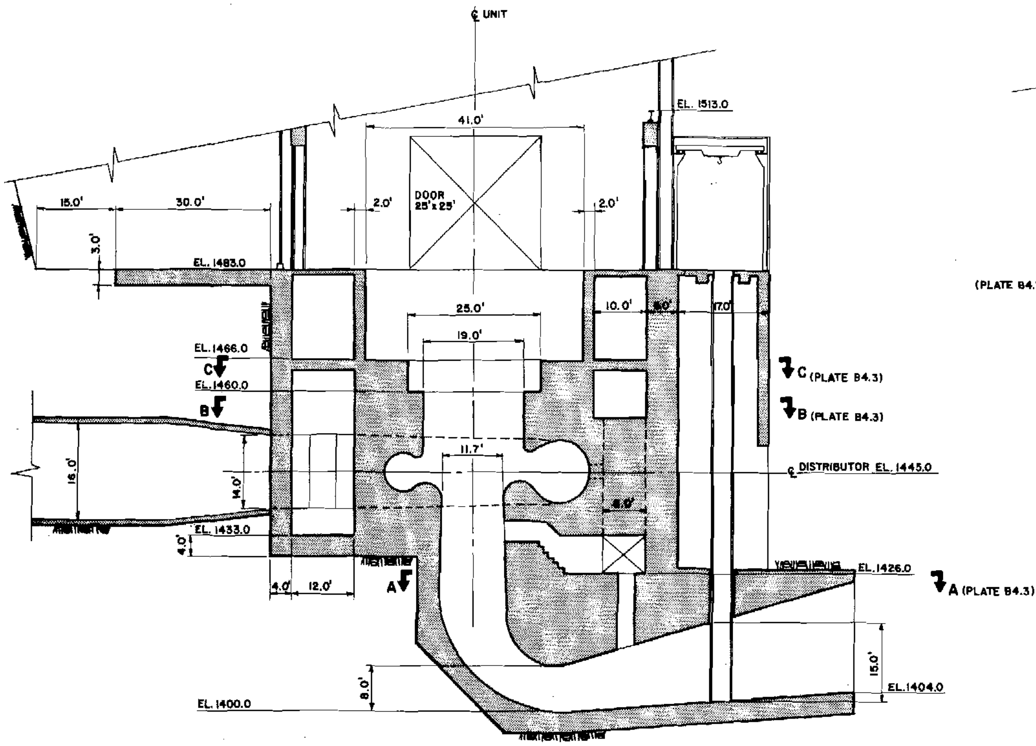
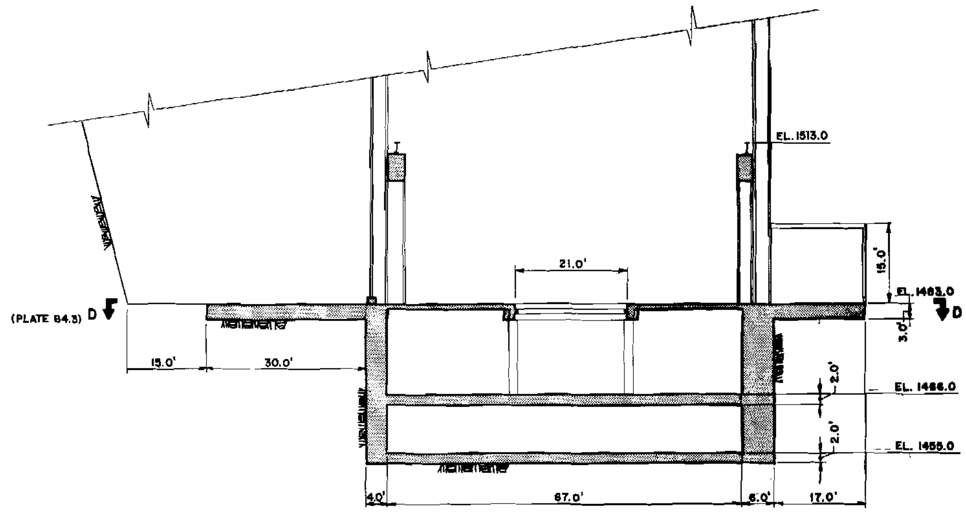
MARCH 1982

PLATE B4.1



SECTION E-E (PLATE B4.7) TYPICAL ALL UNITS



SECTION THRU SERVICE BAY

SCALE 0 10 20 FEET

NOTE

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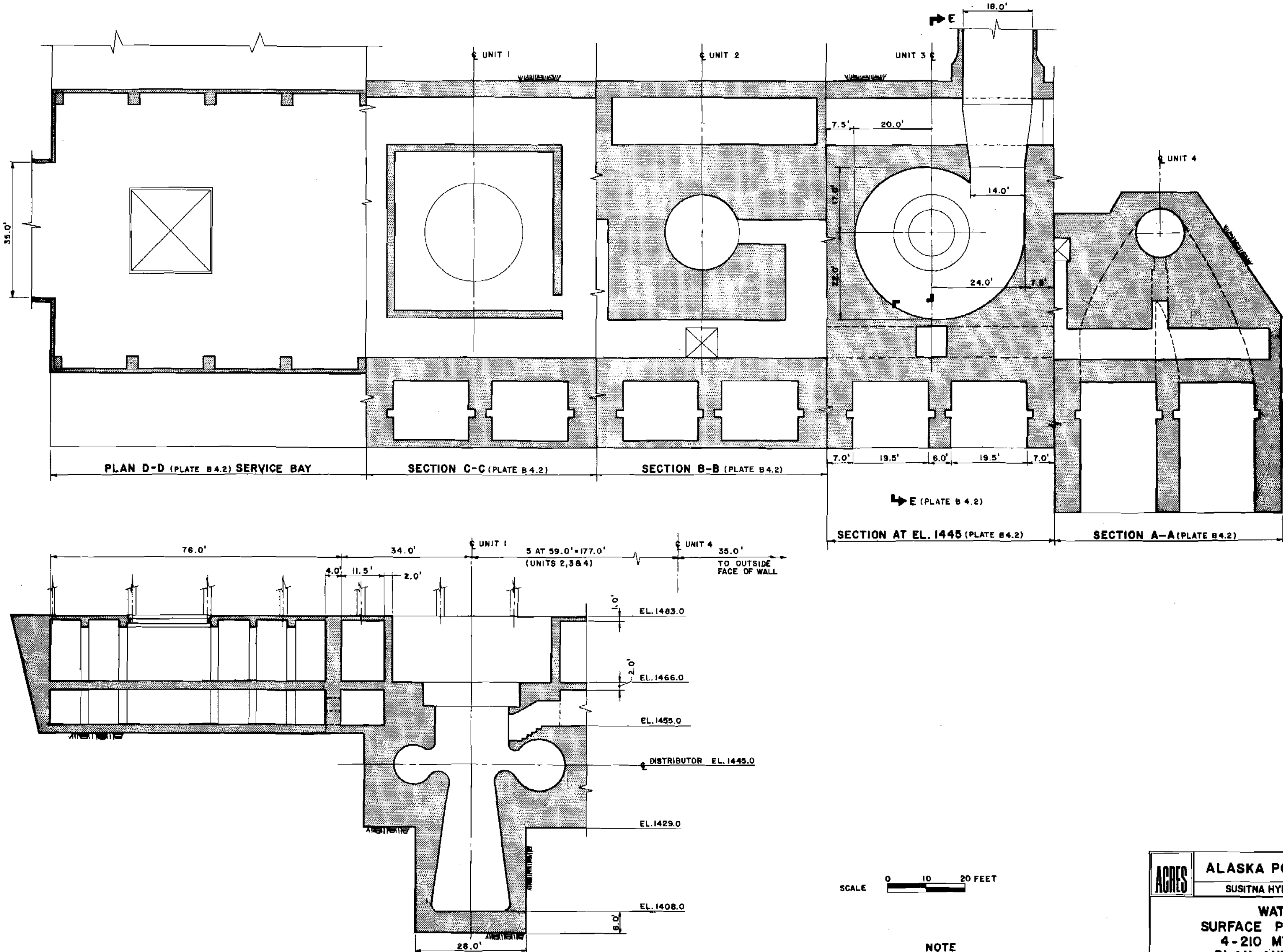
	WATANA SURFACE POWERHOUSE 4-210 MW UNITS SECTIONS
ACRES AMERICAN INCORPORATED	MARCH 1982 — PLATE B4.2



LONGITUDINAL SECTION THROUGH UNITS

SCALE 0 10 20 FEET

NOTE

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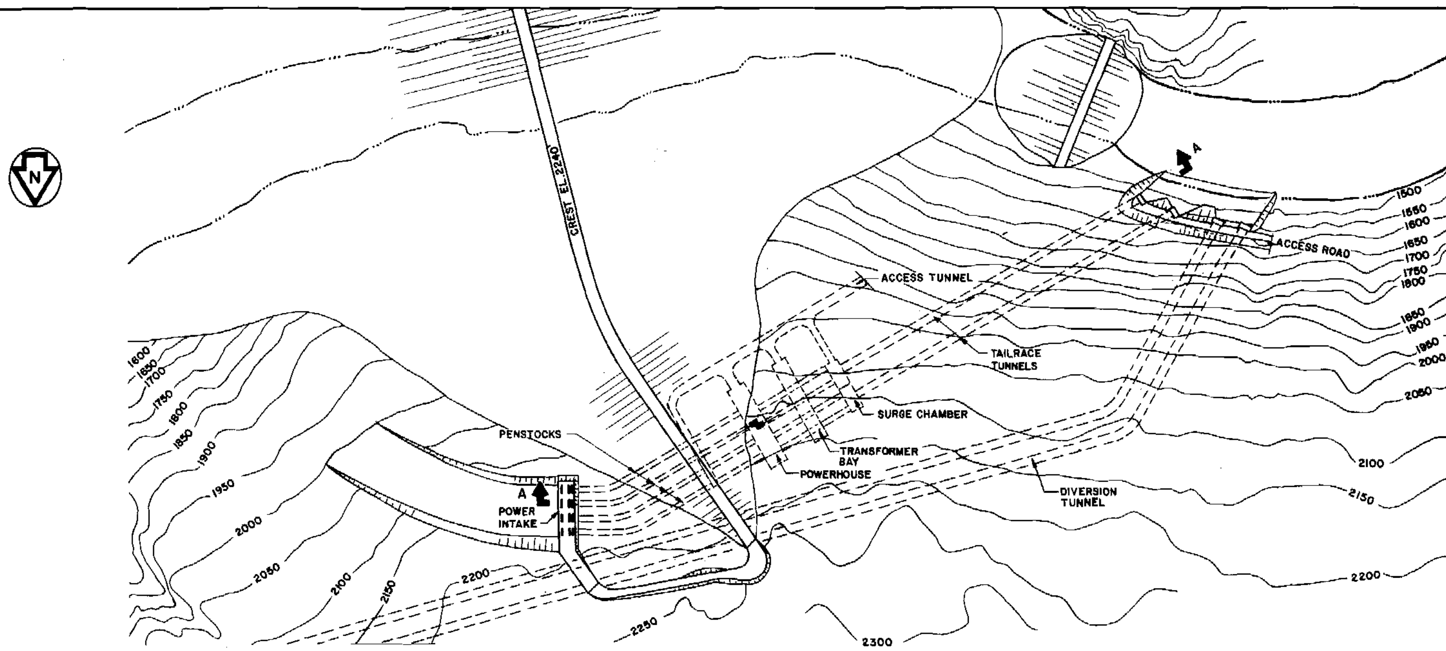
SUSITNA HYDROELECTRIC PROJECT

WATANA
SURFACE POWERHOUSE
4-210 MW UNITS
PLAN AND SECTION

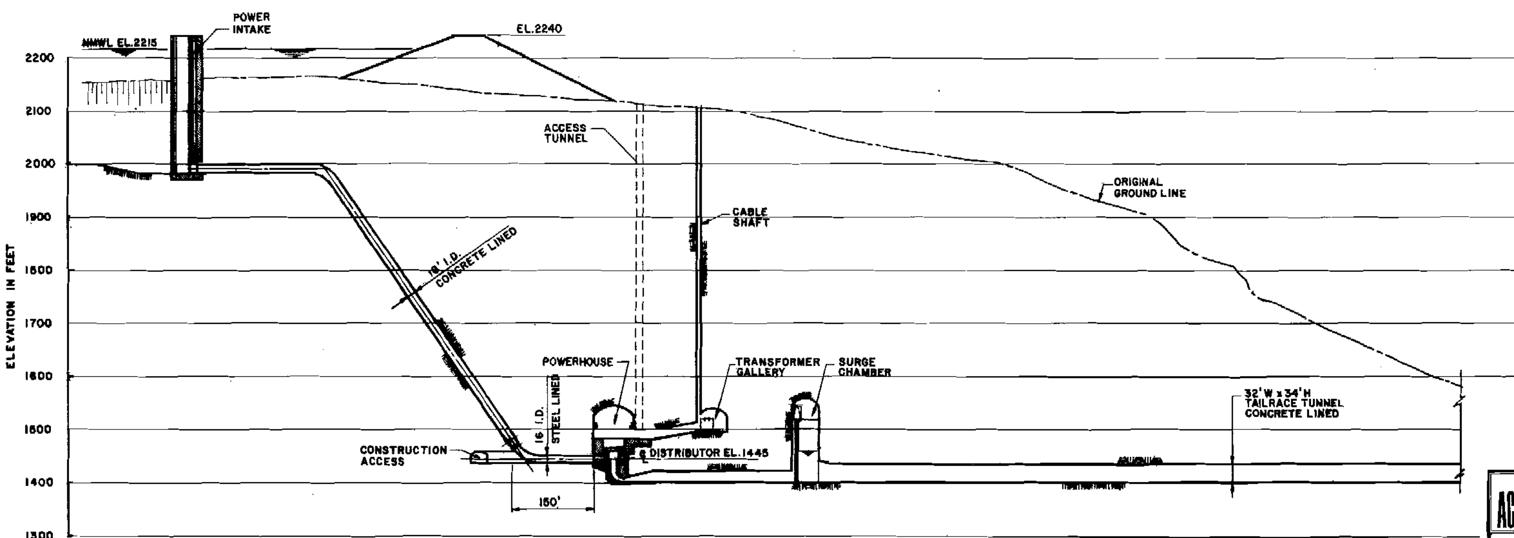
ACRES AMERICAN INCORPORATED

MARCH 1982

PLATE B4.3



GENERAL ARRANGEMENT
SCALE: A



SECTION A-A
SCALE: B

SCALE A 0 200 400 FEET

SCALE B 0 100 200 FEET

NOTE

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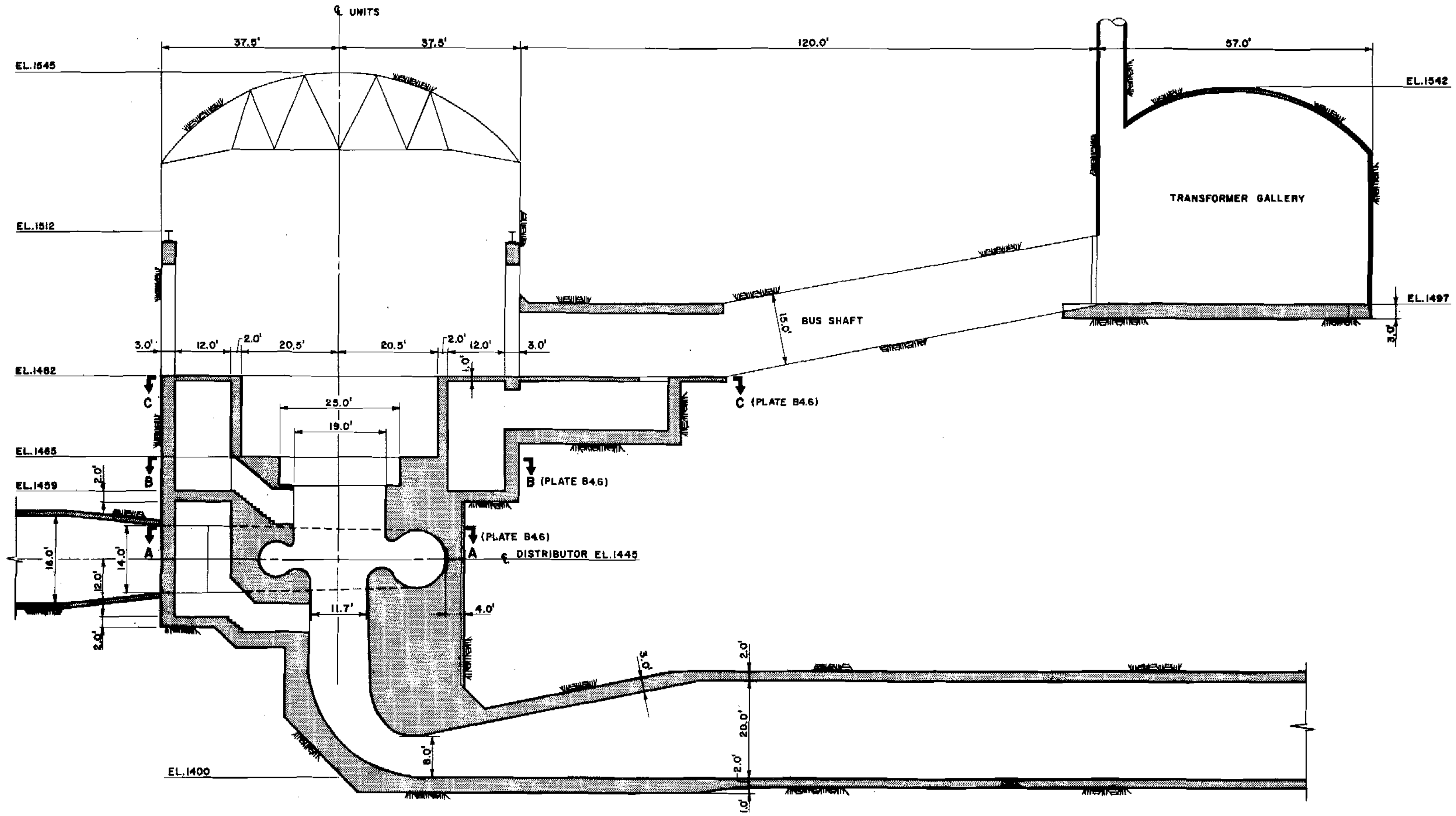
	SUSITNA HYDROELECTRIC PROJECT
WATANA UNDERGROUND POWERHOUSE 4-210 MW UNITS GENERAL ARRANGEMENT & SECTION	
ACRES AMERICAN INCORPORATED	MARCH 1982
PLATE	B44



TYPICAL CROSS-SECTION THRU UNITS

SCALE 0 10 20 FEET

NOTE

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SUSITNA HYDROELECTRIC PROJECT

WATANA
UNDERGROUND POWERHOUSE
4-210 MW UNITS
SECTION

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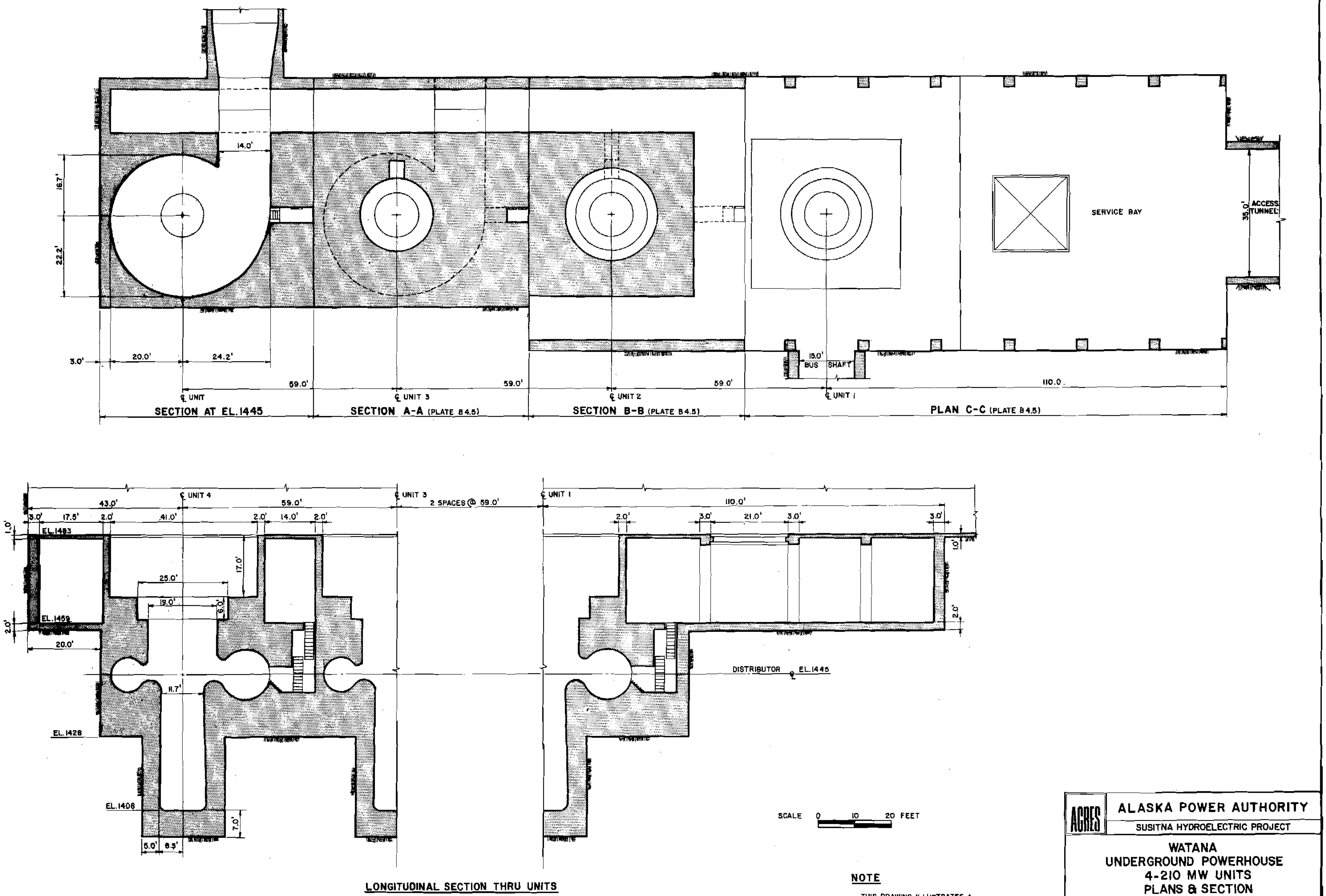
MARCH 1982

PLATE B4.5



NOTE

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WATANA
UNDERGROUND POWERHOUSE
4-210 MW UNITS
PLANS & SECTION

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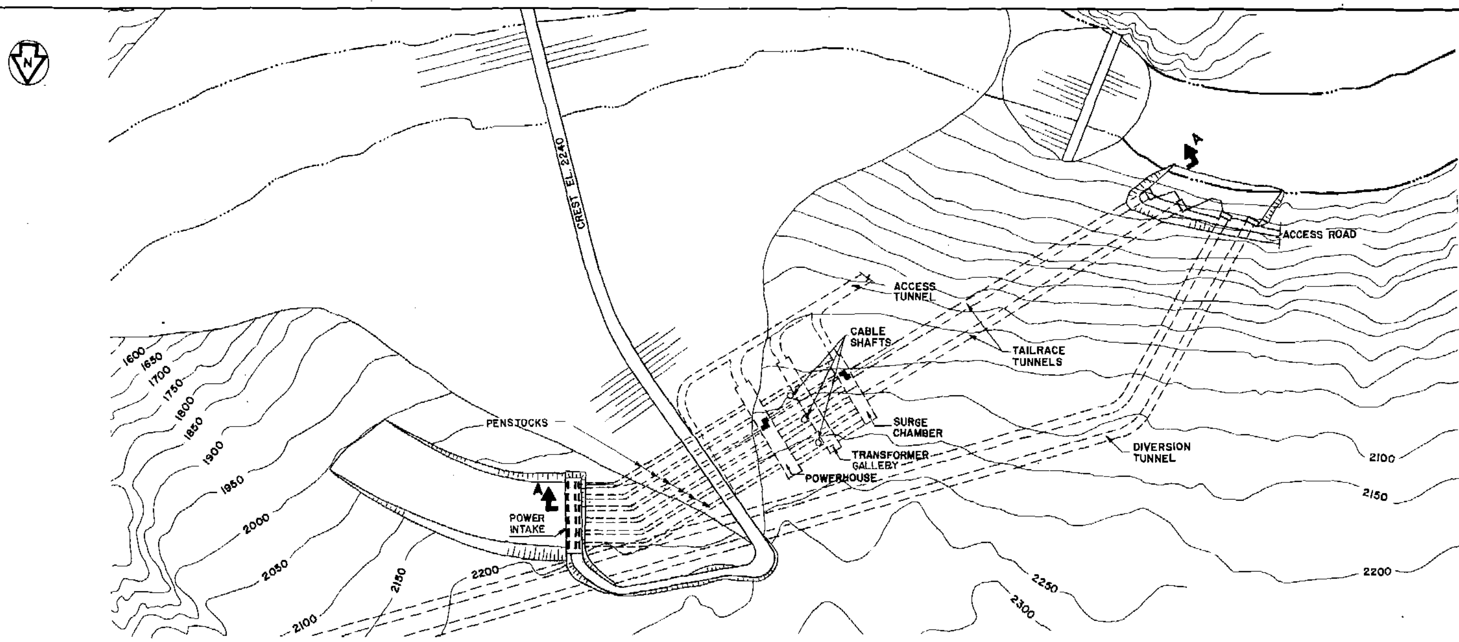
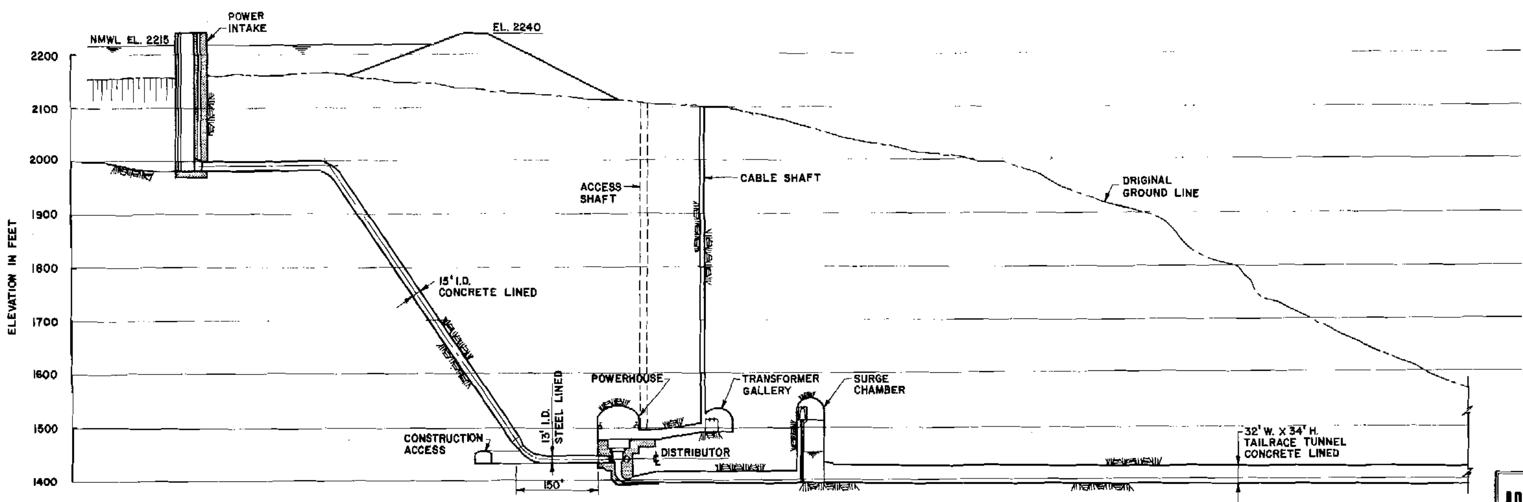


GENERAL ARRANGEMENT

SCALE: A



SECTION A-A

SCALE A 0 200 400 FEET

SCALE B 0 100 200 FEET

NOTE

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WATANA
SURFACE POWERHOUSE
6 - 140 MW UNITS
GENERAL ARRANGEMENT & SECTION

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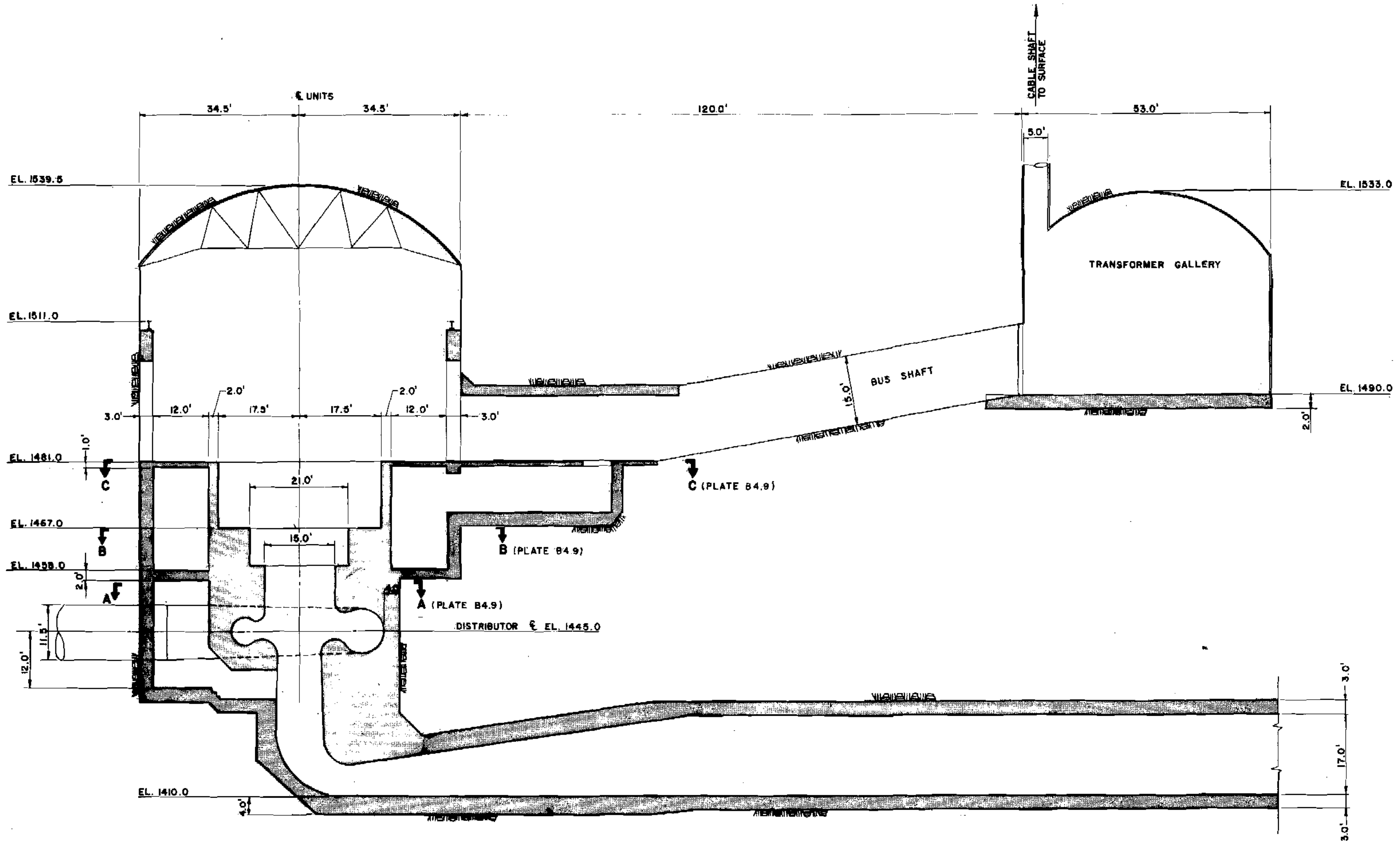
MARCH 1982

PLATE B4.7



TYPICAL SECTION THRU CENTERLINE OF UNITS

SCALE 0 10 20

NOTE

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WATANA
UNDERGROUND POWERHOUSE
6x140MW UNITS
SECTION

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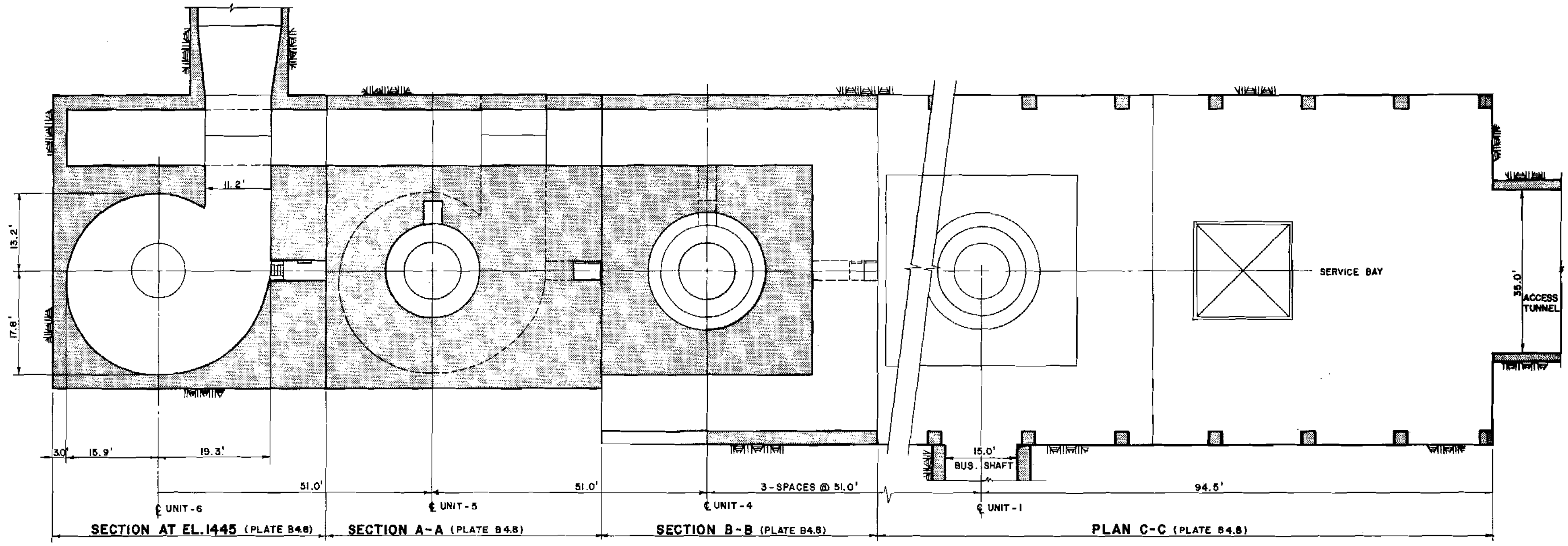
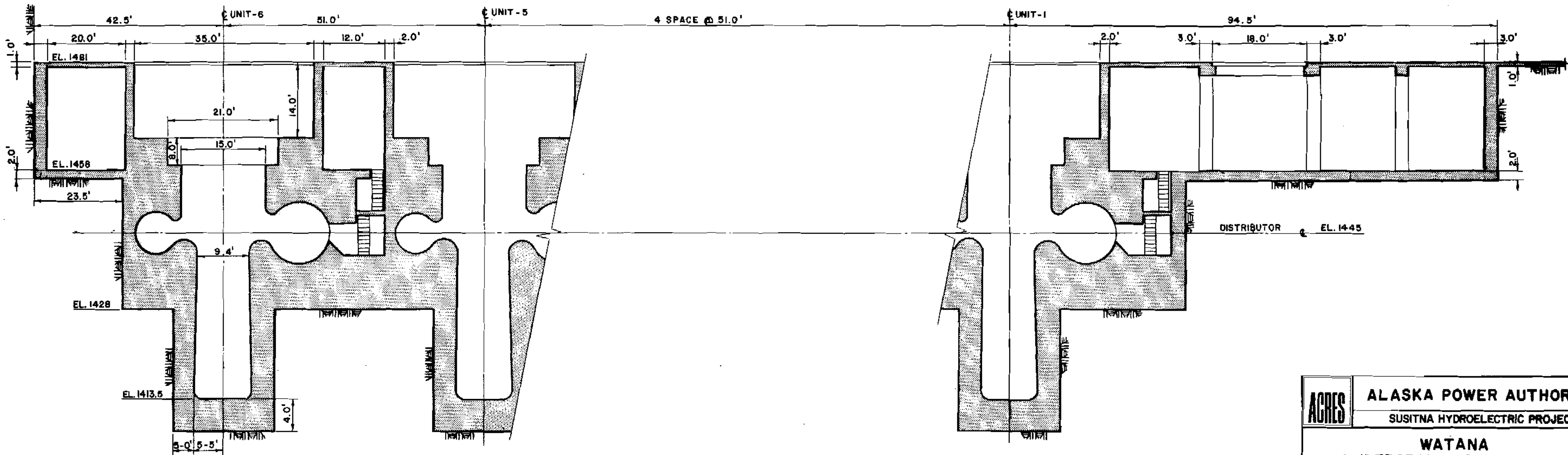
PLATE B4.8





LONGITUDINAL SECTION THRU UNITS

NOTE

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	SUSITNA HYDROELECTRIC PROJECT
WATANA UNDERGROUND POWERHOUSE 6-140 MW UNITS PLANS & SECTION	
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APPENDIX B5

ARCH DAM ANALYSIS

A concrete arch dam has been selected for the Devil Canyon site as being preferable to a rockfill dam or a concrete dam with an arch gravity cross-section on the basis of economy and proven availability of materials, as discussed in Appendix B1, "Dam Selection Studies."

This report covers the succeeding stage of the dam study and describes the development of the geometry and configuration of the main dam together with the procedure for determining the stresses within the structure. The possible loading conditions on the dam are discussed together with material properties of the concrete and the rock in the abutments. The results of the analyses are presented and their significance is assessed.

The preliminary dam configuration adopted for comparative purposes in Appendix B1 was revised through several iterative processes but only analyses based on the final geometry and established foundation conditions are discussed herein.

1 - SUMMARY

1.1 - Scope

The purpose of the study is to determine the feasibility of a concrete arch dam at Devil Canyon based on a dam configuration which will closely resemble the final design.

Stress analyses are carried out for normal and extreme loading conditions and the stability of the abutments is analysed (Attachment 1).

1.2 - Climate and Geology

The dam is founded on metamorphic rock within the unsymmetrical V-shaped canyon. The upper 60 feet of the dam extend above the canyon on the left abutment.

The moderately warm summers and cold winters within the basin subject the dam to a large range of temperatures and consequent thermally-induced stresses within the structure.

1.3 - Dam Configuration

The crest elevation of the dam is 1463 feet. Its maximum height above the foundation is 645 feet and its crest length between thrust blocks is 1260 feet. The upper arches of the dam are contained within two mass concrete thrust blocks - the left bank thrust block to provide lateral bearing and the right bank to reserve a degree of symmetry in the profile.

The crown cantilevers have a double curvature configuration and the two center geometry of the arches produces a larger radius arc on the right and flatter side of the canyon. The radii of arcs forming the downstream face of the arches are smaller than those of the upstream face and provide a thickening of the arches towards the abutments.

1.4 - Design Criteria

The design of the dam is based on a concrete strength of 5000 psi at 365 days.

The dam was analyzed for full reservoir level at Elevation 1455, and also a maximum drawdown level at Elevation 1405. Gravity and hydrostatic loadings were combined with temperature loadings and with seismic loadings. Seismic loadings were conservatively determined on the basis of a Terrain Safety Evaluation Earthquake, magnitude 6.25 at a distance of less than 6 miles from the site. The structure was designed to safely withstand this event using a response spectrum with an affective peak acceleration of 80 percent of the 80th percentile mean peak ground acceleration of approximately 0.57g.

1.5 - Method of Analysis

The arch dam was analyzed for stresses due to gravity and hydrostatic loads, as well as temperature stresses and seismically-induced upstream ground motion stresses using a computer program (ADSAS) based on the trial load method for three-dimensional structures.

Seismically-induced downstream ground motion tends to induce tensile stresses across the upper arches. However, relaxation at the vertical construction joints causes complete redistribution of the loads in the upper central part of the dam into the cantilevers.

The two-dimensional crown cantilever was analyzed by means of the SAPIV computer program.

1.6 - Results

Under normal load conditions of dam self-weight and reservoir hydrostatic pressure the dam is essentially in compression throughout its body.

Under extreme low temperature conditions the tensile stresses of up to -241 psi occur in the central part of the downstream face of the lower arches.

Under seismic loadings producing upstream ground motion acceleration of 0.5g compressive stresses of up to 3261 psi were calculated in the arches and tensile stresses of up to 623 psi in the upstream face of the cantilevers.

In the case of downstream ground motion the vertical joints were assumed to open sufficiently for transfer of stresses of up to -578 psi to occur at the downstream face of the crown cantilever.

For a mean peak spectral ground acceleration of 0.55g, the adjusted dynamic stress in the free cantilevers is calculated as 700 psi tension.

1.7 - Conclusions

The final design of the dam should not vary significantly from the design developed during this study. This design is based on the following concepts which are intrinsic to a safe, economic and efficient design:

- The double curved configuration of the central cantilevers bending downstream;
- The two-center configuration of the horizontal arches;

- The right abutment thrust block balancing that of the left abutment; and
- The broadening of the lower arches towards the abutments.

A detailed finite element analysis of the dam should be undertaken during final design. Such an analysis will generally result in lower calculated stresses than indicated using the trial load method.

Minor improvements to the design may nevertheless be desirable during the final design. These may be in the form of adjustments of arch geometry to provide an improved distribution of stresses.

The dam stresses are less than those allowable under static and dynamic loading conditions and the abutments are stable under thrusts from the dam and hydrostatic loads from the reservoir. The dam delineated by the geometry as described herein is feasible and it can be further refined by adopting the modifications already described.

2 - SCOPE

An initial study undertaken to evaluate the feasibility of an arch dam at this site concluded that future study was warranted (5).

The purpose of this study is to confirm the technical feasibility of an arch dam at Devil Canyon based on a layout which will be subject only to minor variations at the final design stage.

The design of the dam reflects the most economic and efficient structure consistent with the material properties of the concrete and foundation rock, the exposure to climatic and seismic events and the safety requirements of the project.

Included in the study is a review of the foundation conditions and requirements for foundation preparation and grouting and drainage systems. The geometry defining the shape of the arch dam is determined and analyses of the structure are carried out for normal and extreme static and dynamic loading conditions that might be experienced by the structure.

The dam design criteria are based on site characteristics and world arch dam experience. Existing rock level and foundation properties are based on aerial survey mapping, the most recent findings of the 1981-1982 field investigation, and information made available from previous studies. Seismic criteria are developed from data gathered during the Feasibility Study.

The dam foundation and abutments are discussed in Section 13 of the Feasibility Report and in Attachment 1 of this Appendix. The system for grouting and drainage outside the dam is described in Section 8 of this Appendix. The layout of galleries within the concrete and the configuration of construction joints and grouting is also discussed herein.

3 - CLIMATE AND GEOLOGY

3.1 - Topography and Geology

The dam is located at the upstream end of Devil Canyon where the valley takes the form of a steep slightly unsymmetrical V incised into the metamorphic rock of the area. The rock is generally exposed at the surface and weathered to a depth of approximately 40 feet on the abutments and 20 feet within the river. The right (north) bank of the canyon rises above the crest of the dam and has an average gradient of approximately 50° to the horizontal. On the left bank, the rock does not rise above Elevation 1400 and has an approximate slope of 60° to 65° to the horizontal. The width of the canyon is approximately 950 feet at Elevation 1400 and 50 feet at riverbed level.

The rock high on the left side exhibits open jointing up to a depth of 60 feet. Excavation and treatment of the foundation is discussed in Section 8.

3.2 - Climate and Temperatures

The warm summers and cold winters characteristic of the river basin will give a large ambient temperature range producing temperature changes and gradients within the dam which are further influenced by the reservoir. These changes give rise to stresses within the dam which must be accounted for in the analysis.

(a) Ambient Temperatures

Because of the absence of local temperature records, temperatures at the Devil Canyon site have been interpolated from 30 years of record at two stations: Summit (Elevation 2405) and Talkeetna (Elevation 345). The stations are equidistant from Watana and their average altitude is similar to river level at Watana. The temperatures from the two stations were averaged to obtain the following temperatures at the damsite:

AMBIENT AIR TEMPERATURE (°F)

Mean Annual	28.9
High Mean Monthly	55.0
Low Mean Monthly	4.4
Highest Mean Monthly Maximum	63.8
Lowest Mean Monthly Minimum	-3.6
Highest Maximum	91.0
Lowest Minimum	-48.0
Lowest Difference Between Any Mean Monthly Maximum and the Corresponding Mean Monthly Minimum	14.5

Three sinusoidal temperature cycles - annual, 15-day and daily were developed based on USBR Eng Monograph No. 34.

The temperatures obtained were as follows:

Time Period	EXTREME CONDITIONS Above Mean (°F)	Below Mean (°F)	USUAL CONDITIONS Above Mean (°F)	Below Mean (°F)
Annual	26.1	24.5	26.1	24.5
15-Day	28.8	42.2	15.2	23.0
Daily	7.3	7.3	7.3	7.3

(b) Reservoir Water Temperature

The average monthly reservoir temperatures adopted as a design basis were extrapolated from sporadic temperature measurements taken downstream at Gold Creek over a 30-year period. Initial estimates of temperatures throughout the top 50 feet of the reservoir are shown below. Temperatures below 50 feet vary linearly to 39° at a depth of 70 feet.

Month	Top 50 Feet (°F)	Below 70 Feet From Surface to (°F)
April	32	39
May	32	39
June	46	39
July	57	39
August	53	39
September	45	39
October	39	39
November	32	39
December	32	39
January	32	39
February	32	39
March	32	39

More recent studies and operating restraints imposed on the operation of the reservoir for environmental reasons indicate that the temperature in the upper part of the reservoir will also not be less than 39°. This will result in less extreme temperatures within the dam but for the purposes of this study, the more conservative temperatures, as tabulated, have been used.

4 - DAM CONFIGURATION

The V-shape of the canyon and the dense rock foundation are well suited to the construction of the arch dam below 1350 feet. 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 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 bears directly on the rock foundation over its whole length. Concrete plugs and pads as used on some dams, together with the resulting peripheral joints, have not been incorporated, thus avoiding a potential source of leakage.

The dam geometry is shown on Plates B5.1 and B5.2. The dam is a double curvature structure with the cupola 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 thick at the base. The slenderness coefficient of the arch is equal to 90/643 = 0.140, and 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 ratio of crest length to height for the dam is 1260/643 = 1.96 (thrust blocks not included).

The left bank thrust block is 113 feet high and 200 feet long at the base. The right bank thrust block has a maximum height of 113 feet and a length of 125 feet. It is adjacent to the spillway control structure which will act in conjunction with the block and transfer the thrust directly into the rock.

The dam wil be constructed in vertical lifts with vertical construction joints spaced at approximately 100 feet, which will be grouted in two or a maximum of three stages.

Typical sections through the dam are shown on Plate B5.3.

5 - DESIGN CRITERIA

5.1 - Material Properties

The properties of materials considered in both the static and dynamic analyses are given in this section.

The transient conditions induced by seismic events and considered in the dynamic analyses require an adjustment of the material properties from those corresponding to prolonged static conditions. The properties which are most affected by short-term loadings are concrete modulus and strength. The increase in concrete modulus during dynamic loading is well documented by laboratory tests (Ref. 1, 2, 3, 4) and on this basis the dynamic modulus has been increased by 67 percent over the static modulus.

The USBR has cited similar tests in which concrete compressive strengths were 20 percent to 30 percent above and tensile strengths were 30 percent to 66 percent above static values. The selection of an ultimate dynamic tensile strength was based on the assumption that the tensile stresses are transitory in nature and therefore, the modulus of rupture is an appropriate parameter. It was further assumed that the influence of rapid strain rates results in a 50 percent increase in ultimate tensile strength in flexure. Using these percentages and based on a static ultimate compressive strength of 500 psi, an ultimate tensile strength in flexure of 750 psi was selected.

From Acres' studies of concrete dams elsewhere, it has been shown that changes in the rock modulus had only a small effect on stress within the dam. Variation of modulus by a factor of 2 gave no more than a 10-percent change in internal stresses. An instantaneous rock modulus similar to the sustained modulus has been used for these studies.

Material properties are as follows:

- Unit Weight of Concrete - 150 lb/ft^3
- Unit Weight of Water - 62.4 lb/ft^3

(a) Static Properties

(i) Concrete

- Ultimate uniaxial compressive strength at 365 days .... 5000 psi
- Allowable compressive stress .... 1250 psi
- Sustained modulus of elasticity .... 3 x 10^6 psi
- Allowable tensile stress .... 325 psi
- Poisson's Ratio 0.2

(ii) Rock

- Ultimate compressive strength .... 20,000 psi (unconfined)
- Allowable compressive stress .... 5000 psi
- Static modulus of elasticity .... 2 x 10^6 psi
- Poisson's Ratio 0.2

(b) Dynamic Properties

(i) Concrete

- Uniaxial dynamic compressive strength ... 6000 psi
- Instantaneous modulus of elasticity ..... 5 x 10^6 psi
- Allowable linear rapid loading tensile strength .... 750 psi
- Poisson's ratio 0.2

(ii) Rock

- Properties assumed as for static conditions

(c) Thermal Properties

(i) Concrete

- Conductivity of concrete .... 1.52 Btu/ft/hr/°F
- Specific heat .... 0.22 Btu/lb/°F
- Coefficient of thermal expansion .... 5.6 x 10^{-6}/ft/°F
- Diffusivity ....-0.046 ft^2/hr

5.2 - General Parameters

The geometry of the dam is shown on Plates B5.1 and B5.2 and described in Section 4. General criteria are as follows:

- Normal Maximum Reservoir Operating Level .... El 1455
- Minimum Reservoir Operating Level .... El 1405
- Dam Crest Elevation .... El 1463
- Minimum Foundation Level .... El 818

Ambient and reservoir temperatures are given in Section 3.

5.3 - Loading Conditions

(a) General

The arch dam has been analyzed for both static and dynamic load conditions induced by the following:

- Static Loads

  . self weight of the dam
  . hydrostatic pressure from the reservoir
  . temperature changes
  . ice load

- Dynamic Loads Caused by Seismic Events

  . seismic shaking of the dam
  . hydrodynamic loads from the reservoir

The effects of the above loads have been analyzed individually and in various combinations as discussed in this section.

(b) Static Load Conditions

- The self-weight of the dam is assumed distributed through the individual cantilevers forming the dam. It is considered as acting vertically downwards into the foundation with no lateral distribution through the arches. This condition will only exist if the vertical joints within the dam are grouted after the placing of concrete for the structure is complete. However, the condition will be approximated if the grouting is done in no more than approximately three stages during construction.

- Hydrostatic pressure from the reservoir is considered, acting across the upstream face of the dam. Tailwater levels will have only a very small effect on the dam and they are not considered at this time. They will have to be included in the analysis for the final design of the dam.

- Temperature induced stresses are calculated for both uniform temperature distribution through the dam and for temperature differences across the dam caused by the exposure to the reservoir on one side and exposure to the air on the other.

- Ice load transmitted across the dam by the surface ice sheet has been calculated.

Deposition of silt within the reservoir is expected to be minimal and no allowance has been made in this study for silt-induced loads.

Solar radiation would generally cause some temperature rise within the dam, but as the orientation of the dam is in a north-south direction, with the sun striking it obliquely, the effect of this radiation will only be small and has been neglected at this study stage.

(c) Dynamic Load Conditions

- Seismic shaking of the dam induces vibratory motions in the dam. Stresses within the dam are governed by the horizontal ground acceleration, the frequency of the ground motion, the natural frequency of the dam and the degree of energy damping within the structural system. The magnitude of the loadings are discussed in Section 7.

- Hydrodynamic loadings caused by the reservoir acting on the dam are determined by the Westergard "added mass" approach. For the purpose of these analyses the full volume of water, as calculated by Westergard, has been assumed to move with the dam. This is a conservative approach as no allowance has been made for the shape of the dam, the cross-section of the reservoir or the compressibility of water.

5.4 - Load Combinations

Different combinations of the loads in the previous section were examined under two categories as follows:

(a) Usual Load Combination

This consists of groups of sustained loadings which can occur simultaneously over the design life of the dam.

(b) Extreme Load Combinations

This consists of combinations of sustained loads together with short-duration loads caused by seismic motion.

The usual load combinations are:

- UL1 - Dam self weight + hydrostatic load with reservoir at EL 1455;
- UL2 - Dam self weight + hydrostatic load with reservoir at EL 1405;
- UL3 - As UL1 plus extreme winter temperature effects; and
- UL4 - As UL2 plus extreme winter temperature effects.

The extreme load combinations are:

- EL1 - UL1 + extreme earthquake loading; and
- EL2 - UL2 + extreme earthquake loading;

6 - METHOD OF ANALYSIS

6.1 - Static Analysis

The arch dam is analyzed by means of the ADSAS (Arch Dam Stress Analysis Systems) program developed by the USBR. This program is based on the trial load method of analysis which divides the system into a series of vertical cantilever and horizontal arch elements. Continuity requirements are met for three types of displacement - radial, tangential, and twisting, with applied loads divided between the arches and the cantilevers. Stresses at the cantilever/arch intersections are calculated. Abutment effects are incorporated in the analysis using Vogt's equations.

The trial load method was adopted as the appropriate approach for feasibility assessment. This method has been confirmed by a history of use and by prototype measurements to confirm the accuracy of results. The available computer software offers the opportunity at the feasibility stage to examine a number of different dam geometries.

(a) Temperature Stresses

The temperature distribution throughout the dam is dependent on the ambient and reservoir temperatures and the variation of the reservoir levels and temperatures with time.

The two-dimensional heat transfer program "HEATFLOW" was used for the determination of temperature within the dam. The amplitude of annual, 15-day and daily sinusoidal cycles were calculated based on the temperatures given in Section 3.2 and as described in the USBR Engineering Monograph No. 4. These amplitudes were input into "HEATFLOW" and the temperature variations across the thickness of the dam determined. These temperatures were converted manually into a varying linear plus a uniform distribution across the dam at the nodal points. The data was input into the ADSAS program and the resulting stresses determined.

6.2 - Dynamic Analysis

The arch dam was analyzed for seismic loading using the ADSAS program. It was found that tensile stresses are induced in the arches resulting from downstream ground motion. In reality the vertical construction joints in the dam would be unable to withstand high tensile stresses and would open momentarily causing transference of load from the arches to the cantilevers. This result in a two-dimensional mechanism in the form of a series of unrestrained cantilevers over the upper half of the dam. The joint openings are extremely small and of short duration such that water will not enter the joint. Nevertheless, drainage pipes are provided in the final construction.

(a) Earthquake Magnitude

The arch dam was analyzed for the upstream and downstream horizontal ground motions under the selected Safety Evaluation Earthquake (SEE) condition. The mean response spectra for ground accelerations for the selected Terrain SEE magnitude 6.25 are shown on Figure B5.1.

(b) Damping

The degree of damping has been derived from tests on other arch dams under large excitations. The Ambiesta Arch Dam in Italy was subjected to a blast loading from the downstream side and a damping ratio of 6.5 percent was determined. A 10 percent damping ratio was calculated from tests of a 43-foot-high arch dam in Japan which demonstrated that energy losses increase as displacement of the dam become larger. A 10 percent damping ratio has been used for dynamic analysis of Swan Lake Dam in Alaska, the 750-foothigh EL Cajon Dam in Honduras and in verification of the 135-foot-high Salinas Dam in California.

In the case of Devil Canyon, the SEE loading will result in relatively large differential movements, and viscous and dryfriction damping will occur. Under these conditions, a 10 percent damping ratio is realistic.

(c) Peak Accelerations

Figure B5.1 shows mean and 80th percentile response spectra for the ground accelerations occurring at Devil Canyon under SEE conditions. The dam has been conservatively designed to withstand these ground accelerations by assuming a response spectrum scaled down from the 80th percentile spectrum by a factor of 80 percent in the design analysis. The mean peak acceleration is thus 0.57g.

The ADSAS results obtained for a mean peak acceleration of 0.5g and a damping ratio of 10 percent were appropriately adjusted for this slightly higher value.

7 - RESULTS

7.1 - Static Analysis

(a) Self Weight and Reservoir Loads

The extreme stresses at the faces of the dam for loading conditions UL1 and UL2 with reservoir levels of 1455 feet and 1045 feet, respectively are given on Tables B5.1 and B5.2. The complete stress distribution across both faces of the dam is given on Plates B5.4 and B5.5.

In both the arch and cantilever directions the entire structure is in compression and below the allowable stress of 1250 psi, except in a few isolated areas where small tensile stresses occur. The maximum tensile stress of 176 psi occurs in the arch at foundation level where the narrow width of the canyon inhibits the full development of arching action.

(b) Self Weight, Reservoir Loads, and Temperature

The maximum stresses for loading conditions UL3 and UL4, where extreme low temperature conditions are considered together with reservoir levels of 1455 feet and 1405 feet, respectively are given on Tables B5.3 and B5.4. Stress distributions across the faces are given on Plates B5.4 and B5.5.

Tensile stresses of up to 421 psi occur on the downstream face at the center of the lower arches. Slight opening of the vertical construction joints will occur over a small area at the base of the dam causing a small redistribution of the load into the vertical cantilevers. The cantilevers are only stressed up to approximately one-third of their allowable stresses in this area and are capable of accepting these minor increases in load.

7.2 - Dynamic Analyses

(a) Trial Load Method

The maximum stresses under Load Condition EL1 as determined by the ADSAS computer program and based on a reservoir Elevation 1455, and a response spectrum with a mean peak acceleration of 0.5g and 10 percent damping of the system, are shown on Tables B5.3, B5.4 and B5.5. The tables show stresses corresponding to individual and combinations of load conditions. Negative earthquake in the tabulated load combination indicates that the ground motion is in a downstream direction whereas addition of earthquake stresses indicates upstream motion. Tables B5.3 and B5.4 give corresponding horizontal arch stresses at Elevation 1370 and Elevation 1463, respectively. Table B5.5 shows stresses in the crown cantilever.

The program analyzes 14 modes of vibration with which gives the following periods:

Reservoir Elevation 1455: 0.538; 0.500; 0.364; 0.297; ... 0.127 secs,

The different vibratory modes are combined by the program to determine the extreme load combinations.

In the case of upstream ground motion, using the above design assumptions, tensile stresses of up to 623 psi were calculated at the upstream face in the upper part of the central cantilevers. Compressive stresses of up to 3261 psi would occur at the upstream face in the center portion of the upper arches. These values are below the allowable transient tensile and compressive stresses of 750 psi and 6000 psi, respectively. Adjusted values for the 0.57g acceleration case would also be within allowable limits.

An isolated shear stress of 1090 psi was encountered across the base of the cantilever half way up the right abutment. This is an isolated occurrence and could be alleviated at final design stage by excavating deeper into the abutment in this area.

In the case of downstream ground motion, tensile stresses of up to 563 psi were calculated at the downstream face in the upper portion of the central cantilevers. At the upstream face of the center portion of the upper arches, calculated tensile stresses up to 2001 psi (unadjusted) occur. At the downstream face between the crown section and the abutments, tensile stresses up to 1187 psi would occur under the assumed conditions.

The extremely high stresses indicated by the analysis are not realistic. As discovered by field observations and model tests on other projects, earthquake-induced ground movement in the downstream direction would cause the vertical construction joints at the upper part of the arch to open momentarily. The tension induced in the upper part of these arches would be relaxed and the stresses would be redistributed into a set of independent, unrestrained cantilevers deflecting freely in an upstream direction.

In order to accord more closely with actual behavior of the Devil Canyon arch dam, when subjected to strong earthquake motions, dynamic analyses on the unrestrained crown cantilever were performed using the computer program SAPIV.

Model tests on other arch dams with simulated radial construction joints, performed by "ISMES" have shown that opening of the joints took place over the top 1/3 to 1/2 (depending on the narrowness of the gorge) of the dam, while the lower part remained intact. In order to be conservative, the upper half of the crown cantilever section was adopted for this analysis. Full reservoir elevation of 1455 feet and a minimum reservoir elevation of 1405 feet were assumed as previously. For purposes of analysis, a mean peak acceleration of 0.5g was again assumed with damping assumed as 10 percent, and the calculated values adjusted for the 0.57g accleration case. The first 10 modes of vibration were analyzed.

The results of the cantilever dynamic analysis are as follows:

- The natural period for the first three modes of vibration are 0.93s, 0.25s and 0.12s. For comparison, a full height cantilever was assessed. The periods were found to be 3.62s, 0.78s and 0.33s. The stresses in the upper part of the arch in this case were smaller than in the short cantilever.

- The extreme stresses due to hydrostatic, gravity and dynamic loads (assuming 0.5g acceleration) are presented separately and in combination on Tables B5.6 and B5.7 for reservoir elevations of 1455 feet and 1405 feet, respectively. A representation of the loading conditions is shown on Figure B5.2 together with the resulting stresses at the faces of the cantilever. Maximum tensile stresses of 570 psi were calculated at the downstream face approximately 130 feet below crest level. Compressive stresses at the upstream face at this level are 770 psi.

The maximum stresses in the case of reservoir drawdown at Elevation 1405 are 578 psi tension at the downstream face and 778 psi compression at the upstream face approximately 130 feet below crest level. These stresses are within allowable limits. Adjusted values for an acceleration of 0.57g would also be within the same limits.

8 - FOUNDATION TREATMENT

8.1 - Excavation

(a) Excavation for Dam

The dam foundation will be excavated to sound rock over its whole area except in the vicinity of certain narrow shear zones. It will be further trimmed to provide a smooth profile, thus avoiding any abrupt changes of grade and corresponding stress concentrations within the structure and the foundation.

Generally, the rock is only lightly weathered to fresh at the surface. However, shear zones which trend in the N-S direction across the valley, are weathered to 200 feet or more where weathering is limited to iron staining or other features which do not substantially effect the compressibility and permeability of the rock mass will not be excavated. The depth of excavation and what is considered as sound rock will also depend on the spacing of the shear and fracture zones. Where the shears are widely spaced, dental excavation of the weathered material and replacement with concrete will be sufficient; but where the zones are closely spaced, general excavation down to better quality rock may be required. Detached blocks of rock will be removed or rock bolted and/or grouted. Rock overhangs will be trimmed and a regular surface formed against which the concrete of the dam may be placed. Weathered rock at depth which is not practical or economic to remove will be treated by grouting.

One particular area of open jointing to considerable depth has been observed on the left bank and is discussed later under "Thrust Blocks". The open joints form detached blocks and it is unlikely that these can be stabilized sufficiently to be acceptable for the dam foundation. Removal of this rock is allowed, for, however, excavation should be kept to a minimum to avoid increasing the height of the thrust block and span of the arch dam.

(b) Excavation for Thrust Blocks

The excavation must be carried down to sound rock. The rock foundation should have a low compressibility and the location of the dam should be such that the thrust blocks are founded on areas free from major shears and severe jointing.

(i) Left Thrust Block

The left thrust block is in an area of severe open jointing at Elevation 1400. The joints strike in a NW direction (major Joint Set I) and are open by as much as 2 feet. The extent of jointing has not been proven but the joints are expected to be open down to 50 to 60 feet in depth. There is evidence of open jointing 350 feet below at Elevation 1050 on the valley wall which may be the same joint system. Further investigation borings are required in this area to determine the full extent of these joints and other possible discontinuities. The open jointed rock will be excavated down to a depth where the joints are tight or where joints can be treated by grouting. Since the trend of the jointing is almost perpendicular to the direction of thrust, it will not give rise to stability problems.

There is an open joint system downstream of the thrust block striking parallel to the river, Joint Set II but this is located on the River side of the thrust block and should not cause instability.

(ii) Right Thrust Block

The jointing in this area does not present any particularly unfavorable condition, except possibly for minor Joint Set IV which is dipping at a shallow angle towards the river. Since the excavation for the spillway is adjacent to the thrust block, the majority of the thrust will be transmitted in shear to the rock foundation. This joint set could be a potential shear failure surface. Rock anchors may be required to ensure that the load is transfered to rock at depth and that excessive lateral load does not develop against the spillway gate structure.

8.2 - Grouting

The grouting reduces both the permeability and deformability of the rock.

An effective barrier to seepage under and around the dam must be formed and since the potential flow path will be over the short distance of the relatively thin concrete arch, it is essential that the grouting be thorough.

(a) Consolidation Grouting

Consolidation grouting from the surface over the whole area of the dam foundation is required and will extend 100 feet upstream and downstream of the dam. The consolidation grouting assists in forming a cap for the higher pressure curtain grouting. The consolidation holes will be at 10 feet spacings each way with depth ranging from 30 to 70 feet depending on local conditions. The orientation of the consolidation holes should be such that they intersect as many discontinuities as possible. The holes will generally be normal to the rock surface but to some extent will be controlled by access to the steep rock walls of the valley.

(b) Curtain Grouting

The rock at depth at the Devil Canyon site is classified as "very good" to "excellent". The average RQD from all boreholes in this area is about 80 percent. The average permeability of the rock mass, determined from borehole water pressure tests, is less than $1x10^{-5}$ cm/s below 175 feet in depth. Near the surface, the average permeability is $1x10^{-4}$. The seepage in the rock is controlled by the larger joints and shears. It is expected that some areas of the grout curtain will have little or no grout take, whereas the grout holes which intersect the more open joints and shears will take the majority of the grout.

The extent of the grout curtain is indicated on Plate 51. The depth of the holes is to be 0.7xH where H is the maximum head of water at that particular point on the foundation, up to a maximum of 300 feet. This limitation on depth is based on the following considerations.

At this depth, the average permeability is about $5x10^{-6}$ cm/sec which is an acceptable permeability below which treatment would be of little value. The potential flow path under the dam would be about 700 feet giving an average hydraulic gradient of approximately 1.0. When this is considered in combination with the drainage curtain, the downstream gradients will be reduced further.

On the right bank, the grout curtain is to extend under the thurst block and spillway gate structure and beyond the powerhouse. The curtain will be a minimum of 200 feet deep in this area to ensure seepage into the powerhouse cavern area is minimized. The excavation for the intake structure is 100 feet deeper than the base of the thrust block at this point. The grout curtain will extend 100 feet deeper than the intake excavation.

A two-row grout curtain will be constructed using the split-spacing method with primary holes at 40 feet spacing. Use of secondary, tertiary, and quaternary holes will bring the spacing to 5 feet if required. The spacing between rows will be 5 feet with the holes staggered.

The grouting will be performed from galleries, the general arrangement of which is shown on Plate 51 (Volume 3).

8.3 - Drainage

Drainage is required in the rock downstream of the dam to reduce water pressure under the dam foundation and in the abutments. High interstitial water pressures might otherwise lead to instability.

The grout galleries will also be used for drainage with radiating drainage holes 3 inches in diameter.

The drainage holes will be downstream of the grout curtain and generally extend 50 feet deeper than the grout holes. The spacing should be selected to ensure that the maximum number of discontinuities are intersected and is expected to be approximately 10 feet. Extra holes may be required in shear zones and in possible failure planes such as discussed under dam stability.

Free drainage of the lowest grouting/drainage gallery is not possible. It would be undesirable for the gallery to be allowed to flood since this would reduce the effectiveness of the drainage and also prohibit access for inspection. Pumps will be provided to dewater the lowest gallery when required.

Drainage of the gallery system will be by gravity along outlet tunnels just above tailwater level. The outlet tunnels will discharge into the river downstream of the dam. The discharge will be below water level to prevent blockage of the outlet by ice.

9 - CONCLUSIONS

On the basis of the design criteria adopted, present knowledge of foundation conditions at the site and the foregoing analyses, the following conclusions can be made.

9.1 - Arch Dam Configuration

The arch dam defined by the geometry developed as part of this study will approximate very closely to the final design. Several concepts adopted in determining the geometry are intrinsic to a safe, economic and efficient design. The most significant of these are:

- The curved configuration of the central cantilevers resulting in an overhanging crest downstream offsets the tendency of the cantilever to warp in an upstream direction caused by support of the cantilever from the upper arches. A further benefit of the vertically curved upstream face is the undercutting at the base of the cantilever which alleviates the build-up of tensile stresses at the upstream heel of the dam.

- The two center configuration of the horizontal arches, with the arches on the wider side of the canyon circumscribed by arcs of larger radius, largely offsets the effects of the assymetry of the canyon. The thrusts from the arches and thrust block at the wider left abutment are transmitted more normally to the original rock surface and a more uniform distribution of stresses is created across the dam faces.

- The inclusion of a thrust block on the right abutment to improve the symmetry of the profile produces a more uniform distribution of arch stresses.

- The downstream faces of the middle and lower level arches are formed by arcs of smaller radii than those defining the upstream face. This results in a wider distribution of the thrust into the abutments and consequently reduces stresses at the rock/concrete interface and within the rock. It also produces a smooth stress gradient along the arches.

- As a result of the reduced abutment stresses concrete "pads" are not required.

In spite of the above, the following minor amendments could be made during final design:

- A slight increase in the rise of the lower arches; and

- A slight deepening of the excavation into the rock half way up the right abutment in order to reduce the shear stress at this location.

9.2 - Static Loading Conditions

Under the effects of its self weight and the upstream loading from the reservoir, the maximum compressive stresses in the dam would be approximately 830 psi, two-thirds of the stress allowable. In an isolated area on the downstream face of the dam, the arch tensile stress was calculated as 176 psi which may cause a slight local opening of the vertical construction joints. The arch stresses are distributed symmetrically across the dam.

Under the additional influence of low winter temperature, tensile stresses would develop on the downstream face of the lower arches. These were indicated by the analysis to be as high as 421 psi. In reality, the vertical joints would relax, thus redistributing the load into the cantilevers. The cantilevers in this area would only be lightly loaded and could readily accommodate the minor stress adjustments involved.

From the analyses, the stresses occurring under self weight, hydrostatic and temperature loadings would be well within the allowable stresses for the concrete, except for the central area of the downstream face of the lower arches. In this area, relaxation of the vertical construction joints would occur with a minor redistribution of the stresses into the vertical cantilevers which would not be heavily loaded at this point.

No problems are anticipated in the dam under static loading conditions.

9.3 - Dynamic Loading Conditions

The Safety Evaluation Earthquake induced upstream ground motion would cause compressive stresses within the arches up to a maximum of approximately 3300 psi, well below the allowable stress of 6000 psi. Tensile stresses induced in the upstream face of the crown cantilever would be up to approximately 620 psi, below the allowable transient tensile stress of 750 psi.

Downstream ground motion would result in relaxation of the vertical construction joints and the development of a system of free cantilevers in the upper half of the dam. Under an assumed mean peak acceleration of 0.5g, tensile stresses of 578 psi would occur at the downstream face, less than the 750 psi allowable. For a mean peak acceleration of 0.57g, the maximum tensile stress would increase to almost 700 psi, which is still within the allowable limit.

9.4 - Conclusions

Stresses occurring within the dam are below those allowable and based on a design strength concrete of 5000 psi and known foundation conditions, the arch dam is feasible.

The analyses carried out are based on conservative methodology and it is not anticipated that stresses will be as high as indicated under the given load conditions for the following reasons:

- The linear elastic analyses employed do not accurately represent the stress distribution across the thickness of the dam. In practice, there will be a rounding off of the stresses giving lower extreme stresses at the dam faces.

- In calculating hydrodynamic loads using "Westergard's" equations, no account is taken of the effect of the shape of the canyon or of the dam. These considerations would serve to "stabilize" the dam cantilevers during upstream ground motion.

- In analysis of the free cantilevers, no account is taken of the fact that the cyclical motion of the cantilever is restrained by the arches on the downstream side. They are prevented from acting freely and hence their displacement amplitude is reduced.

- The seismic design response spectrum gives a conservative form of analysis with no direct account taken of the duration of the peak acceleration nor the events leading up to and following this peak. At final design stage, a more thorough understanding of the behavior of mechanism of the structure during seismic events will be obtained from a finite element time history analysis where the pattern of the complete event and the effects of duration and displacement will be accounted for.

Under normal loading conditions, the gravity and hydrostatic loadings produce compressive forces throughout the dam creating an extremely stable structure.

Under short, almost instantaneous loadings, occasioned by cyclical seismic ground motion, relative displacements across the dam are small and would not produce a collapse mechanism even if cracking were widespread and extended through the entire cross section of the dam.

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4. Kramer, M.A., "Analysis and Automatic Design of Gravity Dams", Bureau of Reclamation, Division of Design, Denver, Colorado, November 1973.

5. Acres American Incorporated, Evaluation of Arch Dam at Devil Canyon Site, for Alaska Power Authority, August 1981.

TABLE B5.1: EXTREME STRESSES AT ROCK INTERFACE*

(Loading Combination Stresses in PSI)

	UL-1	UL-2
ARCH:		
Maximum	666 (D El. 1200)	532 (D El. 1100)
Minimum	-176 (D El. 900)	-152 (D El. 900)
CANTILEVER:		
Maximum	724 (D El. 820)	747 (U El. 820)
Minimum	- 13 (D El. 1370)	- 32 (U El. 1285)
PRINCIPAL:		
Maximum	838 (D El. 1100)	747 (U El. 820)
Minimum	-177 (D El. 900)	-152 (U El. 1200)

* - indicates tension
D - indicates downstream face
U - indicates upstream face

MAXIMUM STRESSES IN DAM ABOVE FOUNDATION

	UL-1	UL-2
ARCH:		
Maximum	819 (U El. 1200)	675 (U El. 1100)
Minimum	- 37 (D El. 1000)	- 27 (D El. 1000)
CANTILEVER:		
Maximum	713 (D El. 1000)	638 (D El. 1000)
Minimum	- 2 (D El. 1370)	- 6 (D El. 1370)

TABLE B5.2: EXTREME STRESSES ALONG ROCK/CONCRETE INTERFACE

Loading Combination

	UL-3	UL-4
ARCH:		
Maximum	525 (U El. 900)	436 (D El. 1100)
Minimum	-421 (D El. 900)	-397 (D El. 900)
CANTILEVER:		
Maximum	793 (D El. 820)	816 (U El. 820)
Minimum	-156 (D El. 1370)	-140 (U El. 1285)

EXTREME MAGNITUDES OF STRESSES IN DAM ABOVE FOUNDATION

Loading Combination

	UL-3	UL-4
ARCH:		
Maximum	1119 (U El. 1370)	891 (U El. 1200)
Minimum	-346 (D El. 1000)	-337 (D El. 1000)
CANTILEVER:		
Maximum	596 (D El. 1000)	524 (D El. 1000)
Minimum	- 86 (D El. 1370)	- 32 (D El. 1370)

TABLE B5.3: RESULTANT ARCH STRESSES AT ELEVATION 1370 FOR COMBINATIONS OF STATIC AND EARTHQUAKE LOADS

Reservoir Elevation 1455 feet
Response Spectrum Ag = 0.5g and Damp 10 Percent

Elevation	Face	Hydrostatic + Gravity	Earthquake	Hydrostatic + Gravity + Earth	Hydrostatic + Gravity - Earth	Hydrostatic + Gravity + Temp.	Hydrostatic + Gravity + Temp. + Earth	Hydrostatic + Gravity + Temp. - Earth
Crown	U	630	2631	3261	-2001	1097	3728	-1539
1038	D	219	63	282	156	- 63	0	- 126
1111	U	656	2514	3170	-1858	1119	3633	-1395
	D	210	239	449	- 29	- 68	171	- 307
1203	U	577	1690	2267	-1113	1008	2698	- 682
	D	291	1025	1316	- 734	33	1058	- 992
1360	U	359	682	1041	- 323	710	1392	28
	D	429	1616	2045	-1187	184	1800	-1432
1497	U	230	422	652	- 192	514	936	92
	D	421	1440	1861	-1019	156	1596	-1284
1600	U	149	469	618	- 320	349	818	- 120
	D	387	1172	1559	- 785	148	1320	-1024
Abutment	U	101	795	896	- 694	187	982	- 608
1674	D	353	746	1099	- 393	197	943	- 549

TABLE B5.4: RESULTANT ARCH STRESSES AT ELEVATION 1463 FOR COMBINATIONS OF STATIC AND EARTHQUAKE LOADS

Reservoir Elevation 1455 feet
Response Spectrum Ag = 0.5g and Damp 10 Percent

Elevation	Face	Hydrostatic + Gravity	Earthquake	Hydrostatic + Gravity + Earth	Hydrostatic + Gravity - Earth	Hydrostatic + Gravity + Temp.	Hydrostatic + Gravity + Temp. + Earth	Hydrostatic + Gravity + Temp. - Earth
Crown	U	437	2336	2773	-1899	321	2657	-2015
1038	D	274	909	1183	- 635	74	983	- 836
1111	U	464	2324	2788	-1860	348	2672	-1976
	D	274	1007	1281	- 733	- 75	1082	- 932
1203	U	451	1850	2301	-1399	332	2182	-1518
	D	306	1492	1798	-1186	123	1615	-1369
1360	U	377	1392	1769	-1015	249	1641	-1143
	D	387	1890	2277	-1503	237	2127	-1653
1497	U	303	1189	1492	- 886	136	1325	-1053
	D	379	1700	2079	-1321	190	1890	-1510
1600	U	241	901	1142	- 660	- 30	871	- 931
	D	331	1481	1812	-1150	90	1571	-1391
1674	U	233	1185	1418	- 952	- 55	1130	-1240
	D	330	1259	1589	- 929	70	1329	-1189
Abutment	U	270	1333	2103	-1563	- 43	1790	-1876
1719	D	359	1070	1429	- 711	199	1269	- 871

TABLE B5.5: RESULTANT CROWN CANTILEVER STRESSES FOR COMBINATIONS OF STATIC AND EARTHQUAKE LOADS

Reservoir Elevation 1455 feet
Response Spectrum Ag = 0.5g and Damp 10 Percent

Elevation	Face	Hydrostatic + Gravity	Earthquake	Hydrostatic + Gravity + Earth	Hydrostatic + Gravity - Earth	Hydrostatic + Gravity + Temp.	Hydrostatic + Gravity + Temp. + Earth	Hydrostatic + Gravity + Temp. - Earth
1463	U	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	0
1370	U	99	-711	- 612	810	118	- 593	829
	D	79	642	721	- 563	63	705	- 579
1285	U	65	-688	- 623	753	136	- 552	824
	D	269	670	939	- 401	200	870	- 470
1200	U	10	-545	- 535	555	118	- 427	663
	D	480	556	1036	- 76	370	926	- 186
1100	U	6	-468	- 462	474	127	- 341	595
	D	656	498	1154	158	527	1025	29
1000	U	95	-489	- 394	584	201	- 288	690
	D	713	539	1252	174	596	1135	57
900	U	396	-535	- 139	931	474	61	1009
	D	550	597	1147	- 47	462	-1059	- 135
820	U	724	-359	365	1083	793	434	1151
	D	345	400	745	- 55	269	669	- 131

TABLE B5.6: SINGLE CANTILEVER DYNAMIC ANALYSIS (RES. ELEVATION 1455 FEET)

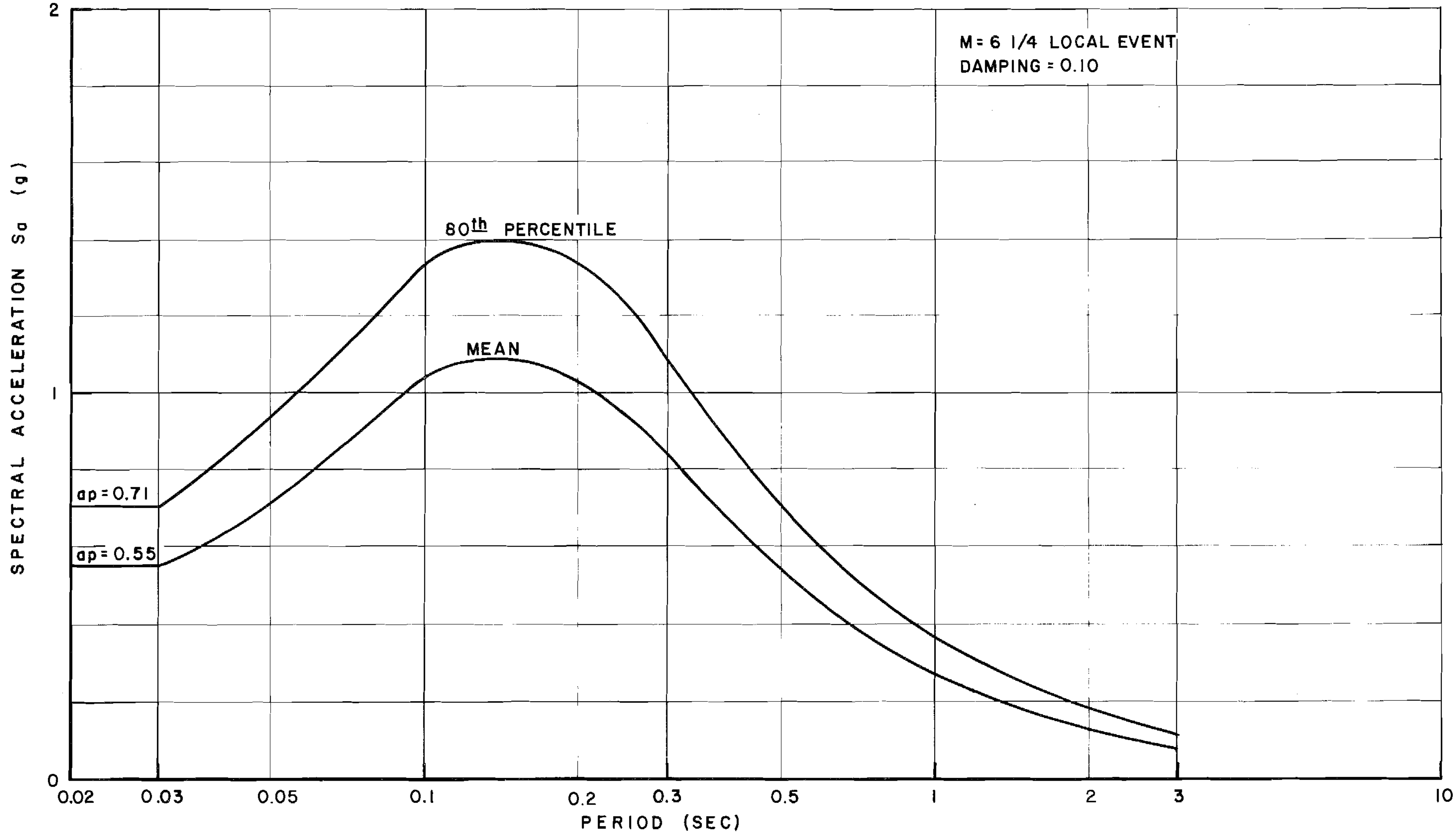
0.5g ground acceleration and 10 Percent Damping

Node	Elevation	Stresses Due to Static Loads (dead load + hydraulics) psi		Stresses Due to Earthquake Loads psi		Total Stresses psi	
		Upstream Face	Downstream Face	Upstream Face	Downstream Face	Upstream Face	Downstream Face
1	1463	0	0	0	0	0	0
2	1416	- 114	190	435	- 435	321	-245
3	1370	- 198	338	890	- 890	692	-552
4	1327	- 320	520	1090	-1090	770	-570
5	1285	- 666	930	1180	-1180	514	-250
6	1243	- 952	1278	1320	-1320	368	- 42
7	1200	-1468	1858	1580	-1580	112	278
8	1151	-1957	2423	2040	-2040	83	383

TABLE B5.7: SINGLE CANTILEVER DYNAMIC ANALYSIS (RES. ELEVATION 1405 FEET)

0.5g and 10 Percent Damping

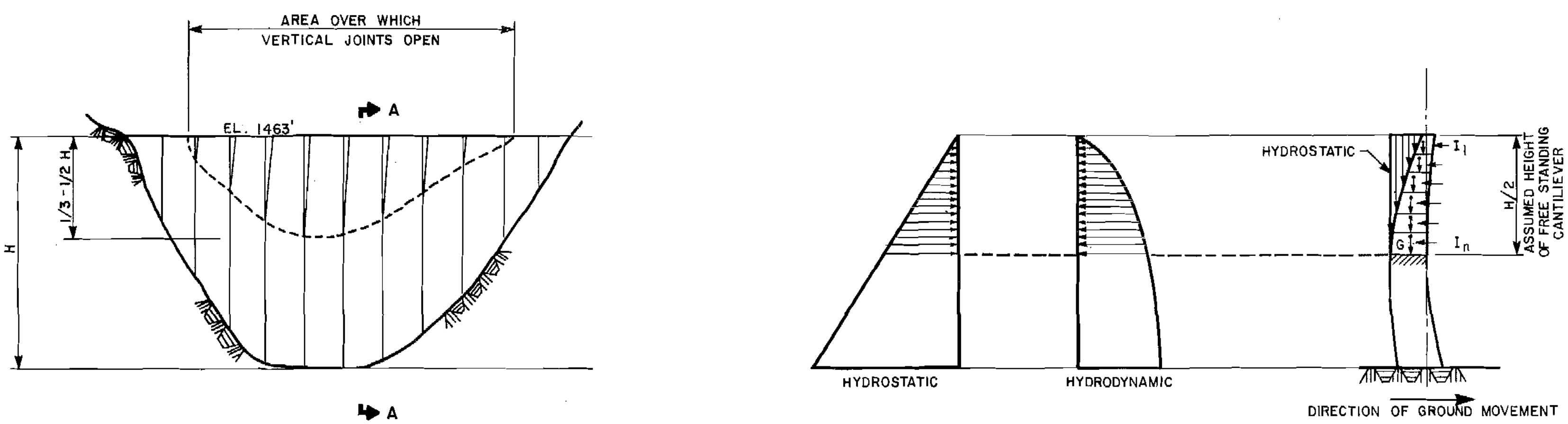
Node	Elevation	Stresses Due to Static Loads (dead load + hydraulics) psi		Stresses Due to Earthquake Loads psi		Total Stresses psi	
		Upstream Face	Downstream Face	Upstream Face	Downstream Face	Upstream Face	Downstream Face
1	1463	0	0	0	0	0	0
2	1416	- 14	90	467	- 467	453	-377
3	1370	- 108	248	770	- 770	662	-522
4	1327	- 162	362	940	- 940	778	-578
5	1285	- 351	615	1065	-1065	714	-450
6	1243	- 533	859	1285	-1285	752	-426
7	1200	- 893	1283	1560	-1560	667	-277
8	1151	-1232	1698	2000	-2000	768	-302



MEAN RESPONSE SPECTRA AT THE DEVIL CANYON SITE FOR SAFETY EVALUATION EARTHQUAKE

ACRES

FIGURE B5.1



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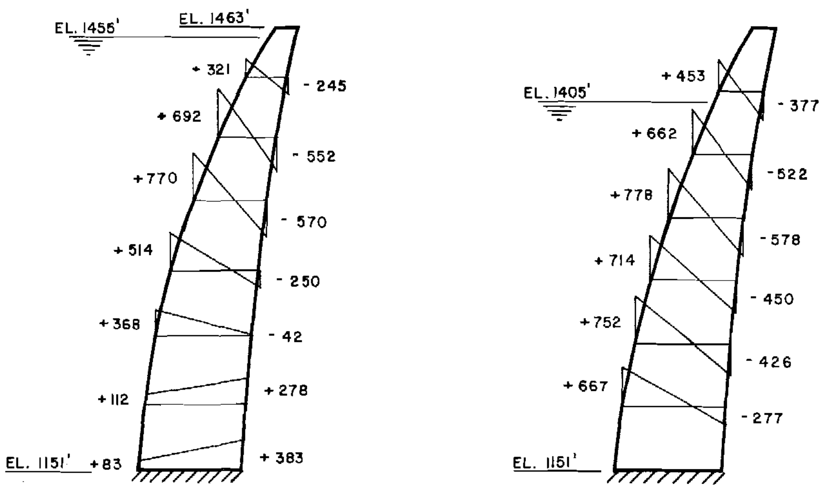


UNRESTRAINED CANTILEVER STRESSES (PSI)
SECTION A-A

NOTES:
- – (MINUS) INDICATES TENSILE STRESS.
- + (PLUS) INDICATES COMPRESSIVE STRESS.

DEVIL CANYON ARCH DAM DYNAMIC ANALYSIS
(ACCELERATION 0.5 G, DAMPING 10%)

FIGURE B 5.2

ACRES

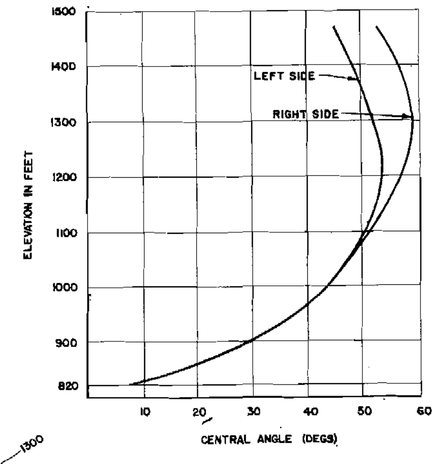
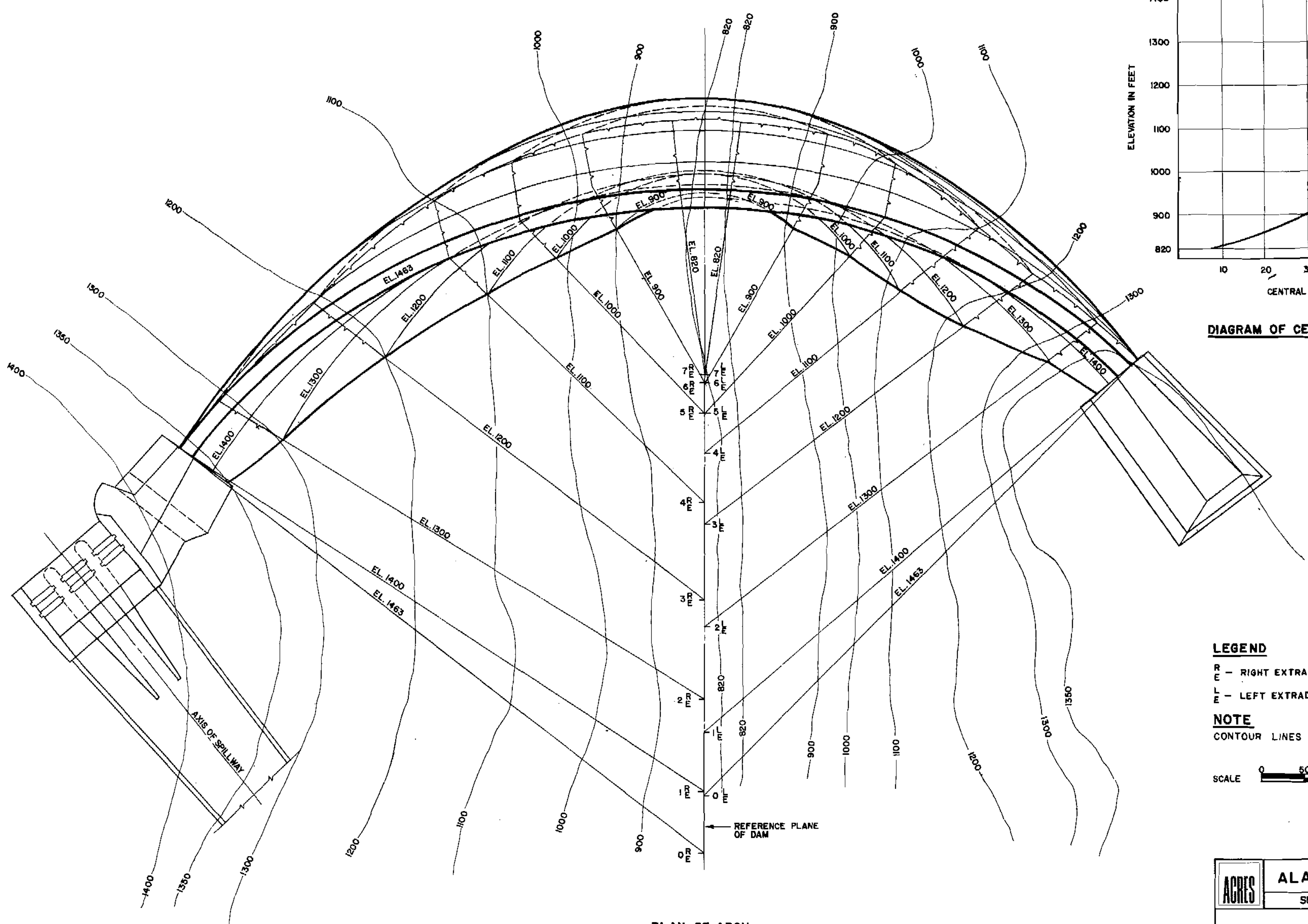


DIAGRAM OF CENTRAL ANGLES



PLAN OF ARCH

LEGEND

R/E – RIGHT EXTRADOS

L/E – LEFT EXTRADOS

NOTE

CONTOUR LINES SHOW SOUND ROCK

SCALE 0 50 100 FEET

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ALASKA POWER AUTHORITY

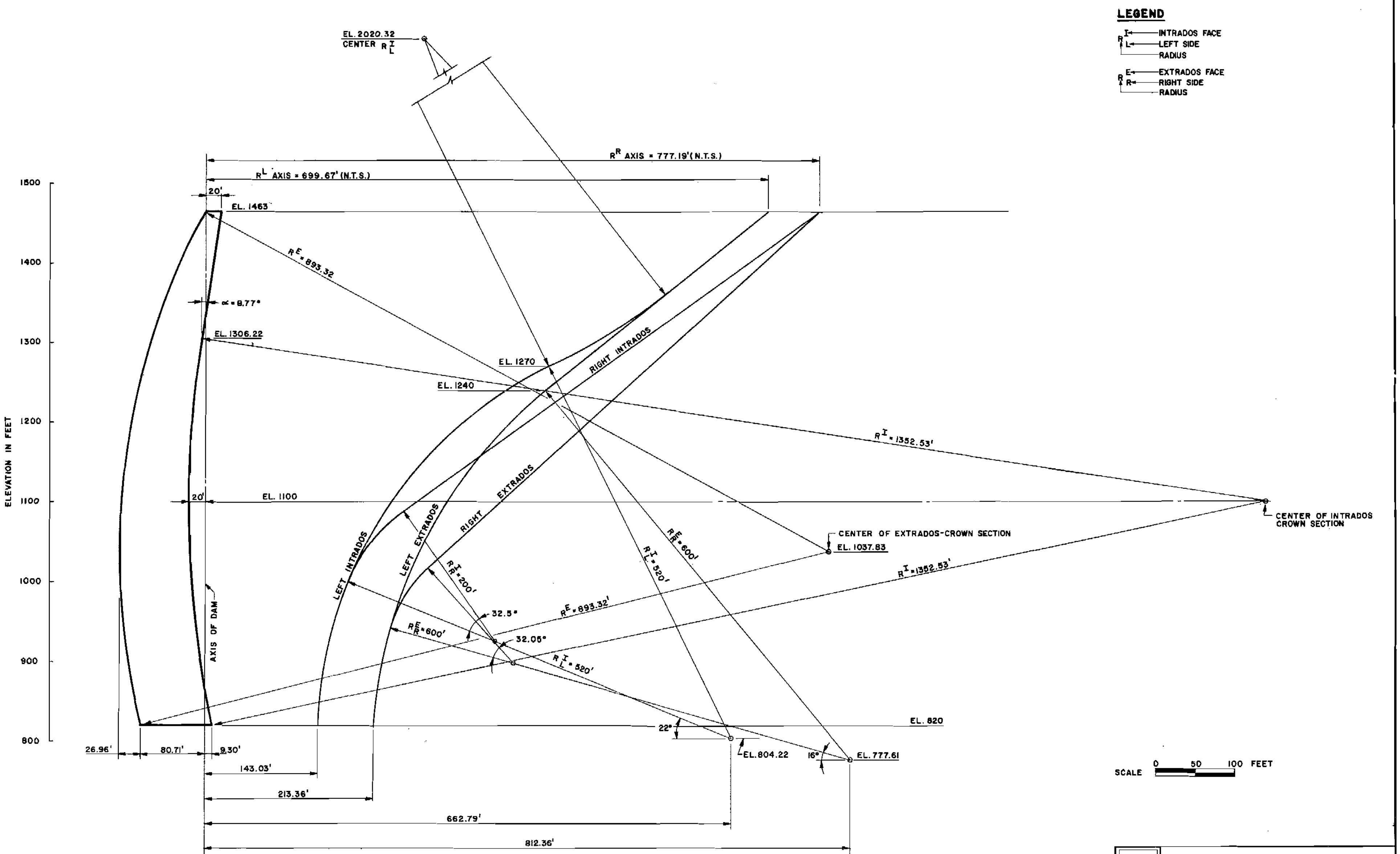
SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON
ARCH DAM
GEOMETRY-SHEET I

ACRES AMERICAN INCORPORATED

MARCH 1982

PLATE B5.I



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ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON
ARCH DAM
GEOMETRY-SHEET 2

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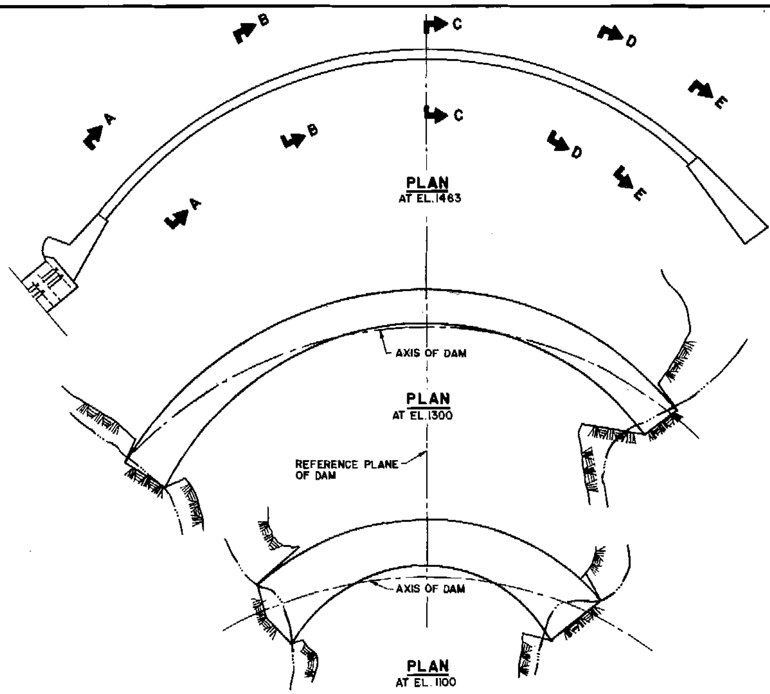
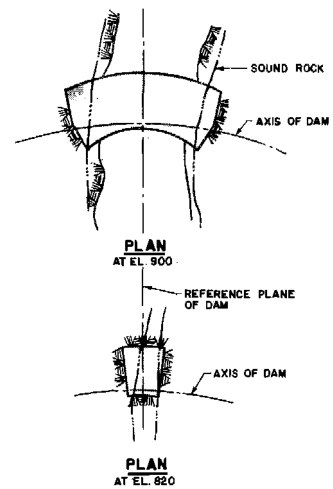
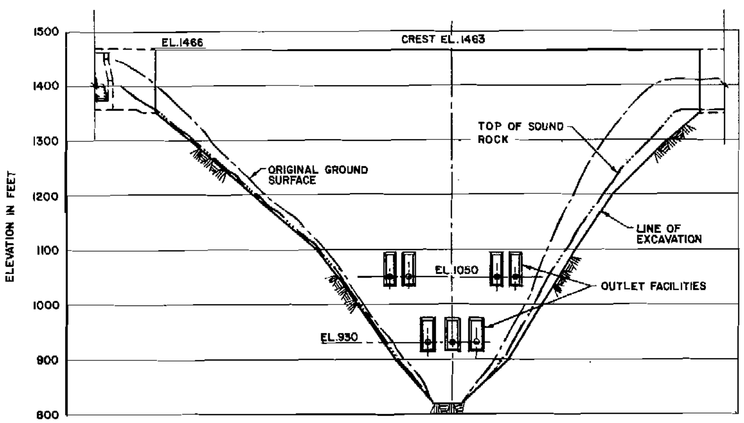
MARCH 1982

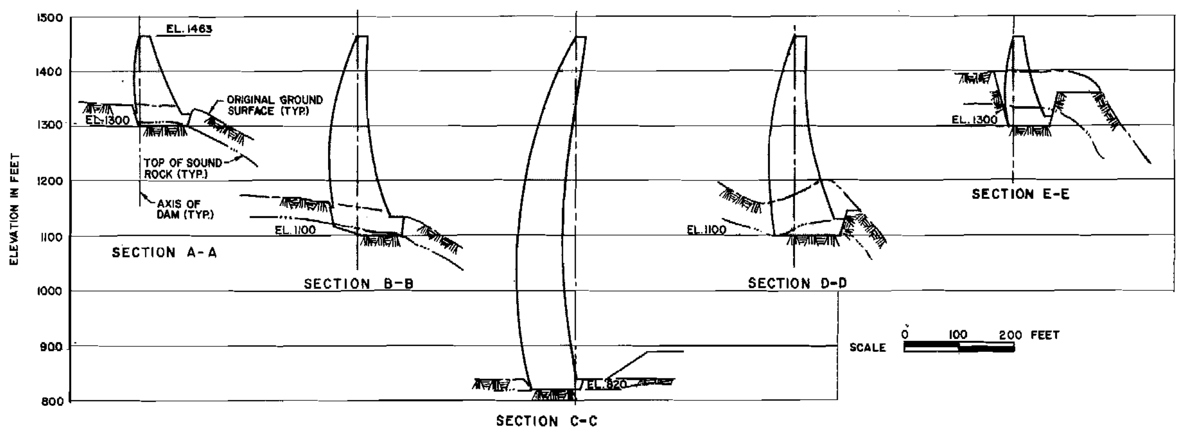
PLATE B5.2







DAM PROFILE



DAM SECTIONS

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ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON
ARCH DAM
SECTIONS

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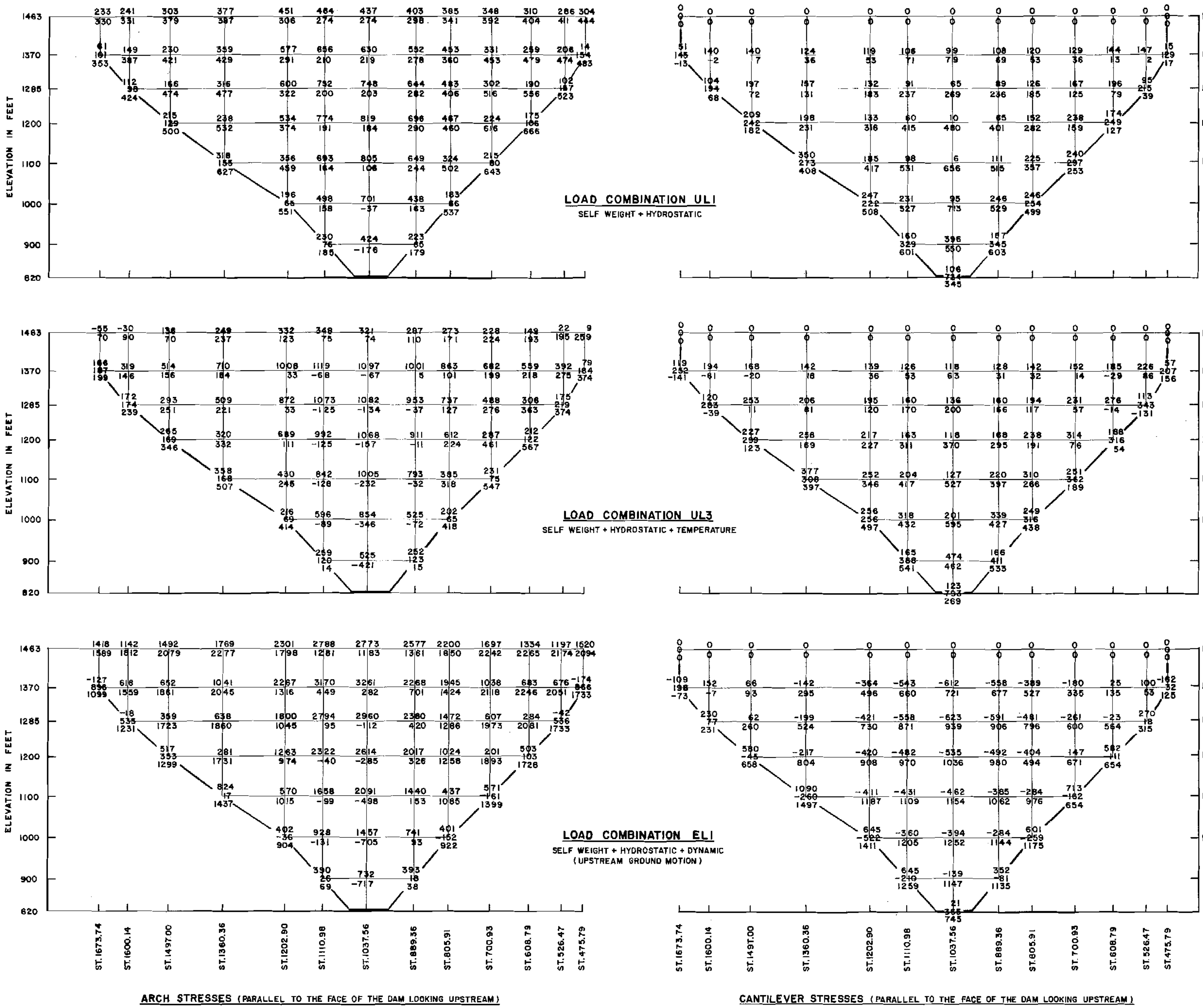
PLATE B53



LEGEND

– (MINUS) INDICATES TENSION

SHEAR STRESS IN P.S.I. WHERE SHOWN

STRESS AT UPSTREAM OR EXTRADOS FACE

STRESS AT DOWNSTREAM OR INTRADOS FACE

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ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON ARCH DAM STRESSES RESERVOIR AT EL. 1455

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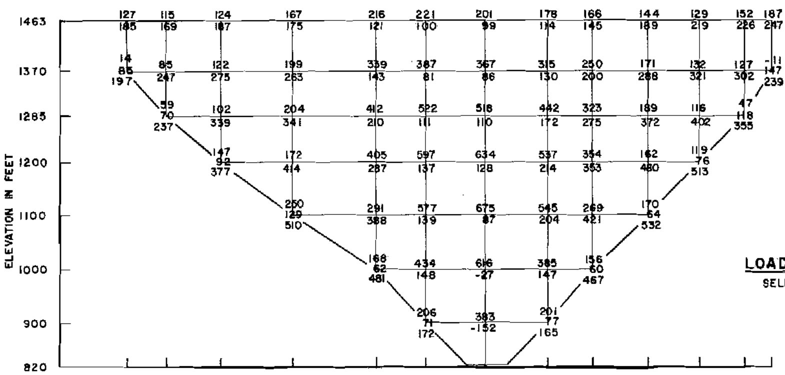
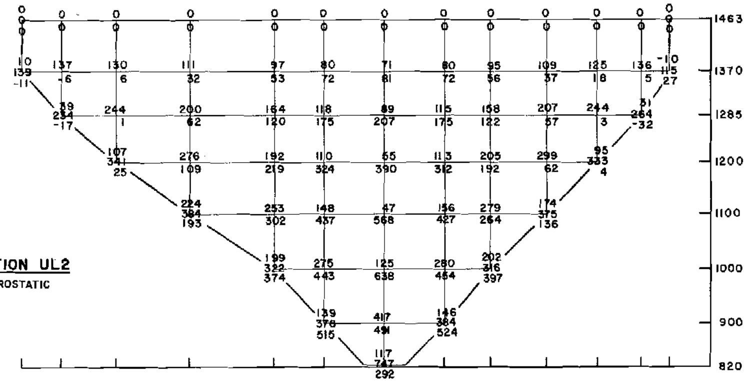
MARCH 1982

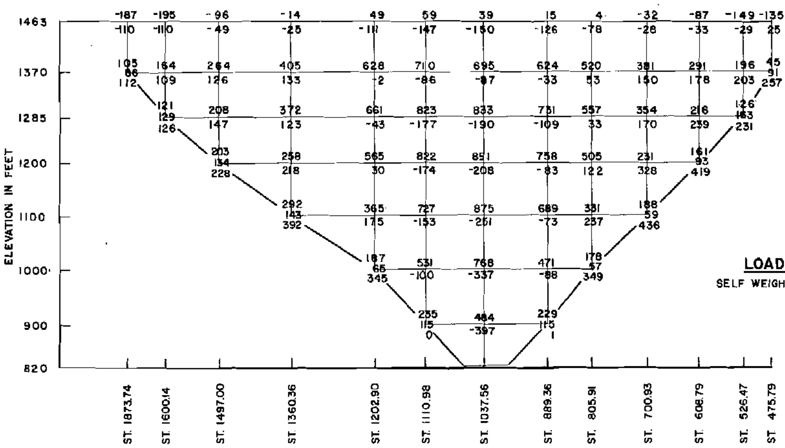
PLATE B5.4

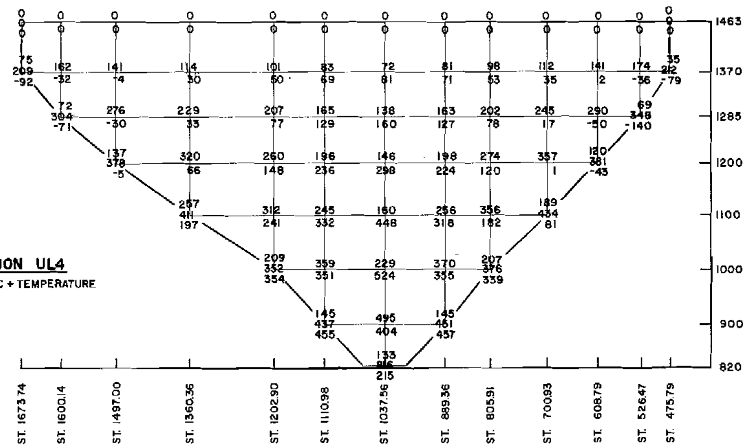




LOAD COMBINATION UL2

SELF WEIGHT + HYDROSTATIC





LOAD COMBINATION UL4

SELF WEIGHT + HYDROSTATIC + TEMPERATURE

ARCH STRESSES (PARALLEL TO THE FACE OF THE DAM LOOKING UPSTREAM)

CANTILEVER STRESSES (PARALLEL TO THE FACE OF THE DAM LOOKING UPSTREAM)

LEGEND

- — (MINUS) INDICATES TENSION
- 590 — SHEAR STRESS IN P.S.I. WHERE SHOWN
- 45 — STRESS AT UPSTREAM OR EXTRADOS FACE
- 658 — STRESS AT DOWNSTREAM OR INTRADOS FACE

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SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON
ARCH DAM
STRESSES
RESERVOIR AT EL. 1405

ACRES AMERICAN INCORPORATED | MARCH 1982 | PLATE B5.5

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ATTACHMENT 1
DEVIL CANYON DAM ABUTMENT STABILITY ANALYSIS

1 - GENERAL

The stability analysis for Devil Canyon abutments was carried out in two phases:

- Preliminary graphical analysis of existing stereographic plots to identify potential failure modes; and

- More detailed analyses on geometrically definable wedge shapes using computer methods.

The sources of geological information for preliminary analysis were:

- South Abutment: Stereographic Polar plot, Joint Station DCJ-1
- North Abutment: Stereographic Polar plot, Joint Station DCJ-2

This information was gathered at locations closest to the proposed foundations. However, as the number of actual joint measurements at each location was limited (93 and 100 measurements, respectively), subsequent analysis was based on the information given in Table 7.1, "Devil Canyon Joint Characteristics", 1980-81 Geotechnical Report, and the likelihood of formation of significant loose wedges assessed in the light of the stated descriptions.

The information was collected from surface mapping at discrete locations, and while it provides definite trends in terms of the orientation and dip of the discontinuities within the rock mass, their continuity is unknown. For the purposes of initial analysis, the joint sets were assumed planar and continuous. This is conservative in that cohesion was assumed to be zero and the natural interlocking of joints was neglected.

2 - GRAPHICAL ASSESSMENT

2.1 - South Abutment

Stereoplot DCJ-1 defined the following significant (greater than 3 percent) joint orientations:

Set	Dip Direction	Dip
IA	070	88°-80°
B	250	88°-80°
II	150°	60°
III	300°	78°
IVA	077°	23°
IVB	330°	38°

Considering the south bank to comprise a foundation slope trending on an east-west strike, and dipping to the north, graphical analysis was carried out on the stereoplot to define potential failure mechanisms in the manner described by Hoek and Bray. The following preliminary conclusions from the analysis could be drawn.

Set II dipping SE into the slope face offered no mechanism for failure (overturning on minor foundation excavations striking 070-250 could be ruled out due to the shallow nature of its dip range).

Set IVB offered potential for plane failure but again in the context of foundation excavations striking 240-060, rather than the general trend of the valley slope from 270-090, as little scatter was indicated in the polor concentration.

The Joint Sets I, III and IV were then examined in combination to identify intersections capable of posing potential problems in the form of two plane sliding wedges. Table B5.8 summarizes the potential sliding wedges for the south bank of the gorge.

Each potential wedge was assessed for sliding failure, according to the methods of Hoek and Bray, and assigned a factor of safety, utilizing a conservative value for friction angle of 23°. These values were utilized to assess combinations suitable for further study.

Combinations F and G (Sets III-IVA, and IVA-IVB) were eliminated, as it was considered that friction would exceed 20° in all cases, and thus sliding on plunge angles of 14° and 20° would appear unlikely.

All combinations A-E merit further consideration, and will be considered for further analysis in Section 3.3.

2.2 - North Abutment

Stereoplot DCJ-2 defined the following significant (greater than 3 percent) joint orientations:

Set	Dip Direction	Dip
IA	066	80
IB	246	88-80
II	168	70
III	Not present	
IVA	060	25
IVB	340	30
IVC	150	22

Graphical analysis was carried out in a similar manner to that carried out on stereplot DCJ-1, but in this instance, considering an east-west striking slope dipping to the south.

Sets IVA and IVB were eliminated from consideration as they dipped into the slope and the shallow nature of their dips precluded toppling mechanisms.

Set II striking within 20° to the slope face offered the potential for plane failure with the gorge slopes but its dip of 70° was greater than that overall slope face, and thus the range of dip scatter examined for modes of potential failure.

The strike of Set IVC also offered the mechanism for plane failure, but this was dismissed as unlikely as it was considered the realistic friction angle for the surface would be greater than the indicated dip of 22°.

Wedge failure combinations are summarized in Table B5.9, all four merited further study, but again the plunge of the combinations should be noted. Those formed by Sets I and II provided steep plunges of a similar order to the valley slopes indicating shallow wedges, while Sets I and IV combined to provide shallow plunges of 22° to 23° comparable with friction.

3 - COMPUTER ANALYSIS

3.1 - Assumption

The method of analysis was by Acres GTEC 150 slope stability program which can assess the stability of a rock slope cut by two joint sets against sliding and rotation of the rock tectrahedron formed by the two joint sets, and which follows the methods outlined by Hendron, Cording an Ayer (1971). Criteria and loading conditions used in the analyses were as follows:

- Unit weight of rock used is 160 lb/ft^3;
- Friction angle of Sets I, II and III was assumed as 30° and Set IV as 35°;
- Cohesion was assumed as zero, and natural interlocking of joints neglected;
- Thrust from the dam computed from results of computer stress analysis for combined gravity and full hydrostatic head case in terms of external resolved loads acting at center of gravity of sized wedge;
- Varying hydrostatic pressure determined from a specified ground water level above the toe of the wedge acting over all the area of the two joint planes;
- Earthquake loading taken as a pseudostatic load of 0.5g acting as a resolved horizontal force along direction of line of intersection.

3.2 - South Bank Slope

Conditions of Sets I, III and IV were defined as potential failure wedges from graphical analysis.

Thus studies of joints having abiguitous continuity through the full height of the slope forming two plane wedges were studied to assess the susceptibility of the factor of safety against sliding to variations in surface friction, the imposition of pseudostatic acceleration loading, and the presence of pore water.

The data output from the studies for two plane wedges formed between Sets IV and I, and III and I, together with graphical plots of their factor of safety against sliding under different variations of loading are contained in reference project files. These analyses showed static stability to be particularly susceptible to the effects of pore water pressure, indicating the need for ensuring adequate drainage of any foundation, and further examination of the in situ permeability of existing site joint systems.

However, from descriptions of observed data obtained to date, Table 7.1, Devil Canyon Joint Characteristics, 1980-81 Geotechnical Report, the continuity of Set IV over the full height of slope would appear unlikely so that the two plane-wedge developed by Sets III and IA and IB was chosen for examination under dam thrust loading.

Sizing of potential wedges which could exist in the zones of the abutment was based on the ground contours and general arrangements shown on drawings SK-5700-C6-614A, Devil Canyon Main Dam, Geometry Plan and Diagram, (January 19, 1982) and SK-5700-C6-620, Devil Canyon Main Dam Grouting and Drainage, Sections and Details.

Once the appropriate orientation and dip of the joints had been chosen, the plunge and direction of their line of intersection was defined by graphical means. A line of section drawn through the slope contours on that line and the maximum realistc height of wedge which could daylight in the slope defined, as well as realistic slope angles for analysis.

Table B5.10 summarizes factors of safety against sliding for a two plane wedge formed between Set III and Sets IA and IB, of a size defined in plan Appendix C, together with data output for wedges analyzed.

3.3 - North Bank Slope

Combinations of Sets I, II and IV were identified as potential wedge failure mechanisms in the north bank slope.

Studies for abiguitous continuity in a 250 foot high slope were carried out for Sets I and II in combination with the slope. Again, this shows that wedges formed by Sets I and II are particularly susceptible to the presence of pore water. However, sizing analyses achieved by making the gorge slope 55° from horizontal, or steepening the dip of Set II from the middle to limit of its range at 70° reveal the wedges to be very shallow and present a problem of limited slope stability rather than of a deep seated shape capable of accepting dam thrust loading.

Set IV could combine with Set I, but would require a tension crack parallel to the gorge slope, or a combination with Set II as the back tension plane to form a 3-plane wedge of realistic proportions. Such a 3-plane wedge is geometrically feasible for sliding, however, the continuity of Set IV must be proved.

4 - CONCLUSIONS

Geometrically feasible sliding wedge failures can develop on both banks of Devil Canyon gorge utilizing combinations of the four joint sets mapped.

Feasible combinations are:

	South Bank	North Bank
2 planes and slopes	Sets I and IV Sets I and III	Sets I and II Sets I and IV
3 planes and slope	Sets I, III, and IV	Sets I, II, and IV

However, geological field mapping indicates that Joint Set IV is discontinuous therefore limiting possible failures with Sets I and III to shallow wedges 25 to 45 feet in thickness paralleling the steep valley sides. These features can be excavated back to a stable slope where necessary and this has been allowed for in the foundation treatment costs.

Stability of wedges formed by Sets I and III south bank and Sets I and III north bank downstream of the dam require some continuity of intact rock within Sets II and III for stability under extreme earthquake and water pressure loadings. Further geological mapping will be required to confirm this continuity. Should this not be found, additional excavation of the potential failure areas or an adjustment in the location of the dam will be required. However, study of the existing slope in the canyon, coupled with the proposed extensive abutment drainage galleries to ensure drainage indicates that only removal of shallow wedges will be necessary.

It is considered that the site is feasible for the arch dam foundation, but it must be emphasized that further extensive geological mapping and exploration is required for final design.

REFERENCES

1. Hoek, E. and Bray, J., 1977, Rock Slope Engineering (Revised Second Edition), Institution of Mining and Metallurgy London.

2. Acres Consulting Services, June 1973, Rock Slope Stability Analysis, GTEC 150 Computer Program.

3. Hendron, A.J., Cording, E.J. and Aiyer, A.K., July 1971, "Analytical and Graphical Methods for the Analysis of Slopes in Rock Masses", U.S. Army Nuclear Catering Group, Technical Report No. 36.

TABLE B5.8: POTENTIAL SLIDING WEDGES, SOUTH BANK, DEVIL CANYON

Combination of Joint Sets	Intersection		Factor of Safety*
	Plunge	Direction	
IB - III	76°	324°	0.26
IB - IVB	50°	334°	0.60
IA - IVB	50°	344°	0.53
IA - III	70°	350°	0.17
III - IVB	42°	017°	1.87
III - IVA	14°	025°	2.06
IVA - IVB	20°	046°	2.00

TABLE B5.9: POTENTIAL SLIDING WEDGES, NORTH BANK, DEVIL CANYON

Combination of Joint Sets	Intersection		Factor of Safety*
	Plunge	Direction	
IA - II	62°	136°	0.28
IB - II	68°	161°	0.15
IA - IVC	22°	153°	1.21
IB - IVC	23°	164°	1.27

*Calculated from Hoek and Bray Stability Charts for friction only, assuming slope is fully drained, cohesion of both planes is 300, and friction angle for all surfaces is Ø = 23°, and using dip and dip direction differences alone.

$$\text{Factor of Safety} = \frac{(R_A + R_B) \text{ ton } Ø}{W \sin \text{(angle of line of intersection with force)}}$$

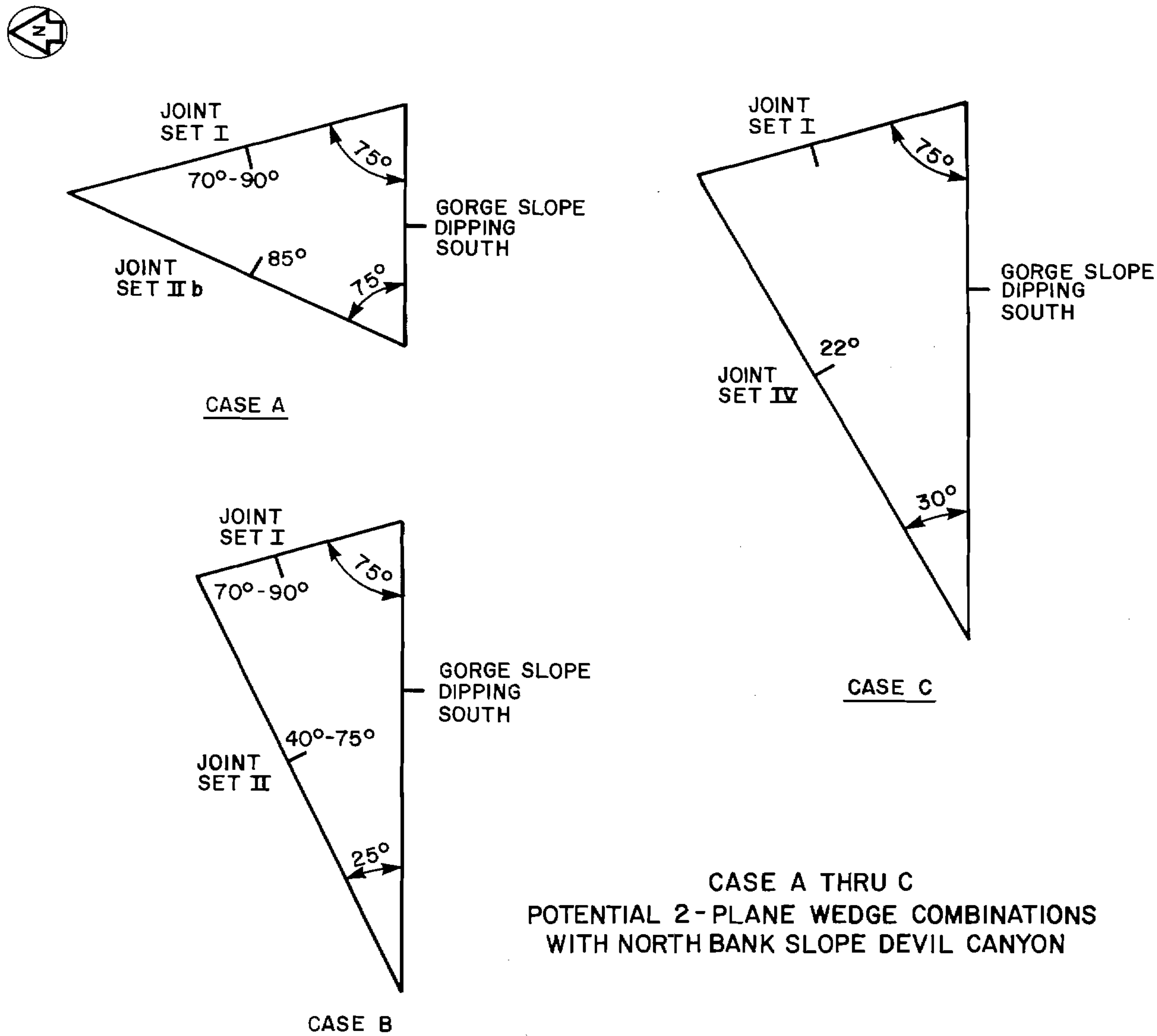
Ø = Friction angle
R_A, R_B = Normal reactions provided by plane resulting from weight of wedge

TABLE B5.10: FACTORS OF SAFETY AGAINST SLIDING

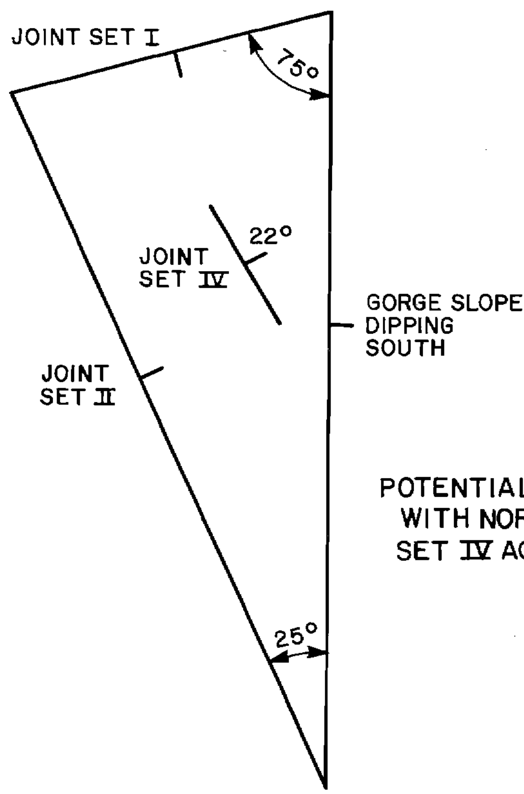
Loading Conditions	Potential Failure Wedge	Potential Failure Wedge
	Strike 025 Dip 65 NW Ø 30.0 Strike 340 Dip 80 NW Ø 30.0	Strike 025 Dip 65 NW Ø 30.0 Strike 340 Dip 80 NE Ø 30.0
	Height of Wedge = 500 ft slope face at 47°	
$W + T_H + Z_{w_1} + E_w$	1.47	5.23
$W + T_H + Z_{w_{50}} + E_w$	1.36	5.16
$W + T_H + Z_{w_{100}} + E_w$	1.25	5.08
$W + T_H + Z_{w_{250}} + E_w$	0.92	
$W + T_H + Z_{w_{350}} + E_w$	0.69	
$W + T_E + Z_{w_1} + E_w$	2.14	
$W + T_E + Z_{w_{50}} + E_w$	2.06	42.66*
$W + T_E + Z_{w_{100}} + E_w$	1.98	42.33*
$W + T_E + Z_{w_{150}} + E_w$		41.99*

Where: W = Weight of wedge
T_H = Dam thrust under peak hydraulic and gravity loading
T_E = Dam thrust under earthquake loading
Z_w = Height of pore water acting from toe of wedge
E_w = Pseudostatic earthquake force acting on weight of wedge

*See Note - Table B5.9



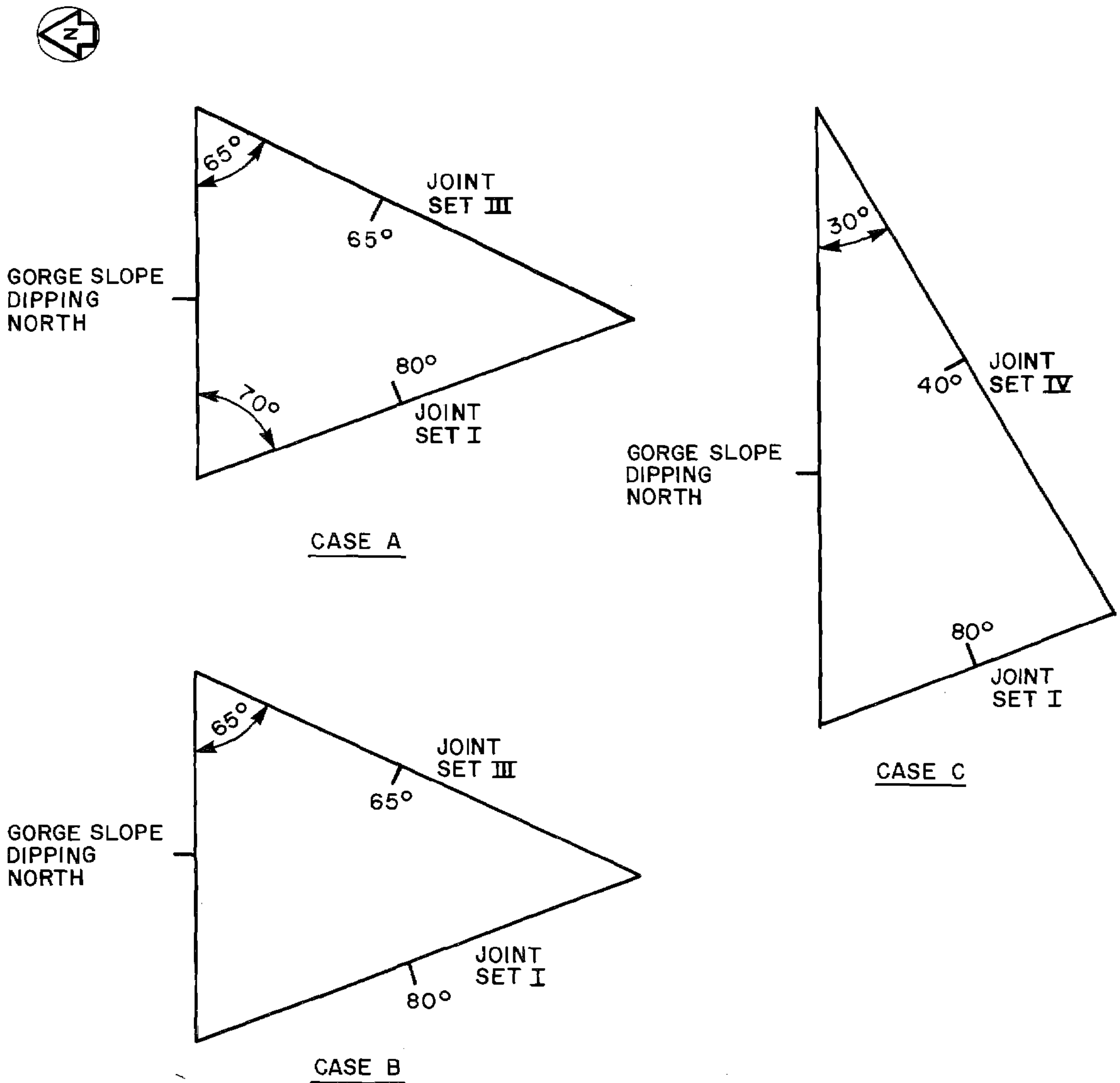
CASE A THRU C
POTENTIAL 2-PLANE WEDGE COMBINATIONS
WITH NORTH BANK SLOPE DEVIL CANYON



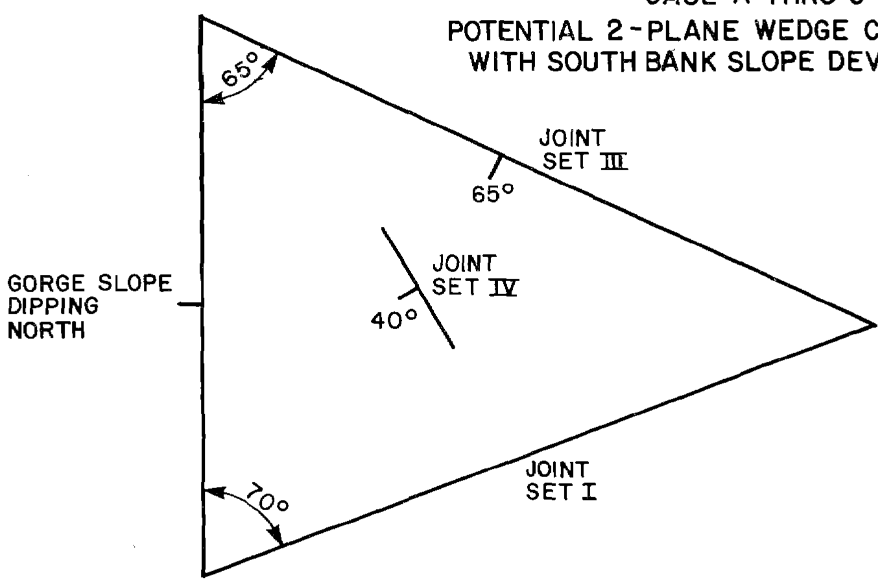
POTENTIAL 3-PLANE WEDGE COMBINATION
WITH NORTH BANK SLOPE DEVIL CANYON
SET IV ACTING AS BASE SLIDING SURFACE

ACRES

FIGURE B5.3



CASE A THRU C
POTENTIAL 2-PLANE WEDGE COMBINATIONS
WITH SOUTH BANK SLOPE DEVIL CANYON



POTENTIAL 3-PLANE WEDGE COMBINATION
WITH SOUTH BANK SLOPE DEVIL CANYON
SET IV ACTING AS BASE SLIDING SURFACE

FIGURE B5.4

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ATTACHMENT 2
DEVIL CANYON DAM

1 - GENERAL

The right bank thrust block is founded deep in the rock and abuts the spillway control structure which directs the thrust from the dam into the abutment. The left bank thrust block is founded on the sound rock surface. It is keyed into the weathered rock but the support from this rock is neglected in stability calculations. The stability of the left bank thrust block against sliding is provided by cohesive and shear friction forces acting at the upperside of the thrust block.

2 - LOADING CONDITIONS

The following loads act on the thrust block:

- Dead Load: This consists of the weight of the thrust block alone and is based on a unit weight of concrete of 150 lb/cf.

- The thrust from the arch dam under static and earthquake loadings: This is taken from the results of the dam analysis.

- Hydrostatic Load: This results from the reservoir and acts directly on the upstream face of the thrust block. Reservoir level is 1455 feet.

- Uplift on the underside of the thrust block was assumed to vary linearly from full headwater at the upstream face to one-half of headwater at the line of pressure relief drains to zero at the downstream end of the thrust block. Uplfit is assumed to be unaffected by earthquake.

- The increased external water pressure caused by earthquake was calculated by Westergaard's formula and based on a ground acceleration Ag = 0.5.

- The active lateral rockfill pressure of the saddle dam: This acts across the end face of the thrust block. Hydrostatic pressure has been considered on the area between the upstream face and the centerline of the thrust block.

- The inertia force of the concrete block has been taken as the resultant of vertical loads on the thrust block multiplied by the ground acceleration. It is applied horizontally in the direction of the resultant of the longitudinal and lateral forces.

3 - LOAD COMBINATIONS

Load combinations considered are as follows:

UL-1 Usual Load Case: Dead load plus thrust from the arch and hydrostatic and lateral loads from the saddle dam. Reservoir at elevation 1455.

ELC-1 Extreme Load Case: As in UL-1 plus earthquake with ground acceleration 0.5g.

4 - SAFETY FACTOR AGAINST SLIDING

The safety factor against sliding has been calculated using the equation:

$$K = \frac{\tan \emptyset V + CA}{H}$$

where: Ø = Angle of friction between concrete and rock, or between rock and rock.

V = Resultant of vertical loads
C = Cohesion between concrete and rock, or between rock and rock
A = Area of base of thrust block
H = Resultant of horizontal loads

The values of Ø and C have been assumed at 30° and 200 psi, respectively. This is a conservative assumption when compared to properties of foundation materials determined for other projects.

Typical parameters from a comparison of the proposed Auborn dam in California, the Salinas dam in California, and analyses of dams in China give a range of values for tonØ of between 30° and 45° and of C of between 161 and 500 psi. These are based on foundations of metamorphised volcanic tuffs, fine grained sandstone and shale bedding, and mica silica schist, respectively, for the three locations.

5 - CONCLUSIONS

The factor of safety against sliding for normal loading conditions is 5.0. The factor of sliding under maximum reservoir and maximum earthquake conditions is 1.1.

Extensive laboratory and in situ testing of foundation materials will be required prior to final design. Based on experience of other projects the assumed rock properties are conservative, particularly in the case of maximum earthquake where loadings are extremely short-lived. However, if it were determined that foundation conditions were less favorable than anticipated, the base of the thrust block would be broadened.

APPENDIX B6

WATANA DAM ANALYSIS

The stability of the Watana dam during an earthquake depends on the static stresses in the embankment prior to the earthquake, the dynamic stresses generated by the earthquake accelerations, and the dynamic stress-strain properties of the materials in the embankment. The static and dynamic stresses were determined following the procedures recommended by Dr. H. Bolton Seed in his Rankine Lecture (1). The basic principles of the procedure consist of the following steps:

- Determine the cross-section of the dam to be used for analysis;

- Determine, in consultation with geologists and seismologists, the maximum time history of base excitation to which the dam and its foundation might be subjected;

- Determine the stresses existing in the embankment before the earthquake; this is done most effectively using finite element analysis procedures;

- Determine the dynamic properties of the soils comprising the dam, such as shear modulus, damping characteristics, bulk modulus, or Poisson's Ratio, which determine its response to dynamic excitation. Since the material characteristics are nonlinear, it is also necessary to determine how the properties vary with strain;

- Compute, using an appropriate dynamic finite element analysis procedure, the stresses induced in the embankment by the selected base excitation;

- Subject representative samples of the embankment materials to a combination of the initial static stresses and the superimposed dynamic stresses and determine the effects of such loading in terms of the generation of pore water pressures and the development of strains. Perform a sufficient number of these tests to permit similar evaluations to be made by interpolation for all elements comprising the embankment;

- From the knowledge of the pore pressures generated by the earthquake, the soil deformation characteristics, and the strength characteristics, evaluate the factor of safety against failure of the embankment either during or following the earthquake, adjusting the section as necessary to achieve the required factor of safety;

- Use the strains induced by the combined effects of static and dynamic loads applied to the safe section to assess the overall deformations of the embankment; and

- Incorporate the requisite amount of judgment in each of the preceding steps, as well as in the final assessment of probable performance in conjunction with a thorough knowledge of typical soil characteristics, the essential details of finite element analysis procedures, and a detailed knowledge of the past performance of embankments in other earthquakes.

These recommended procedures were altered to a certain extent for the stability analysis of Watana dam:

- The maximum cross-section of the Watana dam as shown in Figure B6.1 was analyzed.

- The selected Safety Evaluation Earthquake for design of Watana is a magnitude 8.5 event on the Benioff zone, 40 miles from the site, for which an appropriate time-history was developed.

- The earthquake time-history used in the analysis was developed by Woodward-Clyde Consultants specifically for the Watana site and is shown in Figure B6.17.

- The static stresses were determined using the FEADAM finite element computer program.

- The properties of the materials were taken from appropriate available data developed for other projects, since no specific testing of the proposed materials was performed during this feasibility study.

- The dynamic stresses were determined using the QUAD 4 finite element computer program.

- The proposed gradation of the material to be used in the upstream shell of the dam is such that it would not be subject to the development of excess pore pressure during seismic loading.

- The factor of safety was evaluated by comparing the available static shear strength to the required static and dynamic shear strength as determined by the analysis.

- Approximate deformations for feasibility level analysis were estimated by various procedures prior to computer analysis.

- Judgment indicates that conservative material property values were used in the analysis and the resulting safety of the dam was more than adequate.

1 - METHODOLOGY

Static and dynamic stability analyses have been performed to confirm the stability of the upstream and downstream slopes of the proposed cross-sections of the Watana dam shown in Figure B6.1. The analyses indicate stable slopes under all conditions for a 2.4 horizontal to 1.0 vertical upstream slope, and a 2.0 horizontal to 1.0 vertical downstream slope.

The static analyses were performed using the STABL computer program developed to handle general slope stability problems by adaptation of the Modified Bishop method, and FEADAM, a finite element program for static analysis of earth and rockfill dams, to determine the initial stresses in the dam during normal operating conditions. The results and conclusions are presented in Section 2.1.

The dynamic analyses were performed using the QUAD 4 finite element program which incorporates strain-dependent shear modulus and damping parameters. The design earthquake for the dynamic analyses was developed by Woodward-Clyde Consultants for a Benioff Zone event. The results and conclusions are presented in Section 3.2.

2 - FINITE ELEMENT MODEL

The finite element model consists of 20 layers of elements with 546 nodes and 520 elements (see Figure B6.6). Different soil parameters as described in the following sections have been chosen for the core, the transition material consisting of the fine and coarse filter zones, and the shell material.

2.1 - Static Analysis

The slope stability analyses were carried out using the STABL computer program for the general solution of slope stability problems by a two-dimensional limiting equilibrium method. The calculation of the factor of safety against instability of a slope is performed by an adaptation of the Modified Bishop method of slices which allows the analysis of trial failure surfaces other than those of a circular shape.

The STABL program features a unique random technique for generating potential failure surfaces and subsequently determining the more critical surfaces and their corresponding factors of safety. In the Modified Bishop method of slices, the sliding mass is divided into slices of either finite or unit width, and a number of arbitrary sliding surfaces are investigated to determine which is most critical. An important feature of this method is that earth forces acting on the sides of the slices are considered. The direction of the side forces are assumed parallel to the average slope of the embankment; since the forces are internal forces, they must be balanced to obtain a solution. These factors are incorporated within the STABL program. Additional information can be found in Siegel (2).

(a) Loading Conditions and Factors of Safety

The following conditions were analyzed:

Case	Required Minimum Factor of Safety (3)	Calculated Factor of Safety: U/S Slope	Calculated Factor of Safety: D/S Slope
Construction	1.3	2.0-2.2	1.7
Normal Maximum Operating	1.5	2.0	1.7
Maximum Reservoir Drawdown	1.0	1.8-2.0	1.7
Maximum Reservoir Level During PMF	1.3	2.0-2.1	1.7

The calculated factors of safety as shown in the above table and in Figures B6.2 and B6.5 indicate no general slope stability problems under static loading. Further analysis using FEADAM determined the initial stresses in the dam during normal operating conditions.

Appropriate nonlinear and stress-dependent, stress-strain properties for the soils were taken from information compiled in Table 5 in Duncan et al. (4). Table B6.1 presents the values used in the analysis. Two analyses were performed to show the effects of relatively soft versus stiff core material.

The program calculates the stresses, strains, and displacements in the dam, simulating the actual sequence of construction operations. The nonlinear and stress-dependent, stress-strain properties of the soil are approximated by performing the analysis in increments consisting of the placement of a layer of fill on the embankment. Each increment is analyzed twice, the first time using modulus values based on the stresses at the beginning of the increment, and the second time using modulus values based on the average stresses during the increment. The changes in stress, strain, and displacement during each increment are added to the stresses, strains, and displacements at the beginning of the increment.

During each increment, each element is checked to determine whether it is in a state of primary loading, elastic unloading, tension failure, or shear failure. The resulting output provides the static stress values within the embankment during normal operation. Additional information can be found in Duncan et al. (5).

The following figures were developed from the FEADAM computer program output for the soft and stiff core material:

Figure	Subject
B6.6	Finite Element Model
B6.7	Static Run Soft Core-End of Construction - Vertical Stress
B6.8	Static Run Soft Core-Normal Operating - Vertical Stress
B6.9	Static Run Soft Core-Normal Operating - Vertical Effective Stress
B6.10	Static Run Soft Core-Normal Operating - 2-D Effective Continuing Stress
B6.11	Static Run Soft Core-Normal Operating Local XY Shear Exceedance
B6.12	Static Run Stiff Core-End of Construction - Vertical Stress
B6.13	Static Run Stiff Core-Normal Operating - Vertical Stress
B6.14	Static Run Stiff Core-Normal Operating - Vertical Effective Stress
B6.15	Static Run Stiff Core-Normal Operating - 2-D Effective Confining Stress
B6.16	Static Run Stiff Core-Normal Operating - Local XY Shear Exceedance

Figure B6.6 shows the finite element model which was used for both the static (FEADAM) and the dynamic (QUAD 4) analyses. The model consists of 20 layers with 546 nodes and 520 elements. For the static (FEADAM) analysis, the embankment was "constructed" in 20 steps corresponding to one step for each layer. The reservoir load was applied in an additional four steps to simulate filling of the reservoir.

(b) Results and Conclusions

The static stability of the embankment was assessed by comparing the stresses, XY-induced at any location, with the shear strength available within the material. The effective friction angle Ø' was evaluated based on a summation plot of shearing strength of rockfill from large triaxial tests taken from Leps (6). Figures B6.11 and B6.16 are plots of the induced stresses versus available stresses for soft and stiff core, respectively, and indicate an overall safe and stable embankment based on no local XY shear exceedance.

The vertical stress and vertical effective stress plots for both the soft and stiff cores (Figures B6.7, B6.8, B6.9, and B6.12, B6.13, and B6.14, respectively) indicate minimal arching across the core and normal vertical stress distribution across the remainder of the embankment. The vertical effective stress plots indicate that the vertical effective stress at the center of the core at the base of the embankment is greater than the applied water pressure load. This would prevent any possible hydraulic fracturing of the core material.

These results indicate a safe and stable central core, as well as overall embankment under static conditions.

2.2 - Dynamic Analysis

The dynamic analysis was performed using the QUAD 4 computer program to evaluate the response of the embankment during a given seismic excitation. The program has been written for elements in plain strain; triangular and quadrilateral elements can be used in representing the embankment.

The solution proceeds by assigning modulus and damping values to each element. Because these parameters are strain-dependent, they cannot be calculated at the start of the analysis and an iteration procedure is required. Thus, at the outset, values of shear modulus and damping are estimated and an analysis is performed to compute values of the average strain developed in each element. These strain values are then used to calculate new values of modulus and damping. The whole process is repeated until a solution is obtained incorporating modulus and damping values for each element which are compatible with the average strain developed. Additional information can be found in Idriss et al. (7).

The initial values of shear modulus and damping ratio to be used in the analyses were derived from typical values available in Banerjee et al. (8) as follows:

Zone	K2	Damping Shear Type Curve
Core Material:		
- soft	90	sand
- stiff	120	sand
Transition Material	150	sand
Shell Material	180	sand

The Safety Evaluation Earthquake time-history was developed by Woodward-Clyde Consultants and is shown in Figure B6.17. The significant features are as follows:

- Magnitude 8.5 Richter;
- Location 40 miles from site (Benioff Zone);
- Maximum acceleration of 0.55g;
- Duration of strong motion - 45s; and
- Significant number of cycles - 25.

A preliminary dynamic analysis indicated that peak output values occurred about 24 seconds into the earthquake acceleration time-history. The three iterations for the dynamic analysis were therefore performed using the following sections of the earthquake time-history:

- Iteration 1: from 10 to 30 seconds;
- Iteration 2: from 10 to 30 seconds;
- Iteration 3: from 10 to 30 seconds.

3 - SEISMIC STABILITY EVALUATION

The evaluation of the seismic stability of the embankment cross section is based on a comparison of shear strength available in the soil to the earthquake-induced shear stresses. This comparison is presented herein as factor of safety.

3.1 - Failure Criteria

For the embankment section, the available undrained dynamic shear stress is based on an earthquake-induced shear strain of 5 percent. The available drained dynamic shear stress is based on the effective vertical confining stress and the friction angle of the material, taking into account the static shear stress already in the embankment.

(a) Undrained Dynamic Shear Stress Criteria

The induced stresses within the embankment are compared to the stresses required to cause 5 percent shear strain in 25 cycles of strong motion with a K_c = 2.0 for Oroville dam shell material (8) (see Figure B6.8). This strain criteria has been established on the basis of correlations between the results of seismic stability evaluations by the procedure used for the present studies and the performance of earth dams which have been subject to significant earthquake loading (9,10). Case histories of earthfill dams that have been subjected to earthquake loading show that if the strain at any location within the dam and its foundation is smaller than 5 percent, the earthquake had no effect on the stability and integrity of the dam.

It should not, however, be concluded that the stability and integrity of the dam is impaired if the strain exceeds 5 percent at some locations within the dam and its foundation. The effect of strains exceeding 5 percent depends on the zone of the dam where they may occur, and on their relative extent and location within the specific zone.

The undrained shear stress exceedance ratio, which is considered to represent a local factor of safety against the development of 5 percent strain, is shown in Figures B6.20 and B6.29 for soft and stiff core, respectively. On the basis of the explanation given in the preceding paragraph, a value of this ratio less than 1.0 indicates an ample margin of safety.

(b) Drained Dynamic Shear Stress Criteria

The induced stresses within the embankment are compared to the stresses available within the embankment calculated from the effective vertical confining stress times the tangent of the friction angle of the material, minus the existing static shear strength within the embankment. The drained shear stress exceedance ratio, which is considered to represent a local factor of safety against slope failures, is shown in Figures B6.19 and B6.28 for soft and stiff cores, respectively. Based on this comparison, a value of this ratio less than 1.0 indicates an ample margin of safety.

3.2 - Results and Conclusions

The following figures were developed from the QUAD 4 computer program output for the soft and stiff core material during normal operations:

Figure	Subject
B6.17	Earthquake Time-History
B6.18	Cyclic Deviator Stress vs Continuing Stress
B6.19	Dynamic Run Soft Core - Drained Shear Stress Exceedance
B6.20	Dynamic Run Soft Core - Undrained Shear Stress Exceedance
B6.21	Dynamic Run Soft Core - Horizontal Slice No. 1
B6.22	Dynamic Run Soft Core - Horizontal Slices No. 2 and 3
B6.23	Dynamic Run Soft Core - Shear Stress Time History Plots
B6.24	Dynamic Run Soft Core - Shear Stress Time History Plots
B6.25	Dynamic Run Soft Core - Shear Stress Time History Plots
B6.26	Dynamic Run Soft Core - Shear Stress Time History Plots
B6.27	Dynamic Run Soft Core - Maximum Acceleration vs Height
B6.28	Dynamic Run Stiff Core - Drained Shear Stress Exceedance
B6.29	Dynamic Run Stiff Core - Undrained Shear Stress Exceedance
B6.30	Dynamic Run Stiff Core - Horizontal Slice No. 1
B6.31	Dynamic Run Stiff Core - Horizontal Slices No. 2 and 3
B6.32	Dynamic Run Stiff Core - Shear Stress Time History Plots
B6.33	Dynamic Run Stiff Core - Shear Stress Time History Plots
B6.34	Dynamic Run Stiff Core - Shear Stress Time History Plots
B6.35	Dynamic Run Stiff Core - Shear Stress Time History Plots
B6.36	Dynamic Run Stiff Core - Maximum Acceleration vs Height

The seismic stability of the embankment was assessed by comparing the maximum dynamic shear stresses induced by the earthquake at any location with the available shear stresses and indicated an overall stable embankment under seismic loading.

For core materials, very little dissipation of excess pore pressures is expected during the short period of earthquake shaking; therefore, the shear stress evaluation was defined on the basis of the undrained dynamic shear stress criteria. In the case of the downstream shell, any pore pressure buildup caused by earthquake shaking should be negligible; hence, the shear stress evaluation was based on the drained dynamic shear stress criteria.

For the saturated upstream shell, total dissipation of excess pore pressure will occur and the shear stress evaluation was based on the drained dynamic shear stress criteria.

Figures B6.19, B6.20, B6.28 and B6.29 are plots of the drained shear stress exceedance and undrained shear stress exceedance for the soft and stiff core, respectively. These plots indicate minor zones of shear stress exceedance, however the overall embankment was found to be stable.

Three horizontal slices for each type of core material were taken through the embankment as shown in Figure B6.6. The ratio of the induced dynamic stresses to the available shear stresses is plotted for each element on each of the three horizontal slices as shown in Figures B6.21, B6.22 and B6.30, and B6.31 for the soft and stiff core, respectively. These plots show zones of shear stress exceedance on the surfaces of the embankment, however, the overall stability of the embankment is apparent. Stress histories for various elements are shown in Figures B6.23 through B6.26 and B6.32 through B6.35 for the soft and stiff core, respectively.

The maximum accelerations for each nodal point on a vertical slice through the center of the dam are shown in Figures B6.27 and B6.34 or the soft and stiff core, respectively.

These results indicate limited zones of shear stress exceedance adjacent to the toe of the upstream shell, near the upstream crest, and in the surface layer of the downstream shell. Since they are localized zones not extending into the embankment, the overall embankment will be stable under seismic loading.

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(1) Seed, H.B., "Considerations in the Earthquake-Resistant Design of Earth and Rockfill Dams," Geotechnique 29, No. 3, 215-263, 1979.

(2) Siegel, R.A. (1975), "STABL User Manual," Joint Highway Research Project, Engineering Experiment Station, JHRP-75-9, Purdue University, June 1975.

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(4) Duncan, J.M., Byrne, P., Wong, K.S., and Mabry, P., "Strength, Stress-Strain and Bulk Modulus Parameters for Finite Element Analyses of Stresses and Movement in Soil Mass," Report No. UCB/GT/80-01, Department of Civil Engineering, University of California, Berkeley, August, 1980.

(5) Duncan, J.M., Wong, K.S. and Ozawa, Y, "FEADAM: A Computer Program for Finite Element Analysis of Dams," Report No. UCB/GT/80-02, Department of Civil Engineering, University of California, Berkeley, December 1980.

(6) Leps, T.M., "Review of Shearing Strength of Rockfill," JSMFD, ASCE, SM4, July 1970.

(7) Idriss, I.M., Lysmer, J., Hwang, R. and Seed, H.B., "QUAD-4, A Computer Program for Evaluating the Seismic Response of Soil Structures by Variable Damping Finite Element Procedures," Report No. EERC 73-16, College of Engineering, University of California, Berkeley, July 1973.

(8) Banerjee, N.G., Seed, H.B. and Chan, C.K., "Cyclic Behavior of Dense Coarse-Grained Material in Relation to the Seismic Stability of Dams," Report No. UCB/EERC-79/13, College of Engineering, University of California, Berkeley, June 1979.

(9) Seed, H.B., Lee, K.L. and Idriss, I.M., "Analysis of Sheffield Dam Failure," JSMFD, ASCE, 95, No. SM6, Proc. Paper 6906, November 1969.

(10) Seed, H.B., Lee, K.L., Idriss, I.M. and Madkisi, F., "Analysis of the Slikes in the San Fernando Dams During the Earthquake," February 9, 1971, Report Egk Engr. Res. Ctr., University of California, Berkeley, March 1973.

TABLE B6.1: ASSUMED PROPERTIES FOR STATIC ANALYSES OF WATANA DAM

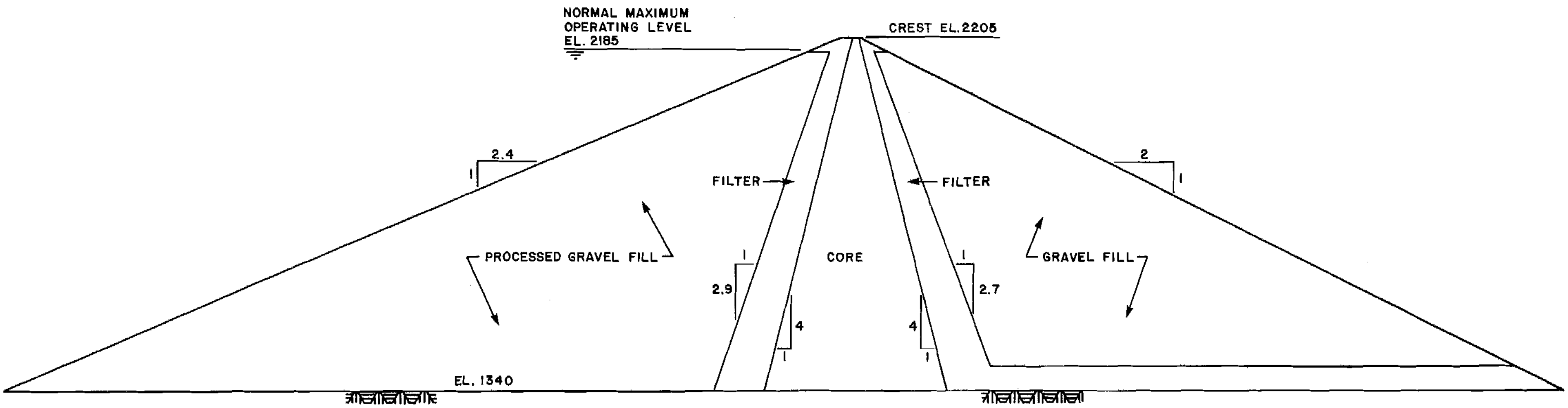
Material	γ	K	Kur	n	Rf	Kb	m	C	ϕ	δ	Ko
CORE:											
-- Soft(1)	140	200	300	.8	.6	60	.8	0	35	0	.43
-- Stiff(2)	140	700	800	.35	.8	280	.2	0	35	0	.43
TRANSITION(3)	145	1300	1500	.4	.72	900	.22	0	35	6	.43
SHELLS (4)	145	1800	2000	.4	.67	1300	.16	0	35	6	.43

where:

γ = Unit weight, pcf
K = Modulus number, ksf
Kur = Elastic unloading modulus number, ksf
n = Modulus exponent
Rf = Failure ratio
Kb = Bulk modulus number, ksf
m = Bulk modulus exponent
C = Cohesion, psf
ϕ = Friction angle, degrees
δ = Decrease in friction angle perlog cycle increase in σ_3, degrees
Ko = Earth pressure coefficient

Note: Values taken from Duncan et al., 1980, "Strength, Stress-Strain and Bulk Modulus Parameters for Finite Element Analyses of Stress and Movements in Soil Masses," Report No. UCB/GT/80-01, University of California, Berkeley.

(1) Mica Creek Dam Core, 2 percent wet of optimum
(2) Mica Creek Dam Core, 2 percent dry of optimum
(3) Oroville Dam silty sandy gravel
(4) Oroville Dam Shell - Amphibolite gravel

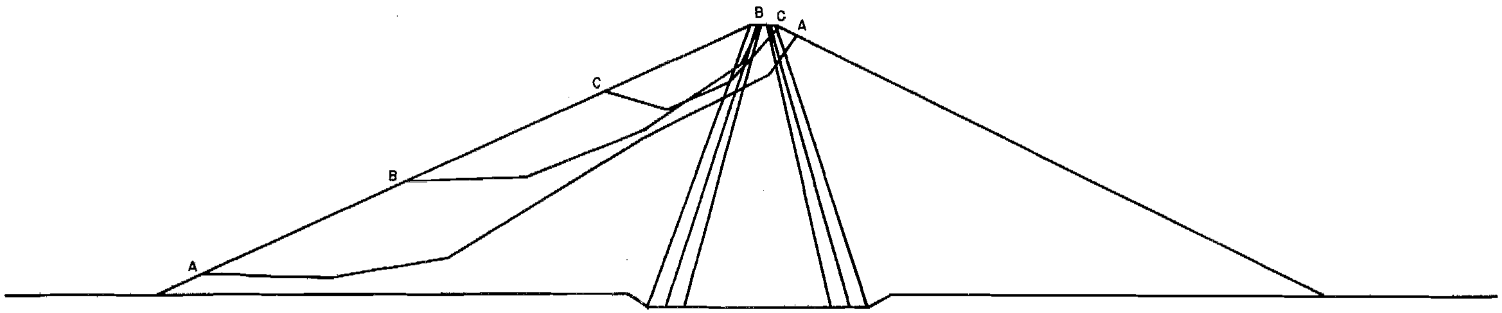


NOTE:
FOR DETAILED CROSS SECTION SEE PLATE 9 IN VOLUME 3 OF FEASIBILITY REPORT.

WATANA DAM
MAXIMUM CROSS SECTION

FIGURE B6.1

ACRES

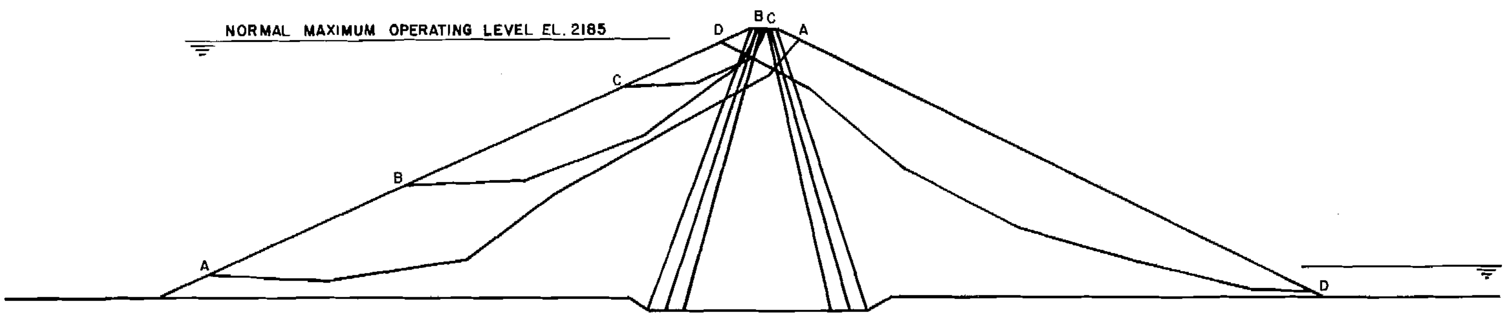


FAILURE SURFACE	SAFETY FACTOR
A-A	2.0
B-B	2.0
C-C	2.2

CONSTRUCTION CASE

FIGURE B6.2

ACRES



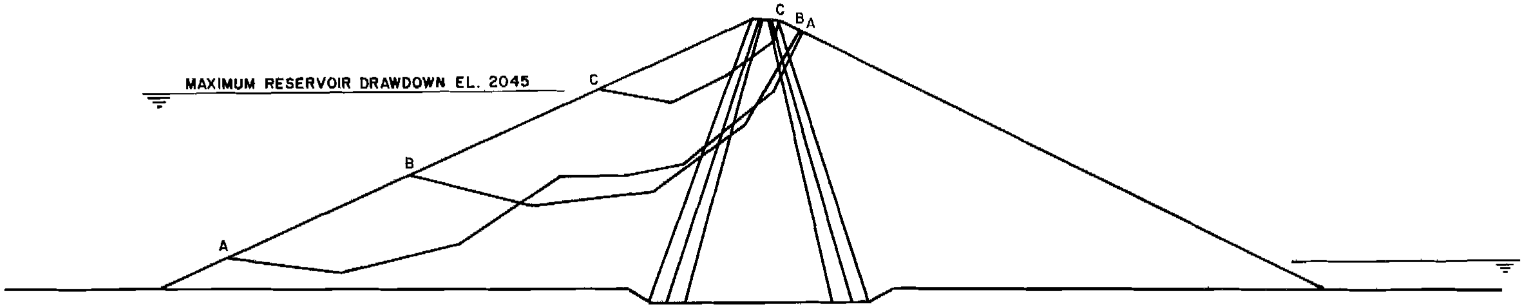
FAILURE SURFACE	SAFETY FACTOR
A-A	2.0
B-B	2.0
C-C	2.0
D-D*	1.7

*TYPICAL FAILURE SURFACE FOR DOWNSTREAM SLOPE (2:1)

NORMAL MAXIMUM OPERATING LEVEL CASE

ACRES

FIGURE B6.3

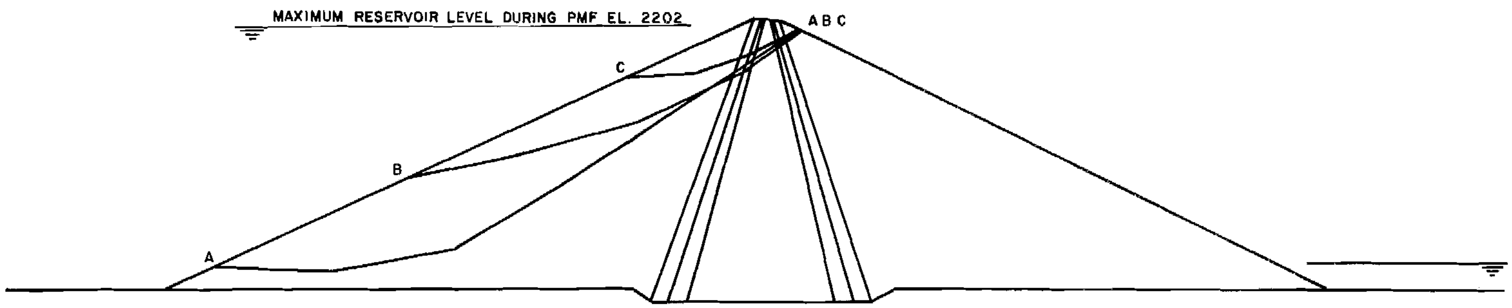


FAILURE SURFACE	SAFETY FACTOR
A-A	1.8
B-B	1.8
C-C	2.0

MAXIMUM RESERVOIR DRAWDOWN CASE

FIGURE B6.4

ACRES

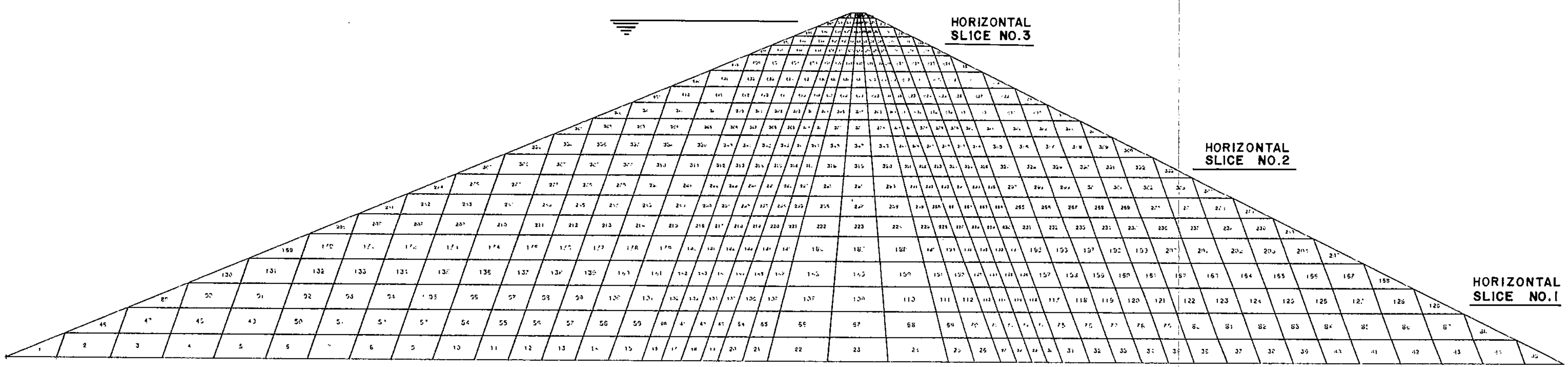


FAILURE SURFACE	SAFETY FACTOR
A-A	2.0
B-B	2.0
C-C	2.1

MAXIMUM RESERVOIR LEVEL DURING PMF CASE

FIGURE B6.5

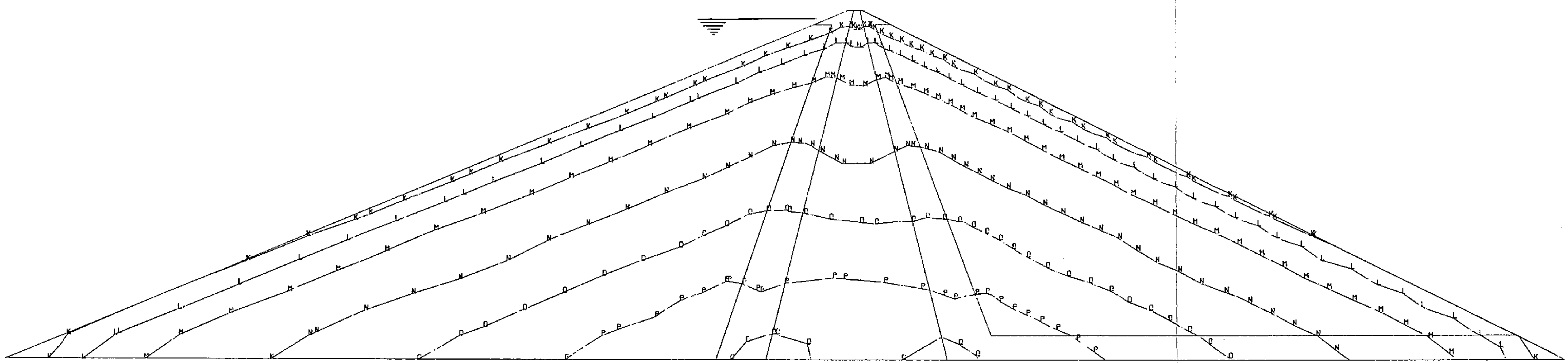
ACRES



FINITE ELEMENT MODEL

FIGURE B6.6

ACRES

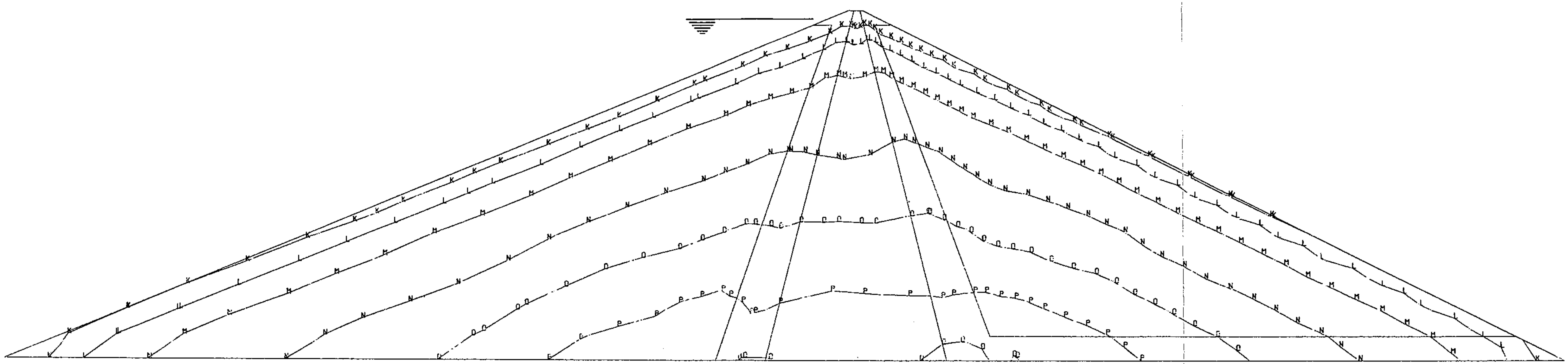


SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	-140.	-120.	-100.	-80.	-60.	-40.	-20.	-10.	-5.	0.
SYMBOL	K	L	M	N	O	P	Q	R	S	
VALUE	5.	10.	20.	40.	60.	80.	100.	120.	140.	

END OF CONSTRUCTION
STATIC RUN SOFT CORE
VERTICAL STRESS (SIGv) (KSF)

ACRES

FIGURE B6.7

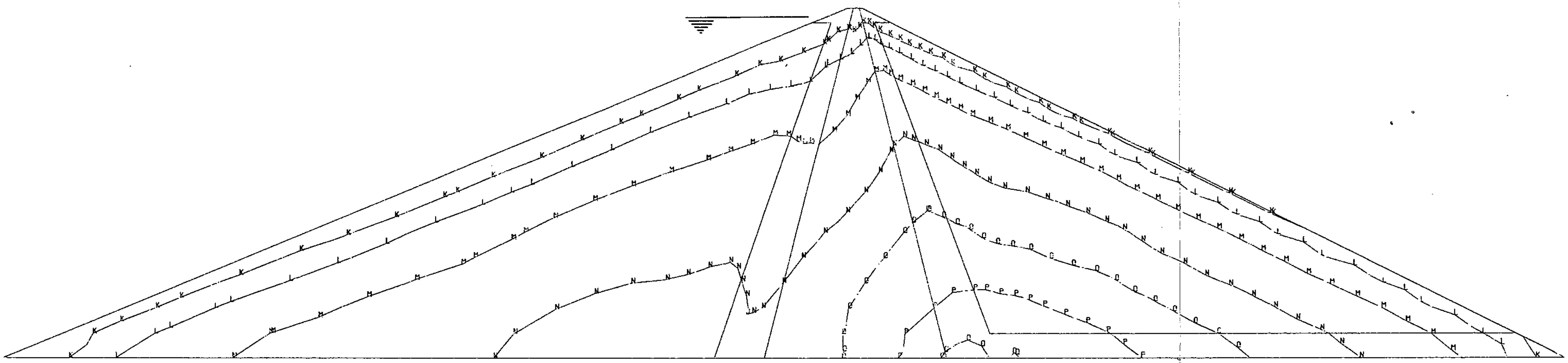


SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	-140.	-120.	-100.	-80.	-60.	-40.	-20.	-10.	-5.	0
SYMBOL	K	L	M	N	O	P				
VALUE	5.	10.	20.	40.	60.	80.	100.	120.	140.	

NORMAL OPERATING CONDITION
STATIC RUN SOFT CORE
VERTICAL STRESS (SIGv) (KSF)

FIGURE B6.8

ACRES



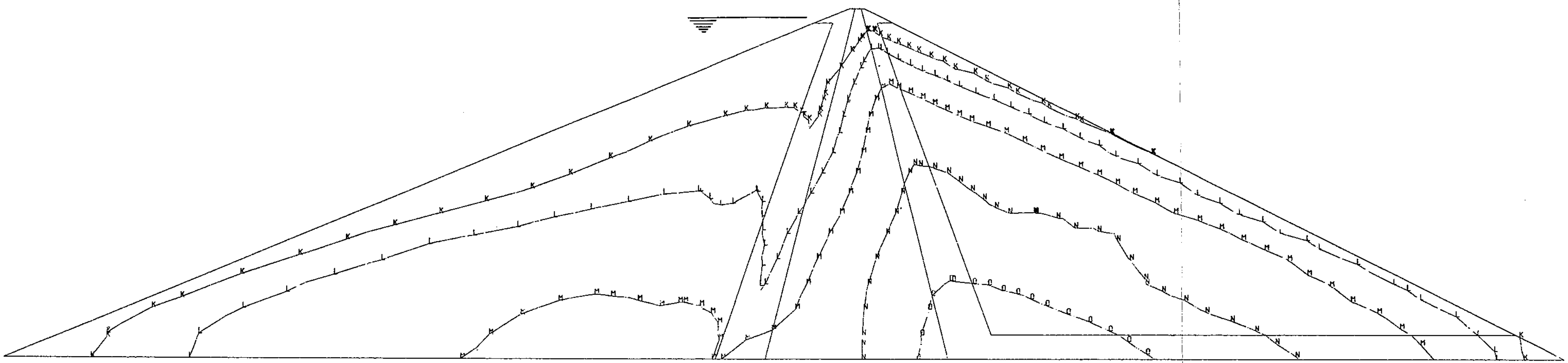
SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	-140.	-120.	-100.	-80.	-60.	-40.	-20.	-10.	-5.	0.
SYMBOL	K	L	M	N	O	P	Q	R	S	
VALUE	5.	10.	20.	40.	60.	80	100.	120.	140.	

STATIC RUN SOFT CORE

VERTICAL EFFECTIVE STRESS (SIGv)(KSF)

FIGURE B6.9

ACRES

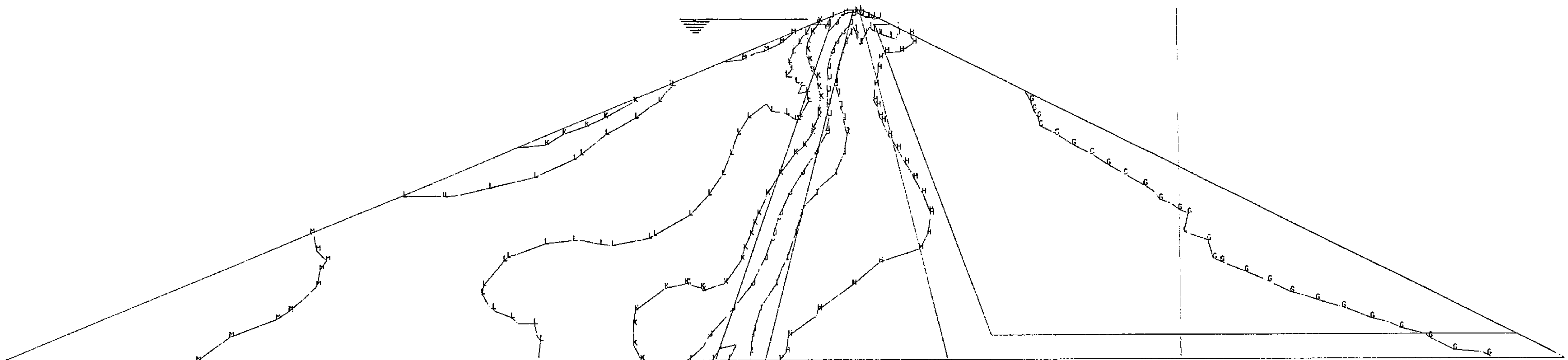


SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	-140.	-120.	-100.	-80.	-60.	-40.	-20.	-10.	-5.	0
SYMBOL	K	L	M	N	O	P	Q	R	S	
VALUE	5.	10.	20.	40.	60.	80.	100.	120.	140.	

STATIC RUN SOFT CORE

2-D EFFECTIVE CONFINING STRESS (SIG 2')(KSF)

FIGURE B6.10

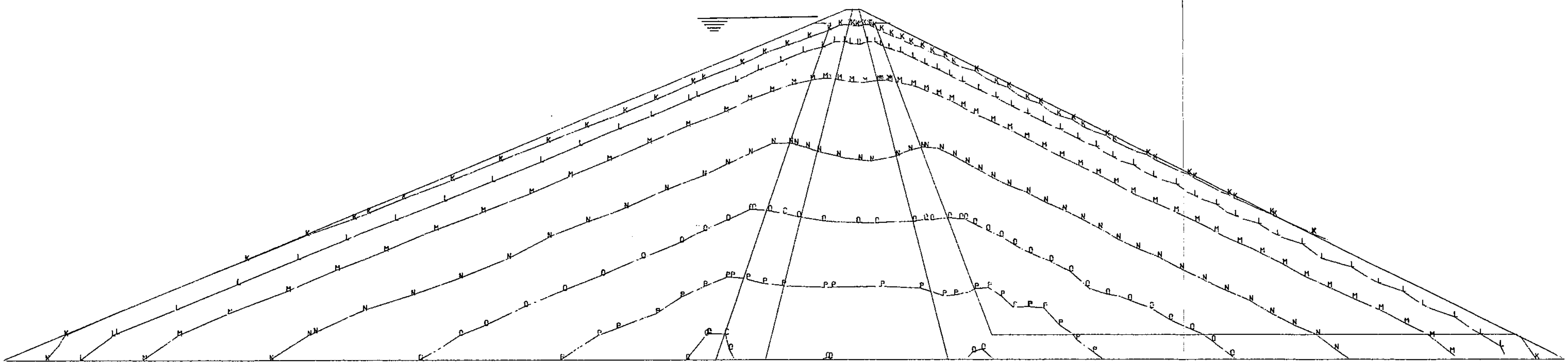


SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	-10.0	-8.0	-6.0	-4.0	-2.0	-1.0	-0.5	-0.2	-0.1	0.0
SYMBOL	K	L	M	N	O	P	Q	R	S	
VALUE	0.1	0.2	0.5	1.0	2.0	4.0	6.0	8.0	10.0	

STATIC RUN SOFT CORE

LOCAL XY SHEAR EXCEEDANCE (TAUxy/SH)

FIGURE B6.11

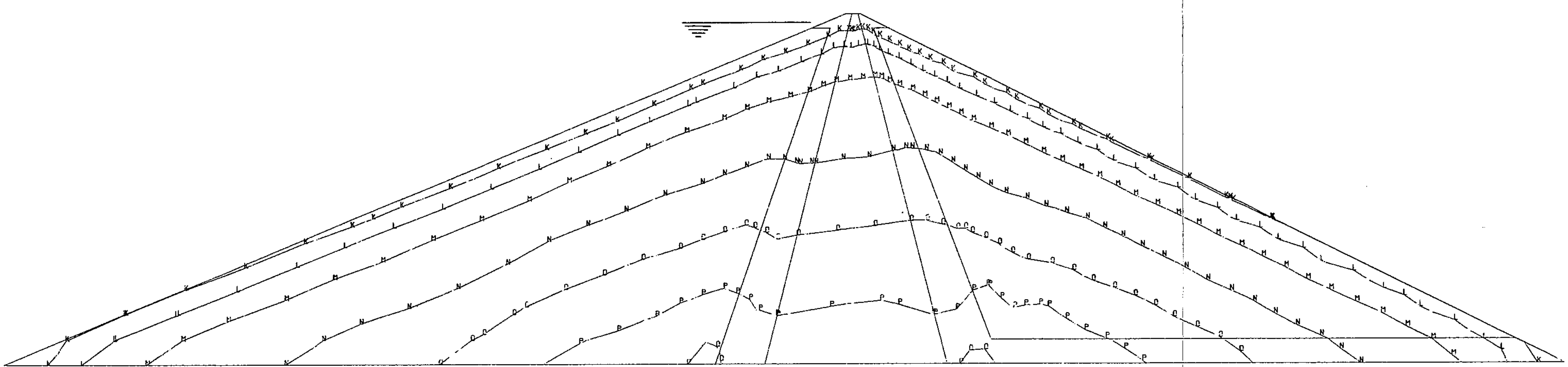


SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	-140.	-120.	-100.	-80.	-60.	-40.	-20.	-10.	-5.	0.
SYMBOL	K	L	M	N	O	P	Q	R	S	
VALUE	5.	10.	20.	40.	60.	80.	100.	120.	140.	

END OF CONSTRUCTION
STATIC RUN STIFF CORE
VERTICAL STRESS (SIGv) (KSF)

FIGURE B6.12

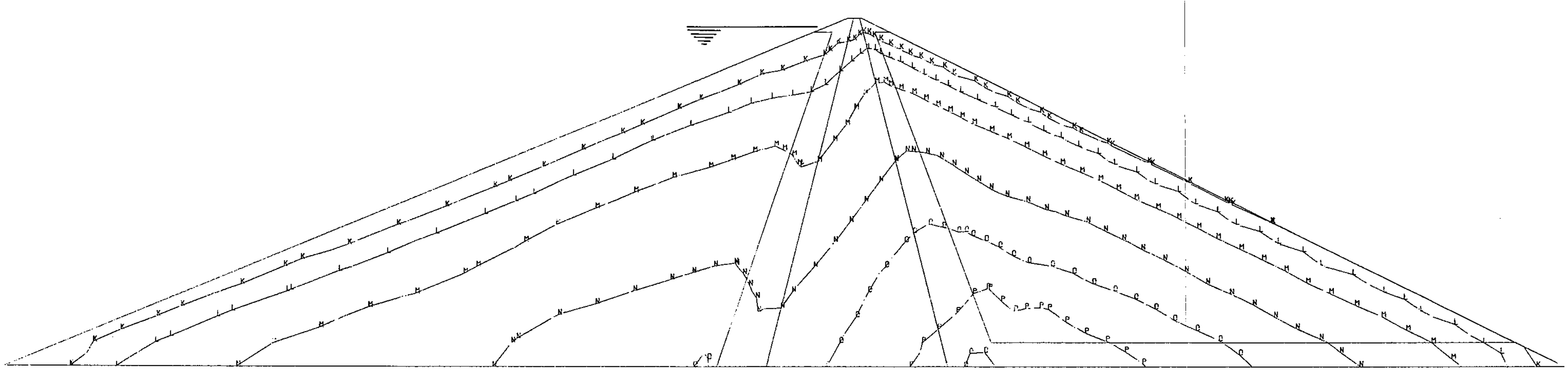
ACRES



SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	-140.	-120.	-100.	-80.	-60.	-40.	-20.	-10.	-5.	0.
SYMBOL	K	L	M	N	O	P	Q	R	S	
VALUE	5.	10.	20.	40.	60.	80.	100.	120.	140.	

NORMAL OPERATING CONDITION
STATIC RUN STIFF CORE
VERTICAL STRESS (SIGv) (KSF)

FIGURE B6.13



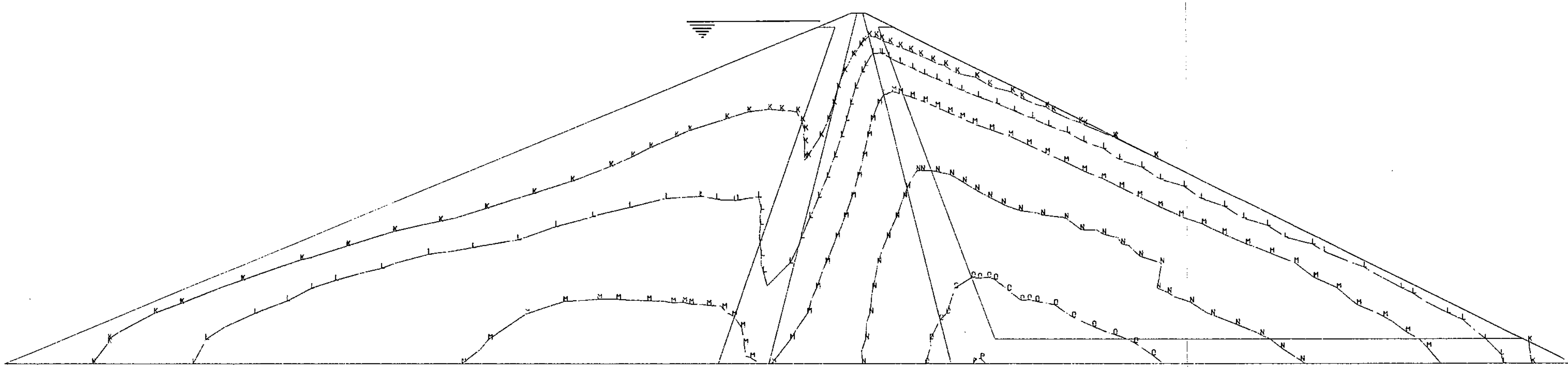
SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	-140.	-120.	-100.	-80.	-60.	-40.	-20.	-10.	-5.	0.
SYMBOL	K	L	M	N	O	P	Q	R	S	
VALUE	5.	10.	20.	40.	60.	80.	100.	120.	140.	

STATIC RUN STIFF CORE

VERTICAL EFFECTIVE STRESS (SIGv') (KSF)

FIGURE B6.14

ACRES



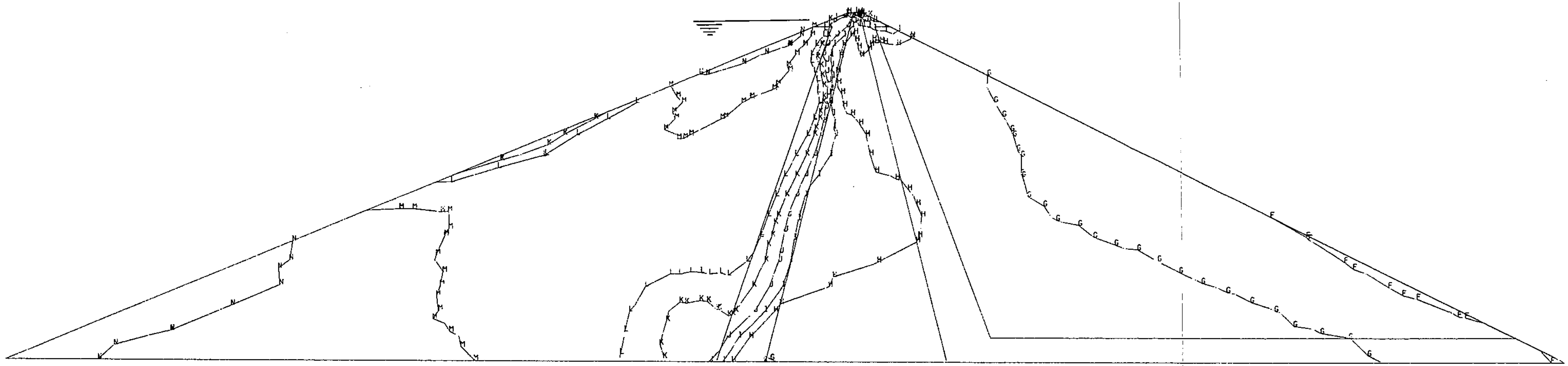
SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	-140.	-120.	-100.	-80.	-60.	-40.	-20.	-10.	-5.	0.
SYMBOL	K	L	M	N	O	P	Q	R	S	
VALUE	5.	10.	20.	40.	60.	80.	100.	120.	140.	

STATIC RUN STIFF CORE

2-D EFFECTIVE CONFINING STRESS (SIG2') (KSF)

FIGURE B6.15

ACRES

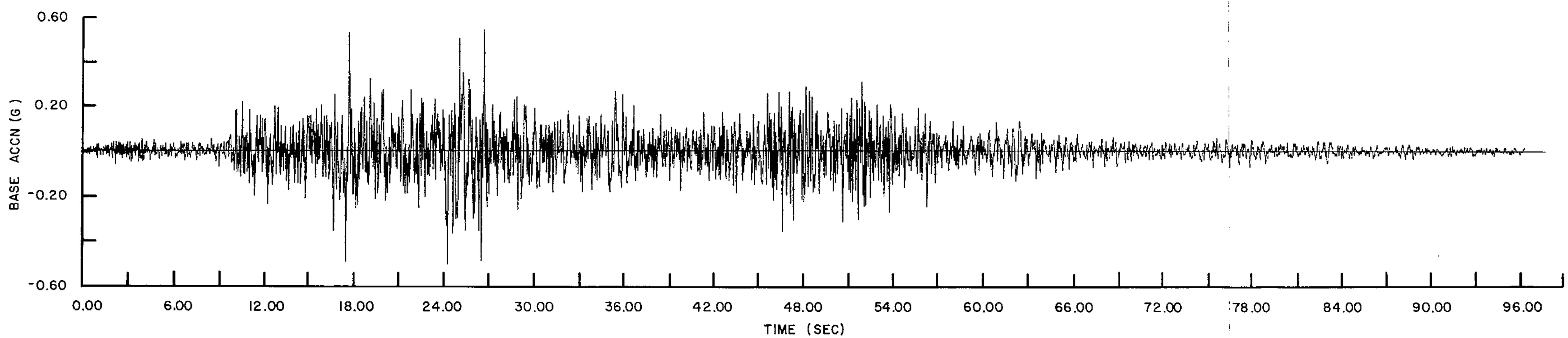


SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	-10.0	-8.0	-6.0	-4.0	-2.0	-1.0	-0.5	-0.2	-0.1	0.0
SYMBOL	K	L	M	N	O	P	Q	R	S	
VALUE	0.1	0.2	0.5	1.0	2.0	4.0	6.0	8.0	10.0	

STATIC RUN STIFF CORE

LOCAL XY SHEAR EXCEEDANCE (TAUxy/SH)

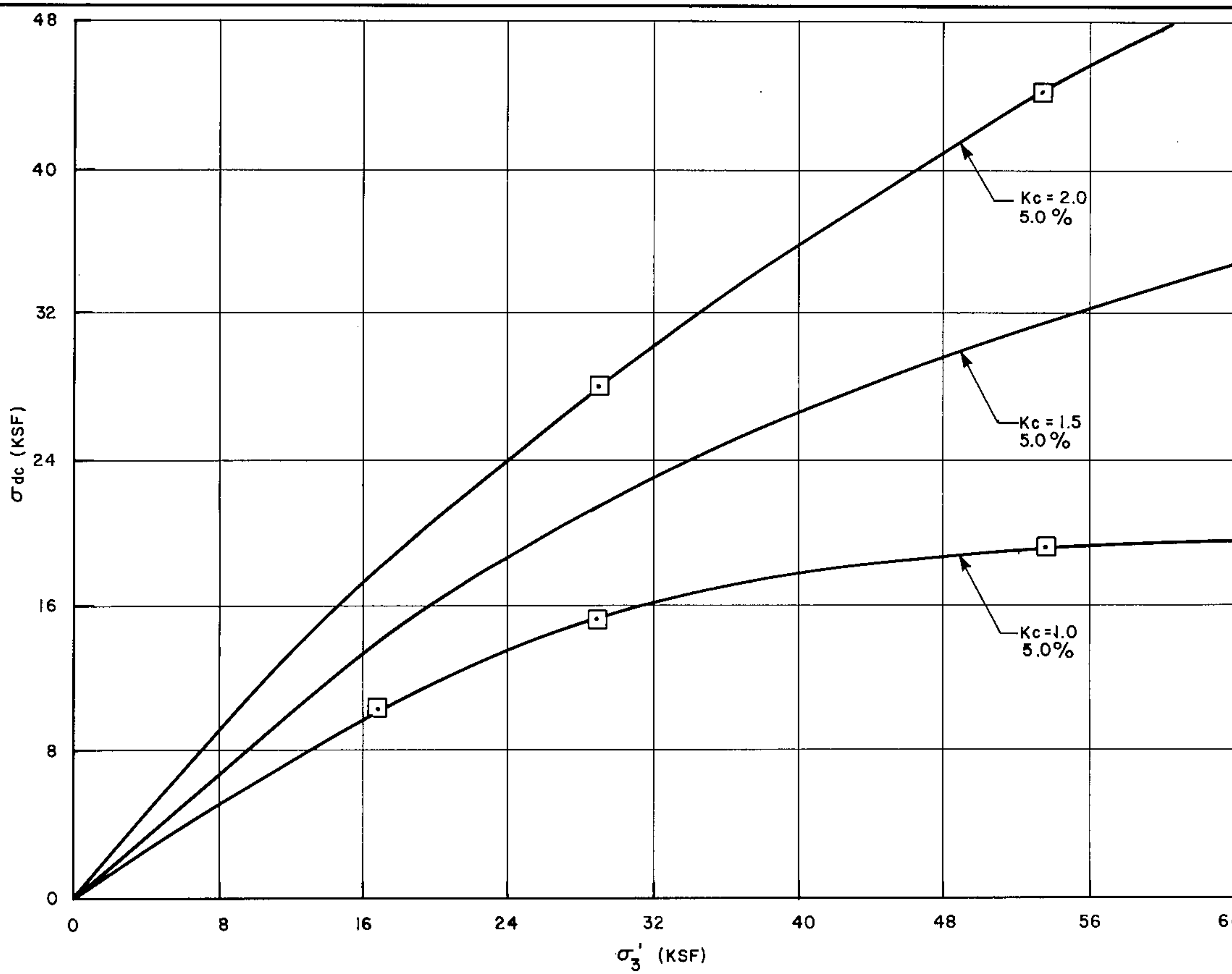
FIGURE B6.16



EARTHQUAKE TIME HISTORY

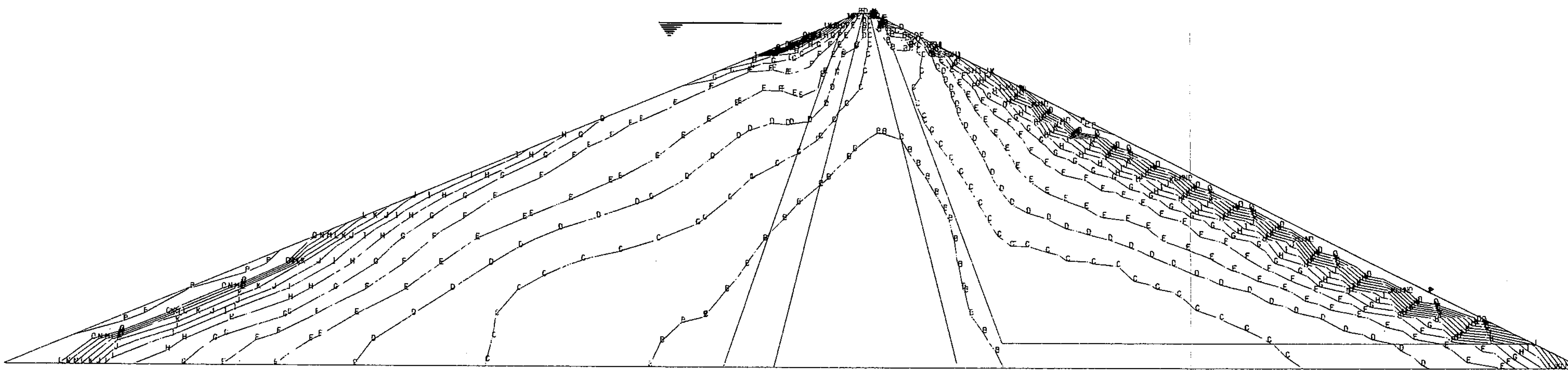
FIGURE B6.17

ACRES



CYCLIC DEVIATOR STRESS VS. CONFINING STRESS

FIGURE B6.18



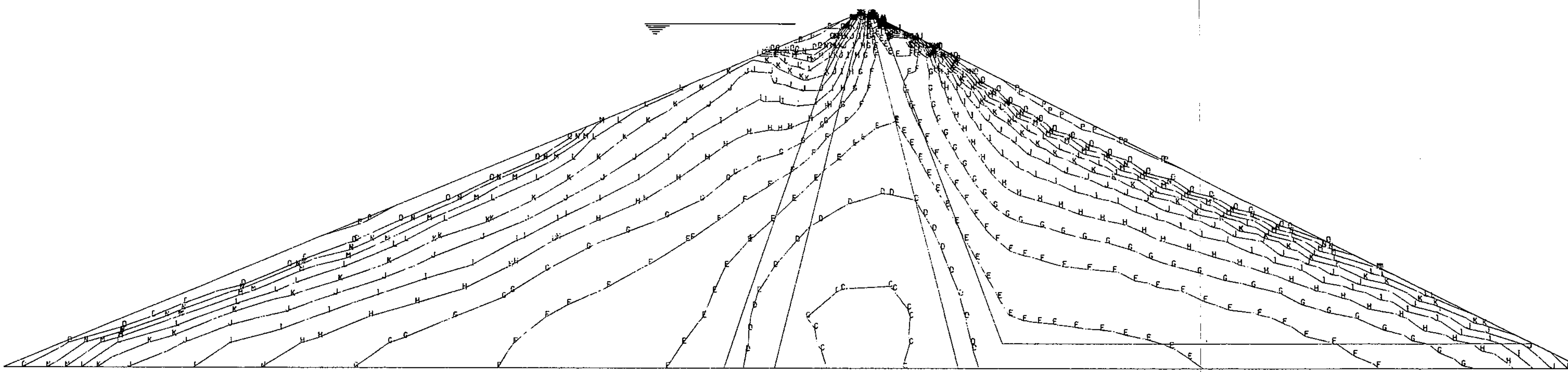
SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
SYMBOL	K	L	M	N	O	P	Q	R	S	
VALUE	1.1	1.2	1.3	1.4	1.5	2.0	4.0	6.0	8.0	

DYNAMIC RUN SOFT CORE

DRAINED SHEAR STRESS EXCEEDANCE (TAUdeff/TAUfd)

FIGURE B6.19

ACRES



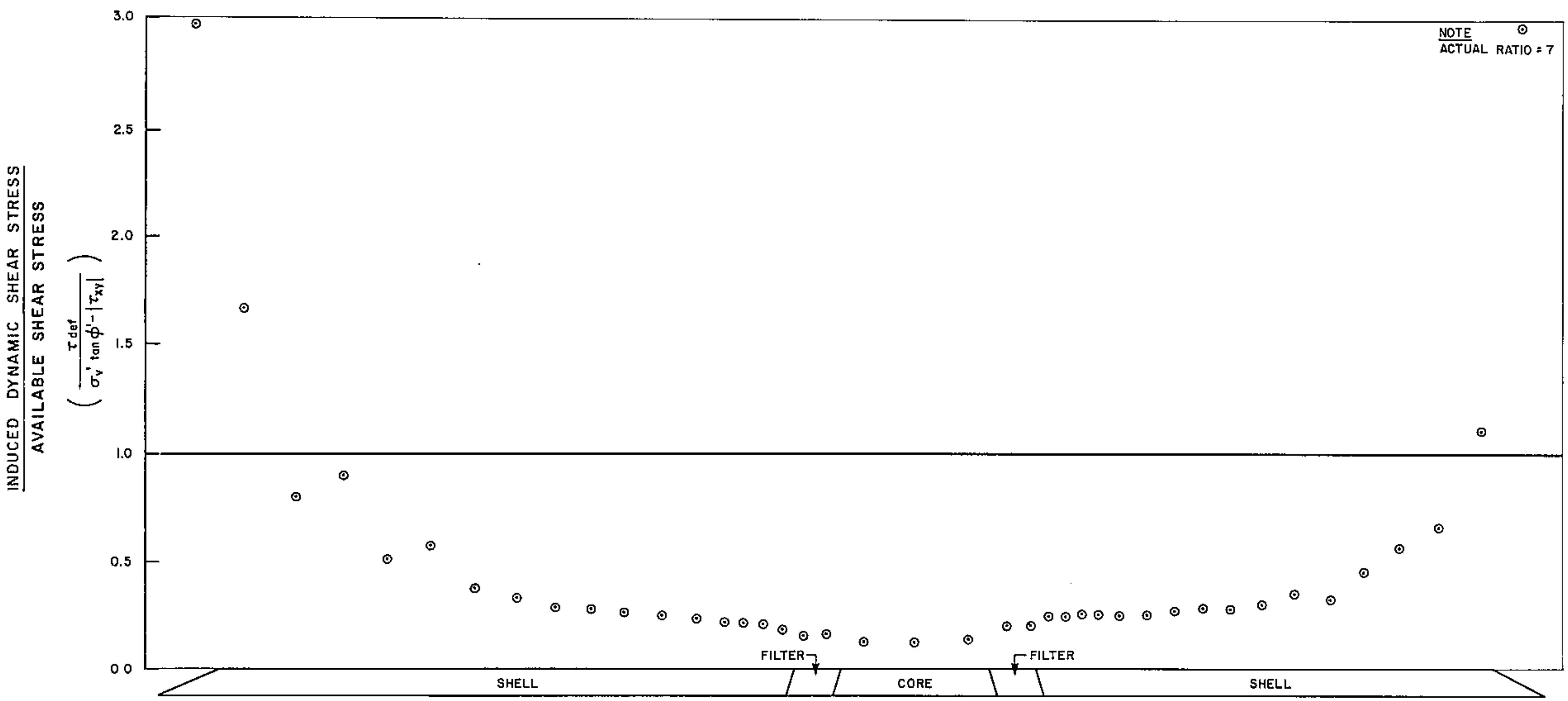
SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
SYMBOL	K	L	M	N	O	P	Q	R	S	
VALUE	1.1	1.2	1.3	1.4	1.5	2.0	4.0	6.0	8.0	

DYNAMIC RUN SOFT CORE

UNDRAINED SHEAR STRESS EXCEEDANCE (TAU d max / TAU c)

ACRES

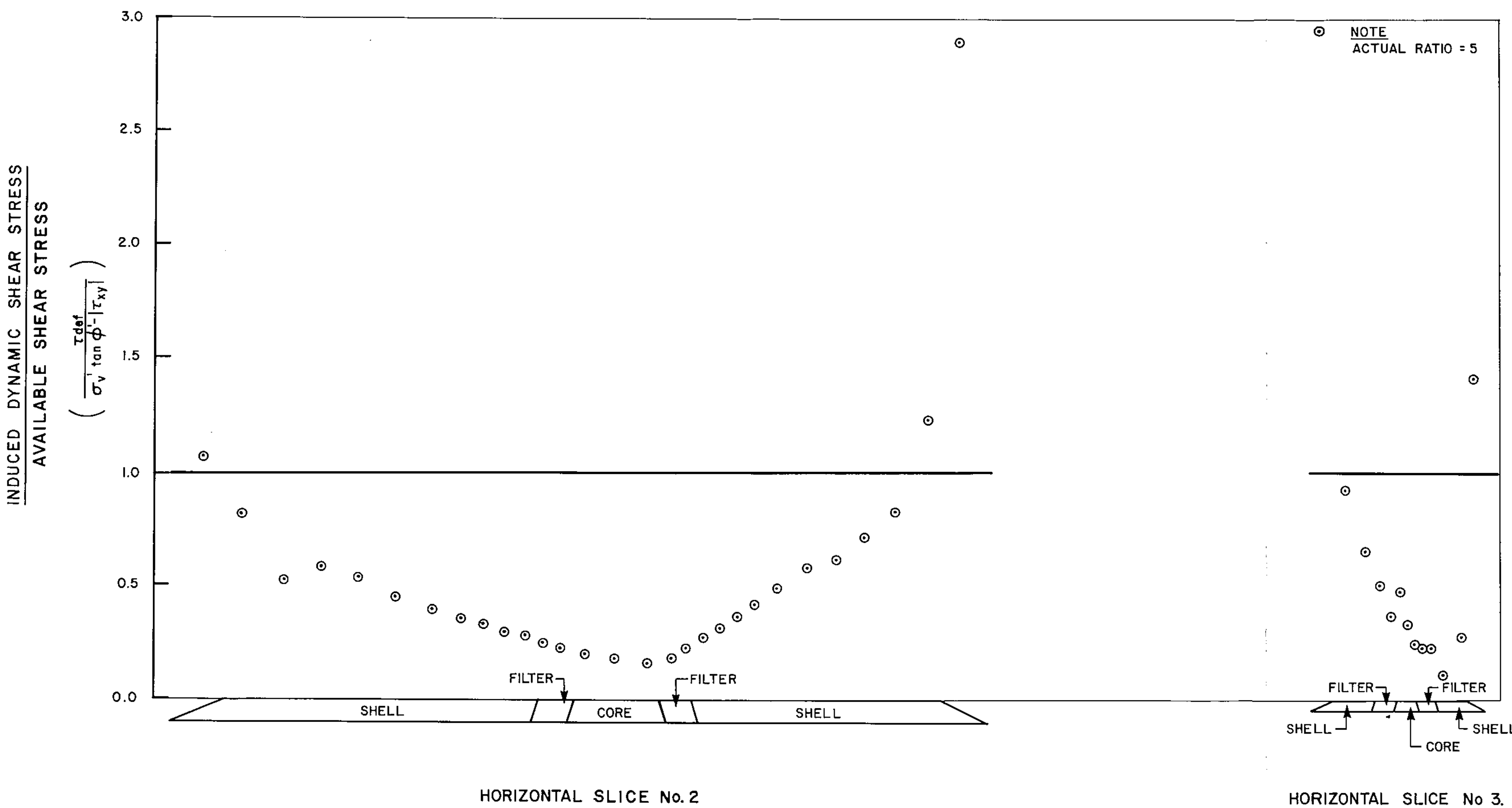
FIGURE B6.20



HORIZONTAL SLICE No. 1

DYNAMIC RUN SOFT CORE
HORIZONTAL SLICE No. 1

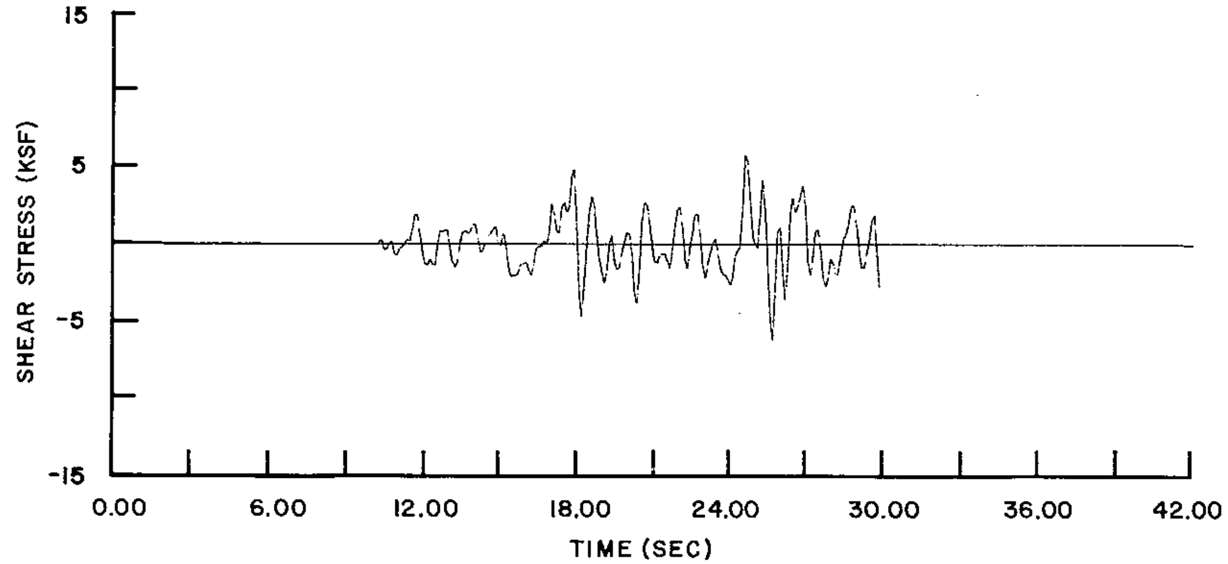
FIGURE B6.21



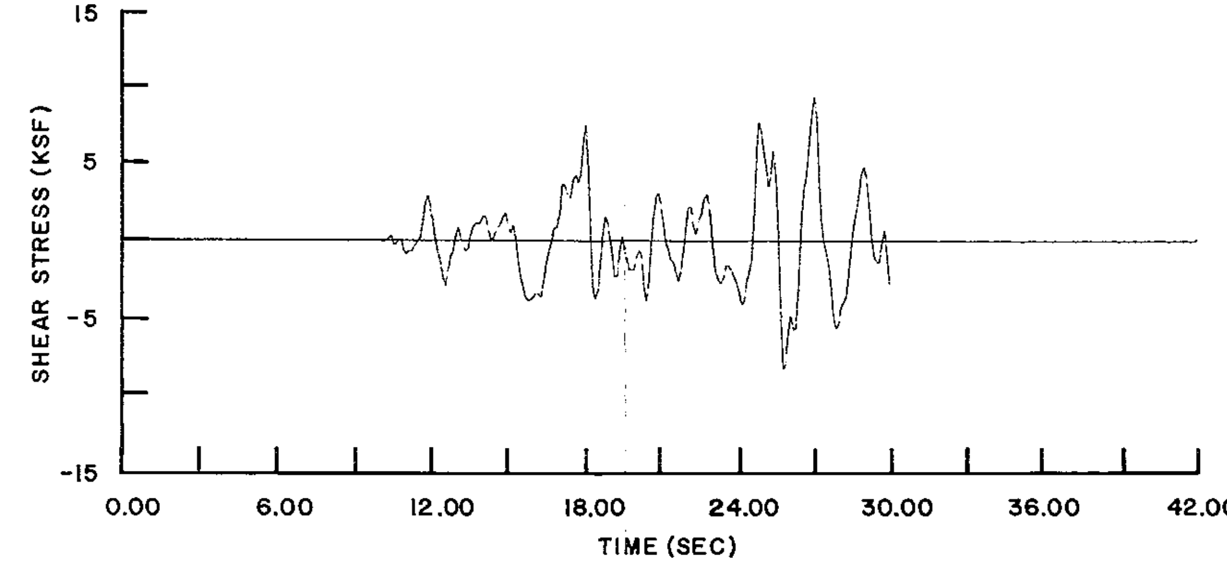
DYNAMIC RUN SOFT CORE

HORIZONTAL SLICES No. 2 & 3

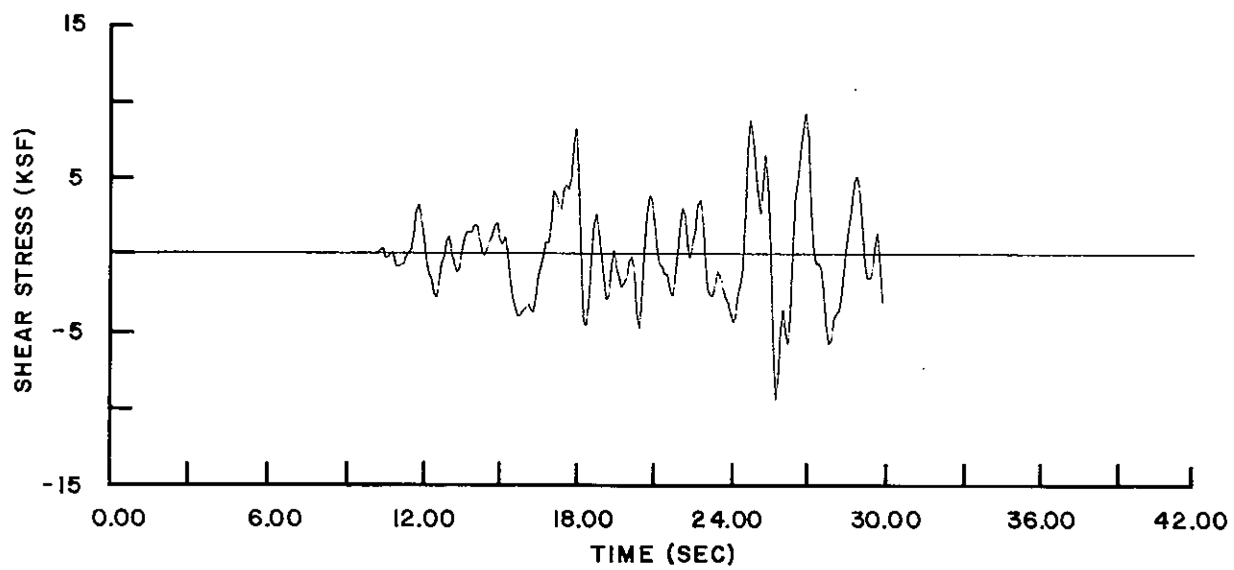
FIGURE B6.22



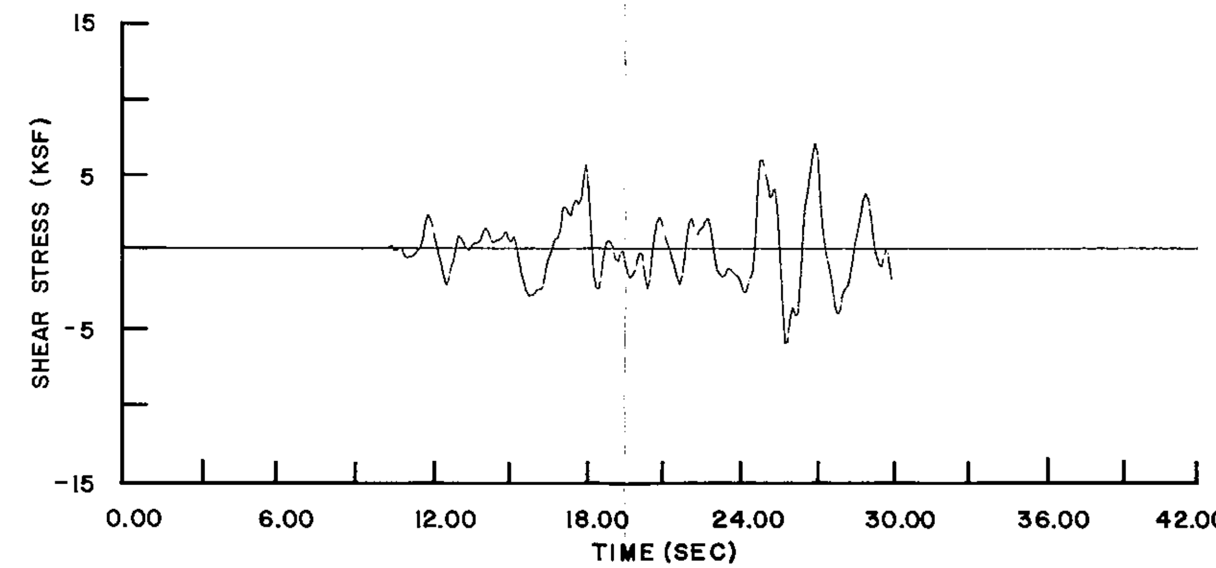
ELEMENT 91



ELEMENT 105



ELEMENT 97



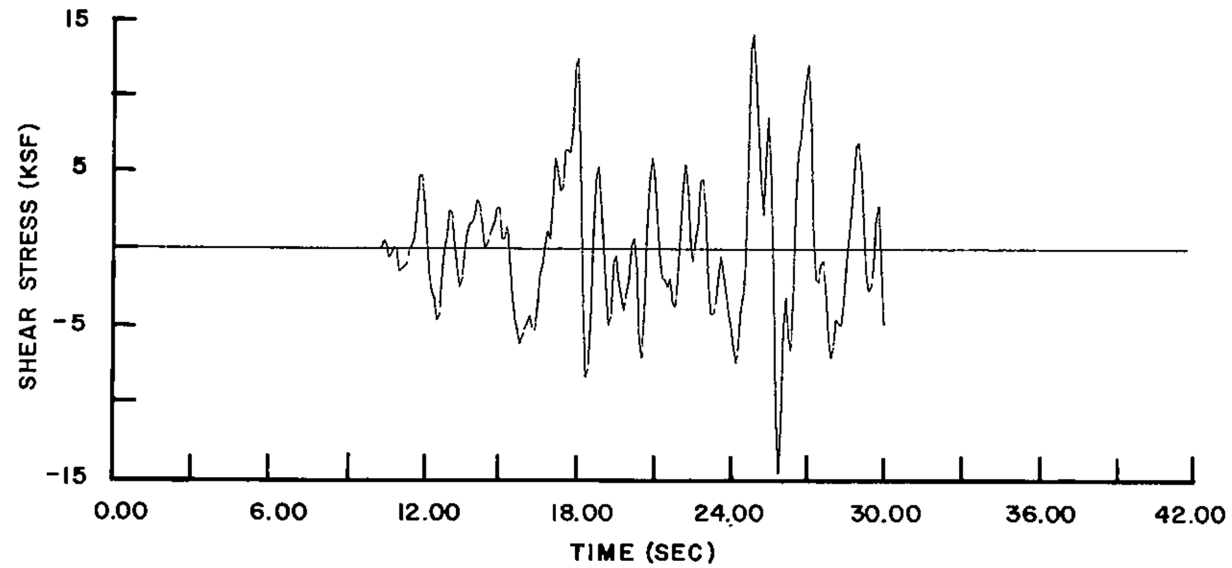
ELEMENT 109

DYNAMIC RUN SOFT CORE

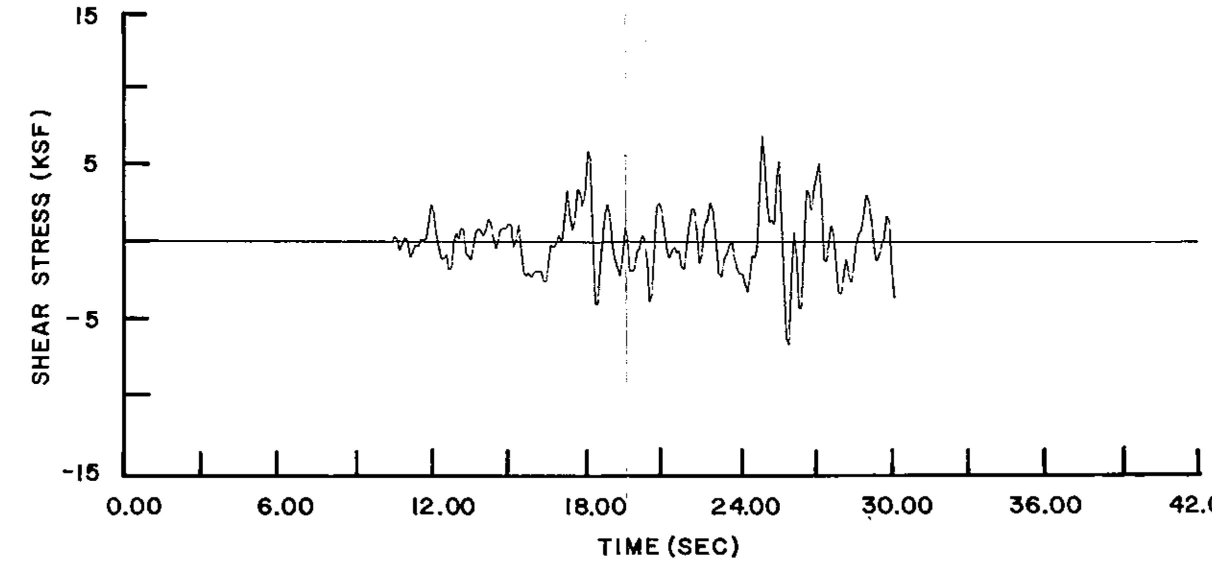
SHEAR STRESS TIME HISTORY PLOTS

FIGURE B6.23

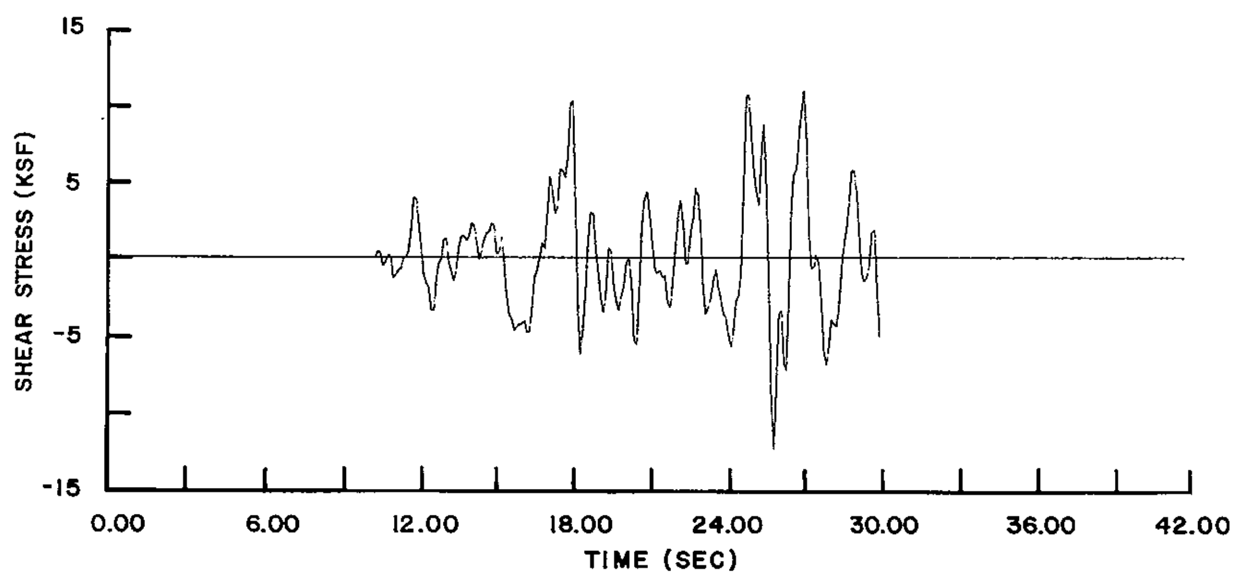
ACRES



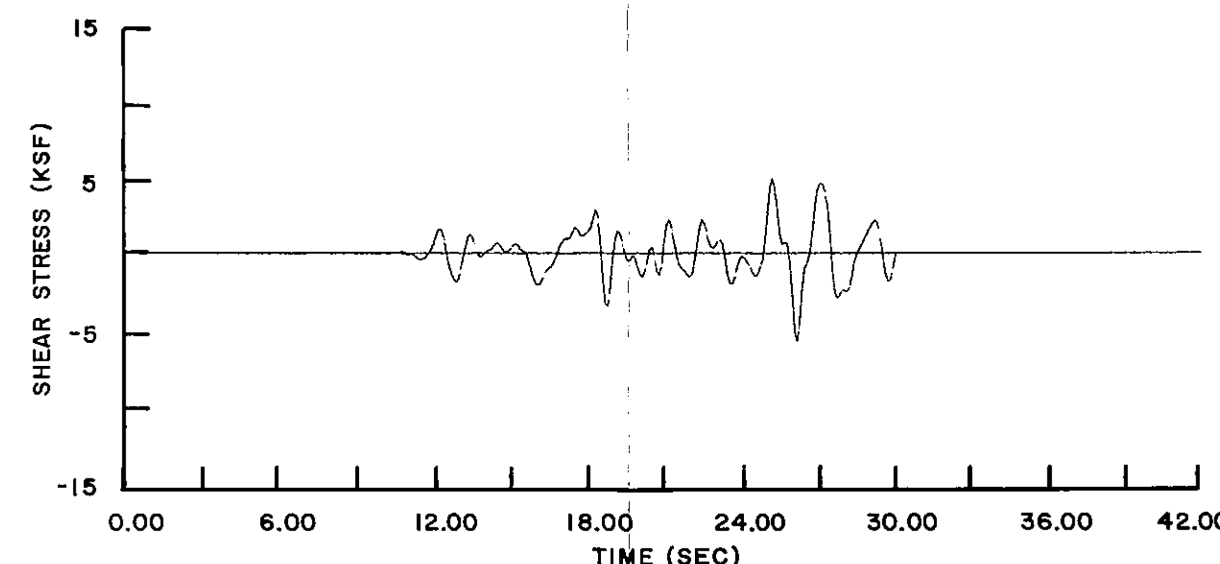
ELEMENT 113



ELEMENT 127



ELEMENT 121



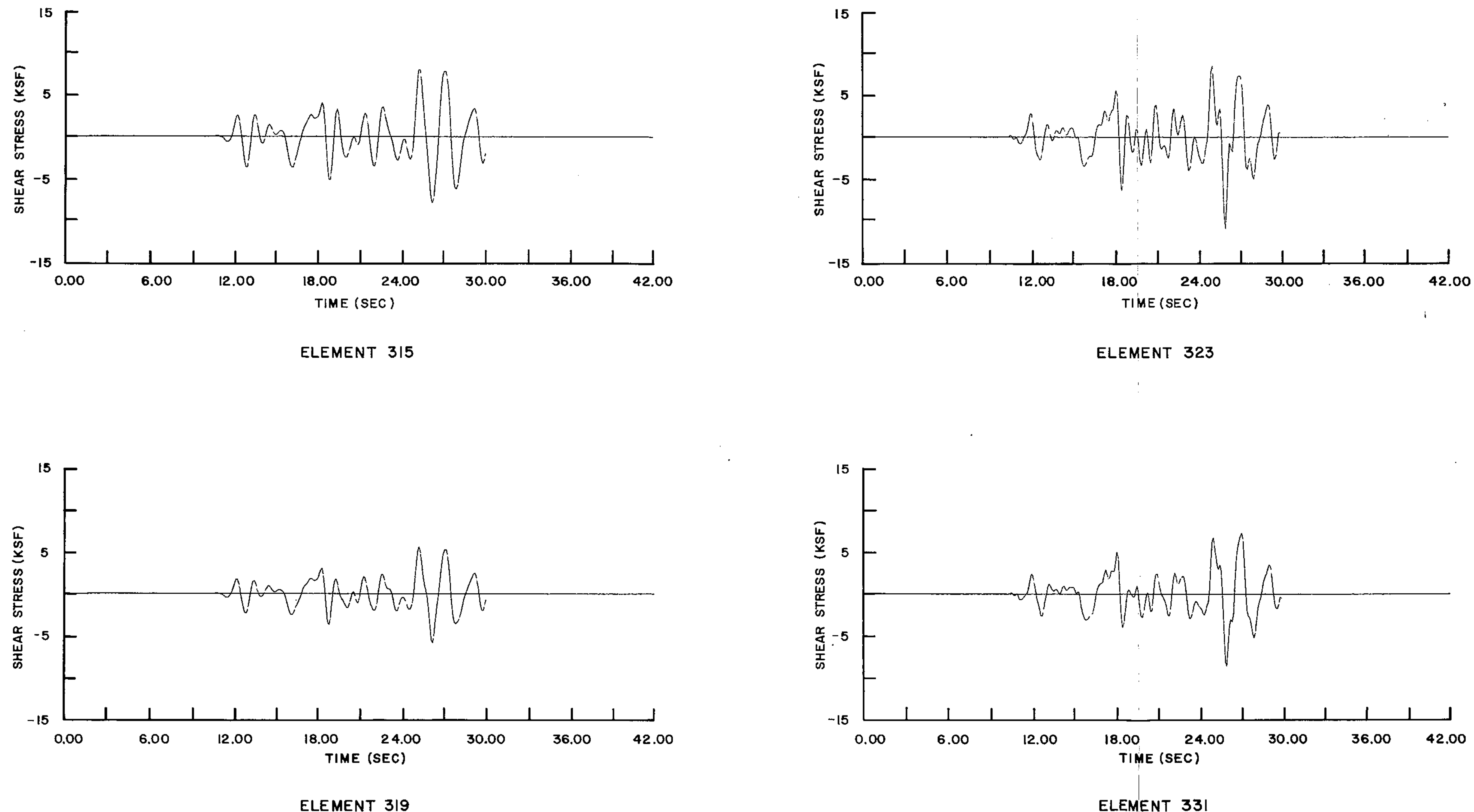
ELEMENT 307

DYNAMIC RUN SOFT CORE

SHEAR STRESS TIME HISTORY PLOTS

FIGURE B6.24

ACRES

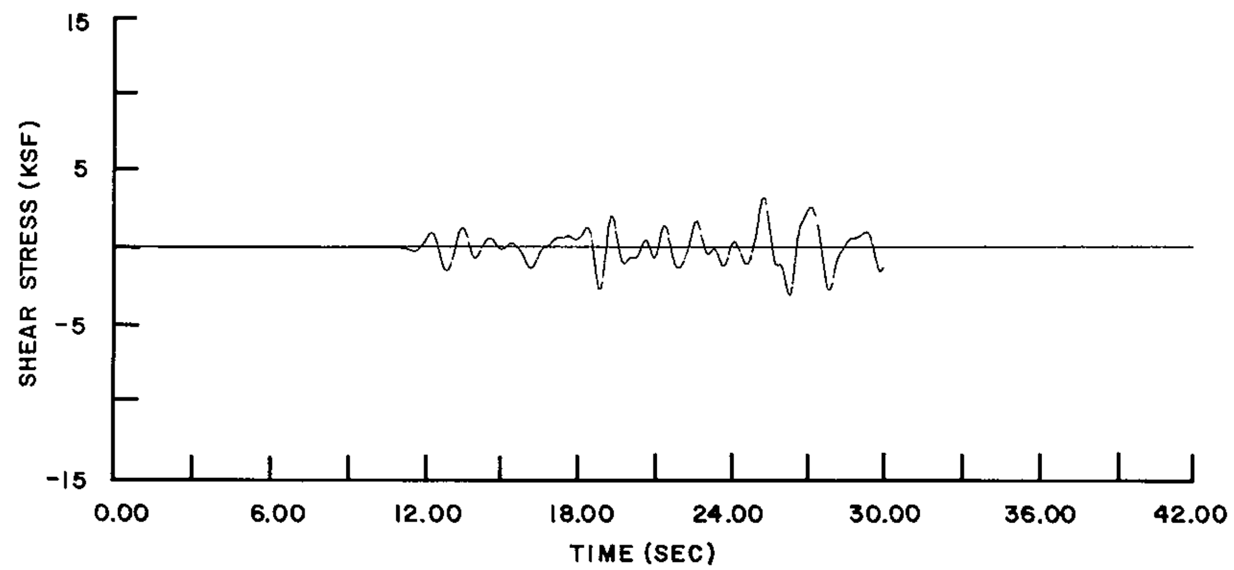


DYNAMIC RUN SOFT CORE

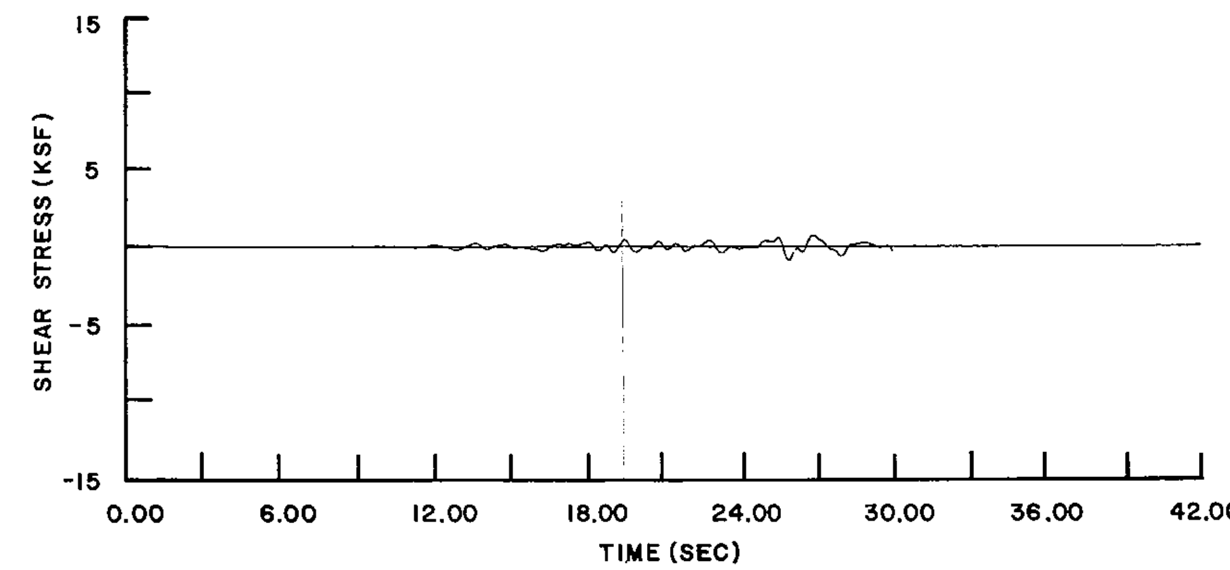
SHEAR STRESS TIME HISTORY PLOTS

FIGURE B6.25

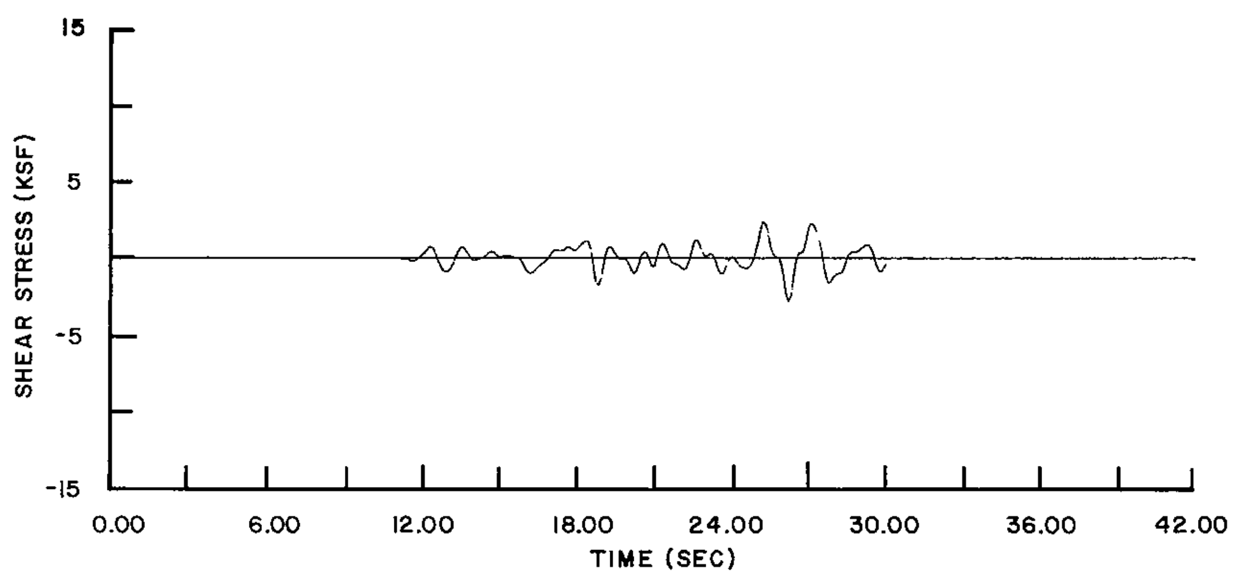
ACRES



ELEMENT 483



ELEMENT 491



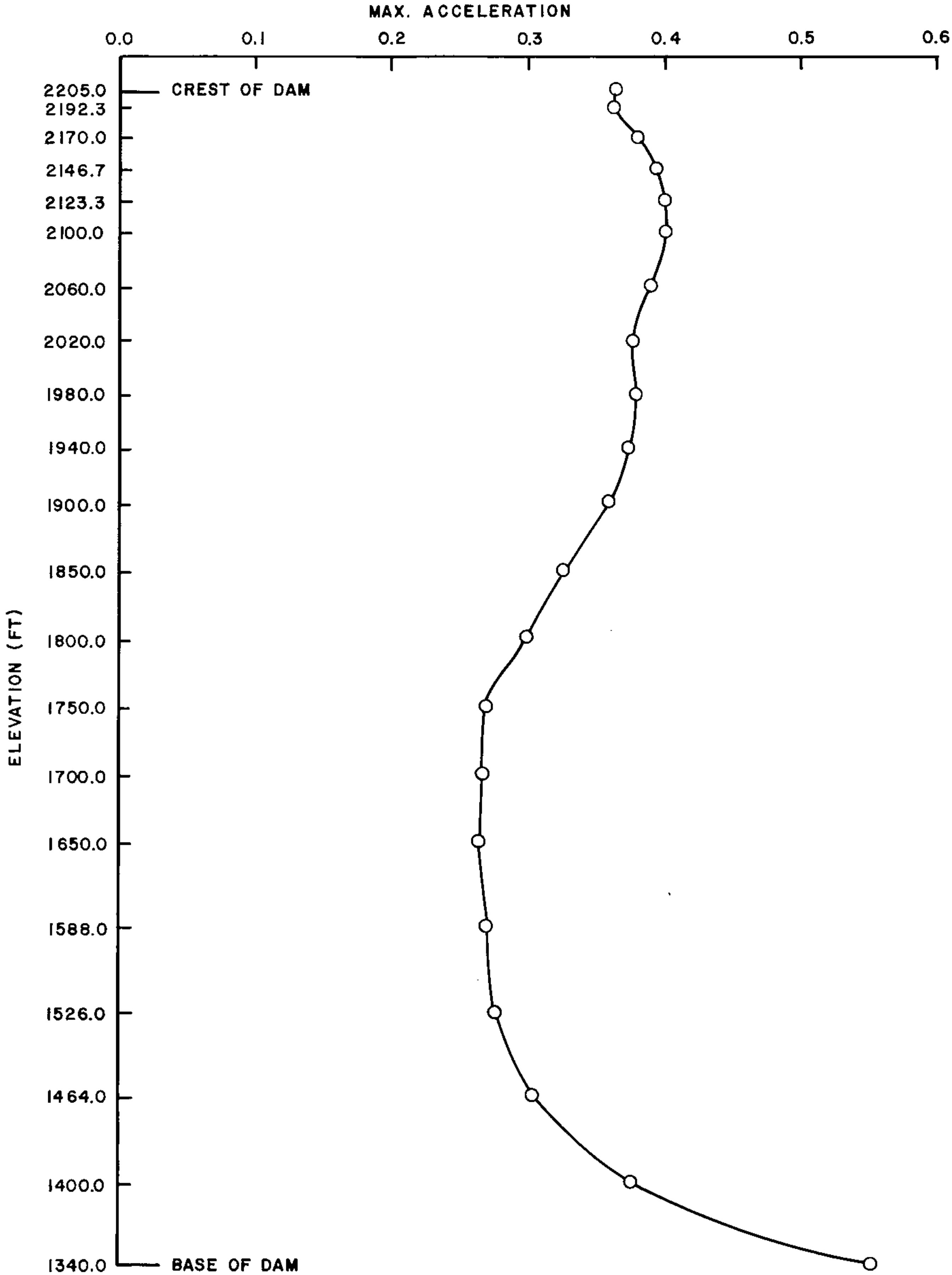
ELEMENT 487

DYNAMIC RUN SOFT CORE

SHEAR STRESS TIME HISTORY PLOTS

FIGURE B6.26

ACRES

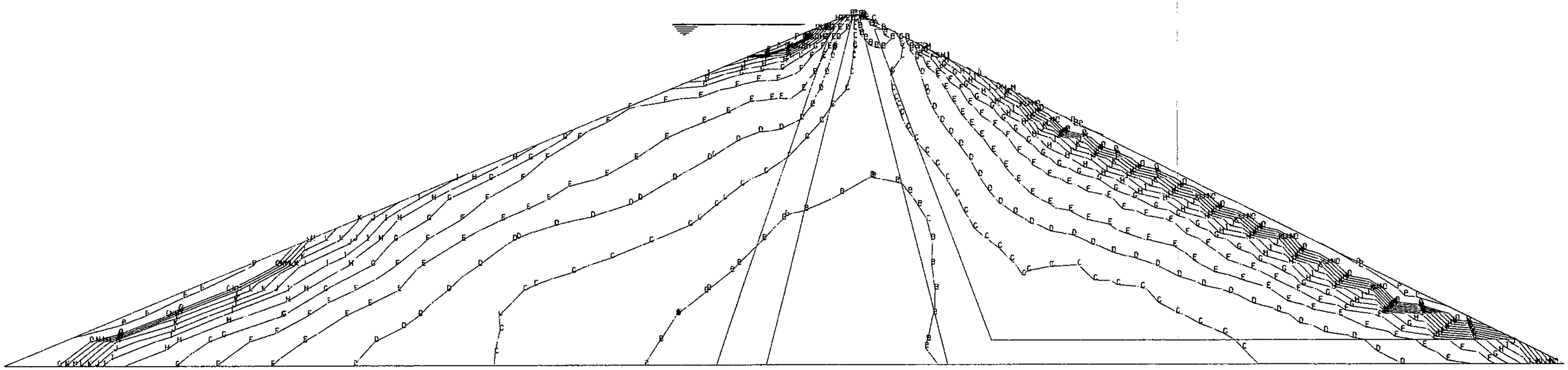


DYNAMIC RUN SOFT CORE

MAXIMUM ACCELERATION VS. HEIGHT

ACRES

FIGURE B6.27



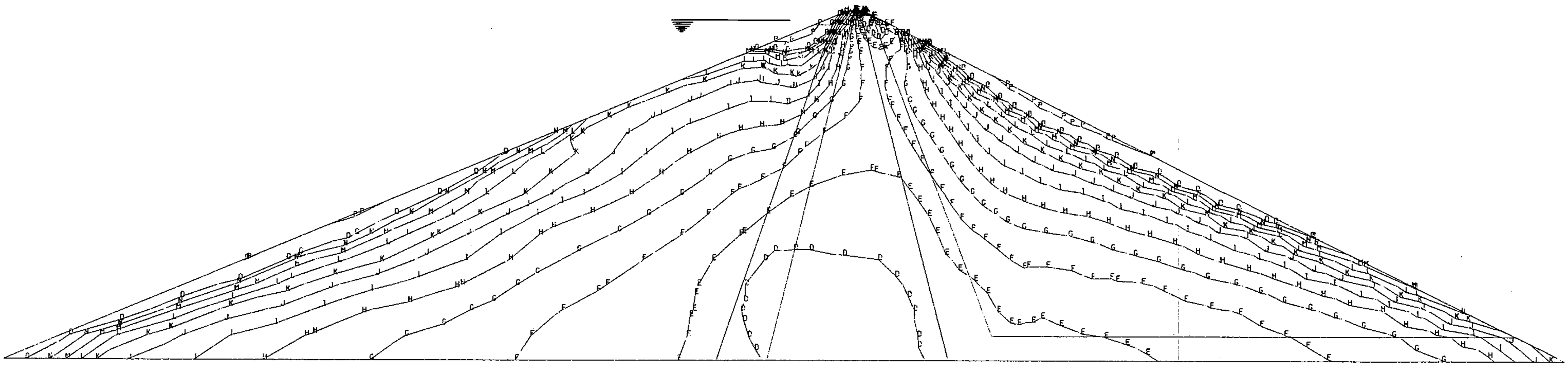
SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
SYMBOL	K	L	M	N	O	P	Q	R	S	
VALUE	1.1	1.2	1.3	1.4	1.5	2.0	4.0	6.0	8.0	

DYNAMIC RUN STIFF CORE

DRAINED SHEAR STRESS EXCEEDANCE (TAUdeff/TAUfd)

FIGURE B6.28

ACRES



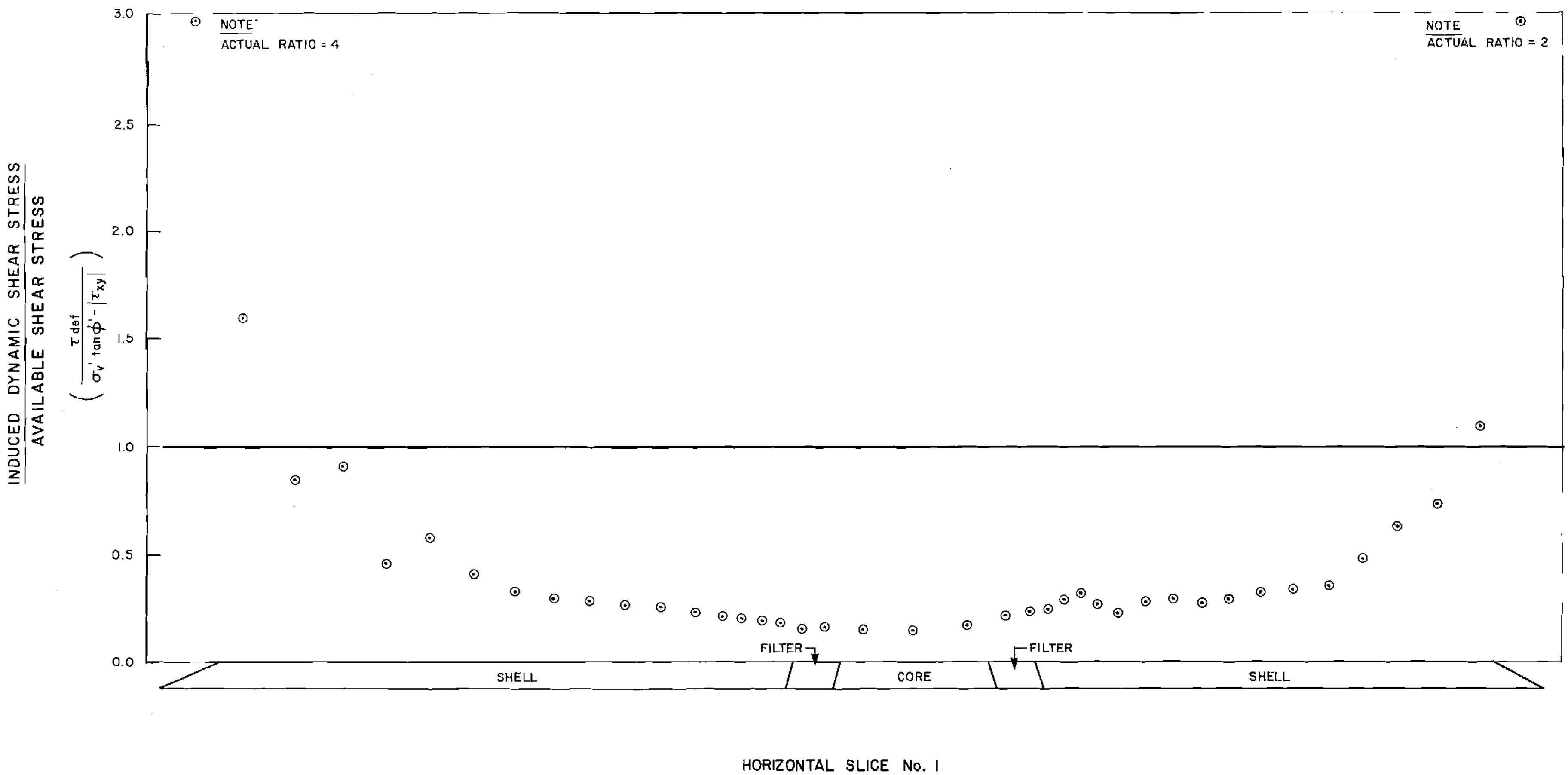
SYMBOL	A	B	C	D	E	F	G	H	I	J
VALUE	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
SYMBOL	K	L	M	N	O	P	Q	R	S	
VALUE	1.1	1.2	1.3	1.4	1.5	2.0	4.0	6.0	8.0	

DYNAMIC RUN STIFF CORE

UNDRAINED SHEAR STRESS EXCEEDANCE (TAUdmax/TAUc)

FIGURE B6.29

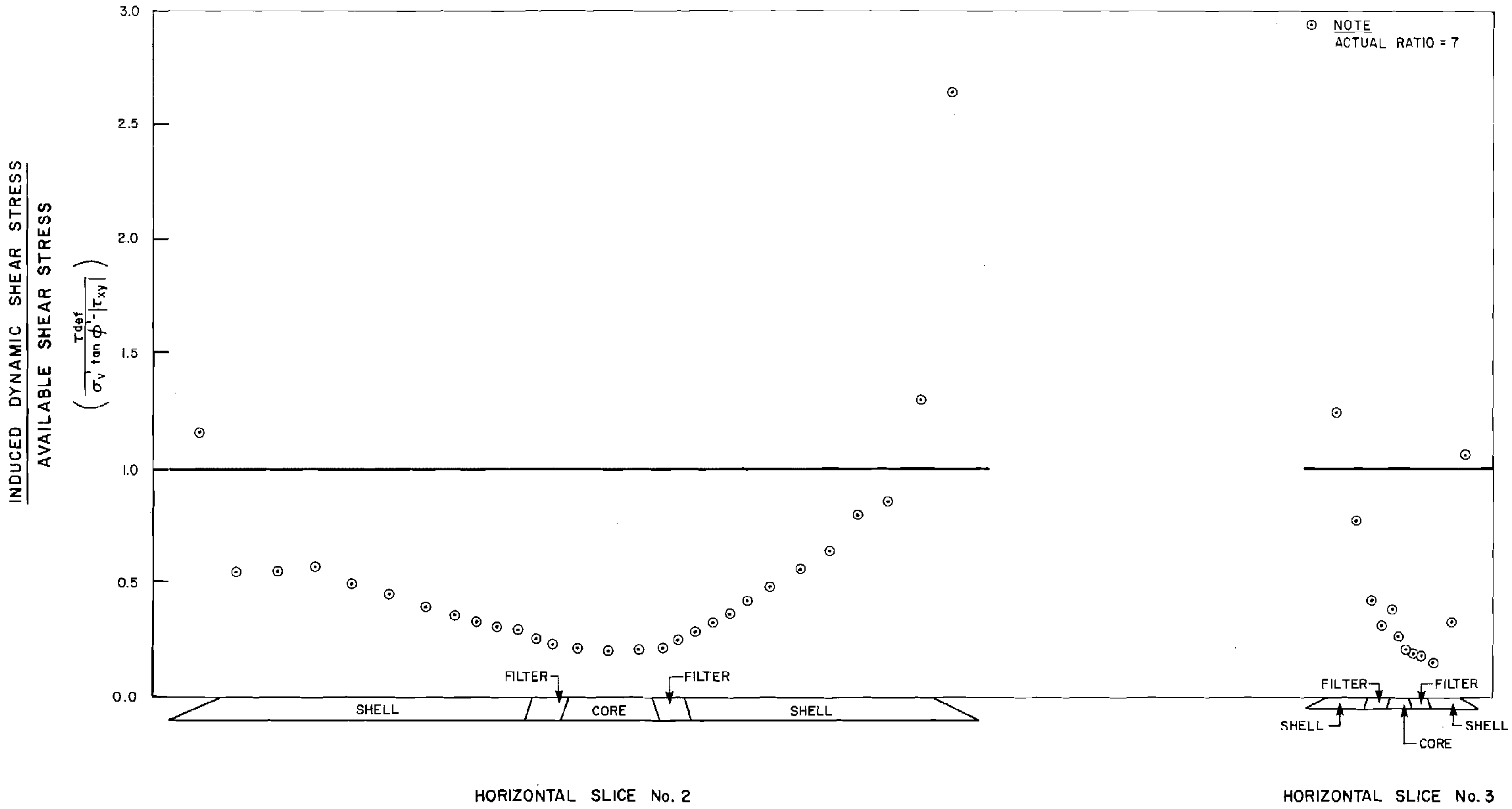
ACRES



DYNAMIC RUN STIFF CORE

HORIZONTAL SLICE No. I

FIGURE B6.30

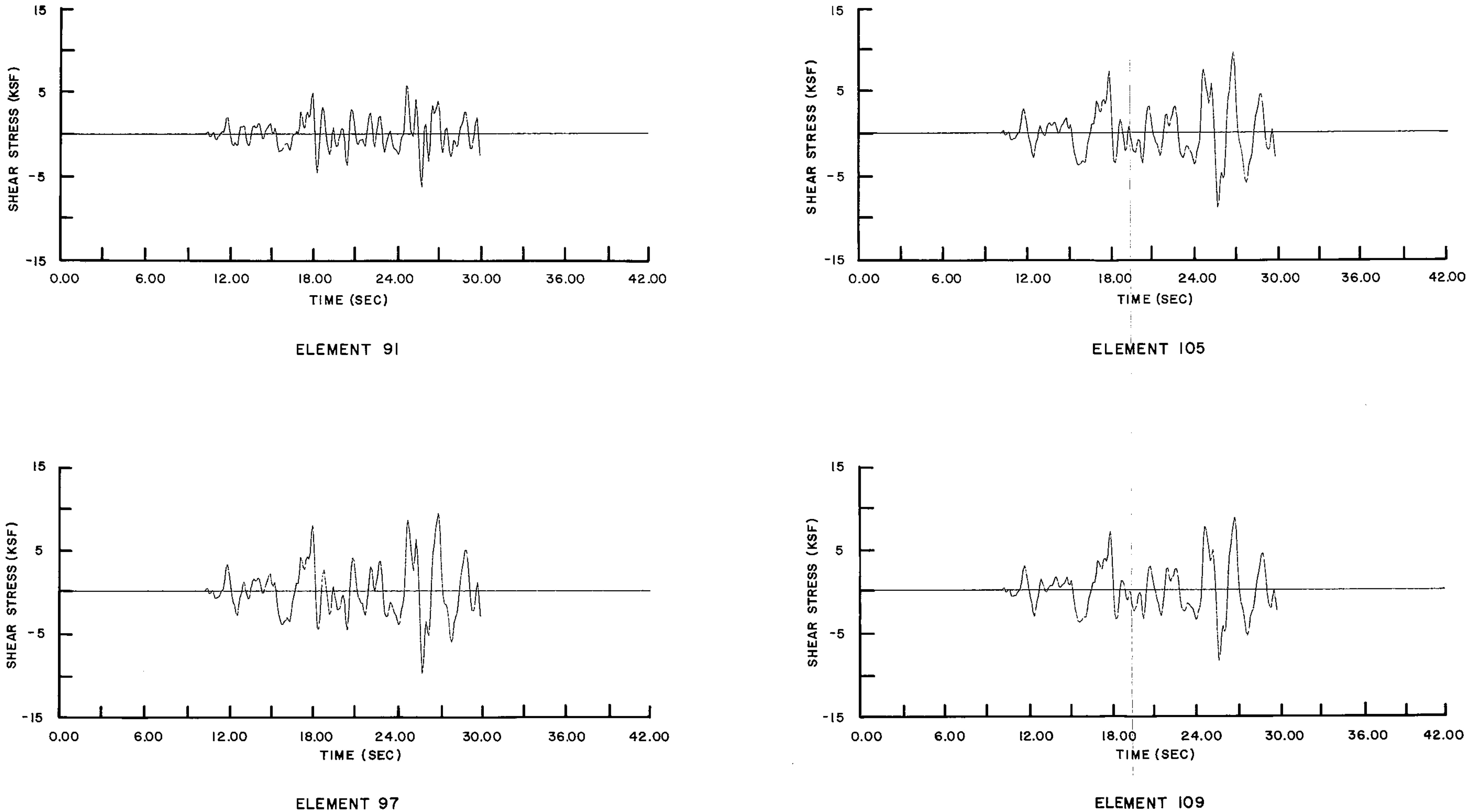


DYNAMIC RUN STIFF CORE

HORIZONTAL SLICE No. 2 & 3

FIGURE B6.31

ACRES

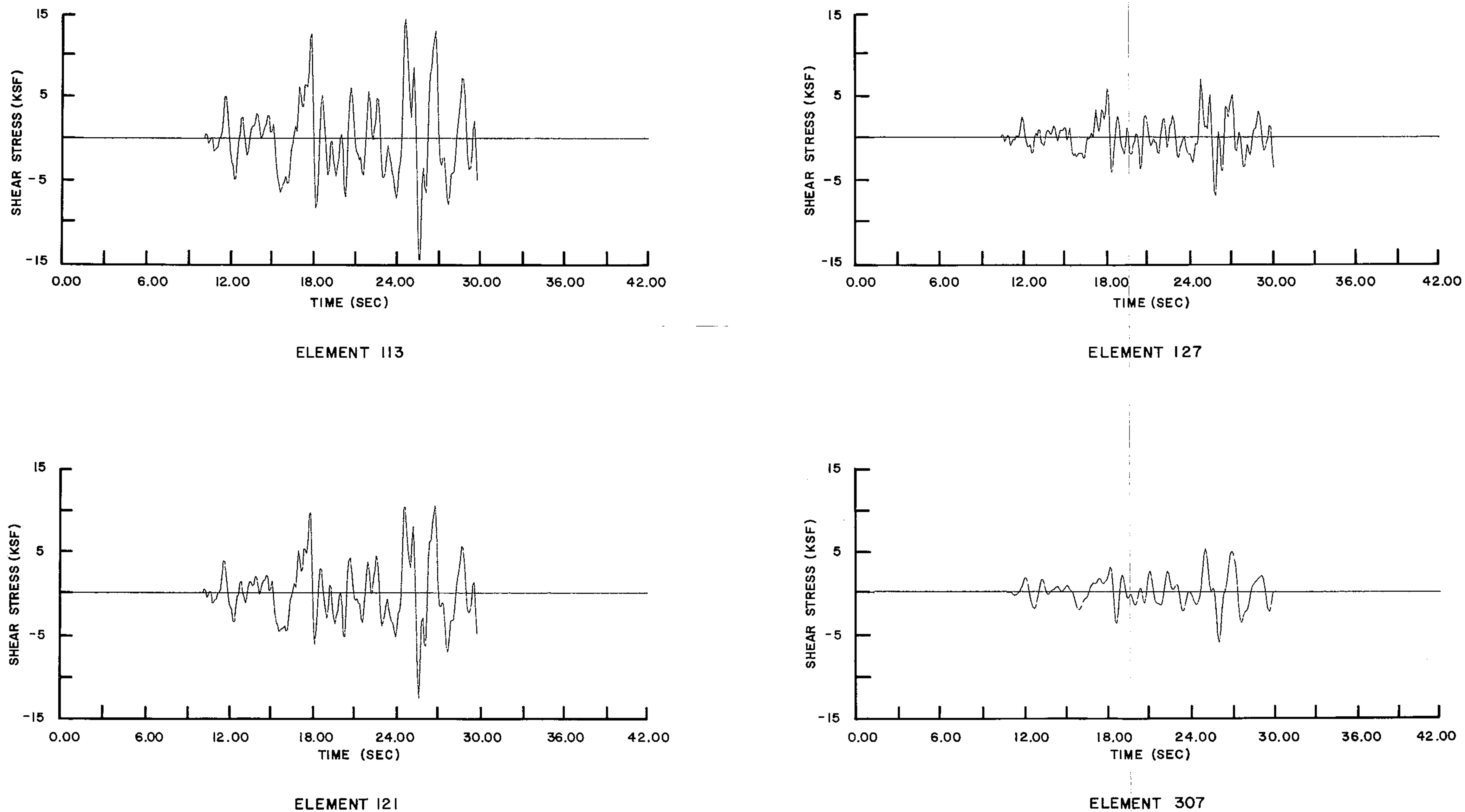


DYNAMIC RUN STIFF CORE

SHEAR STRESS TIME HISTORY PLOTS

FIGURE B6.32

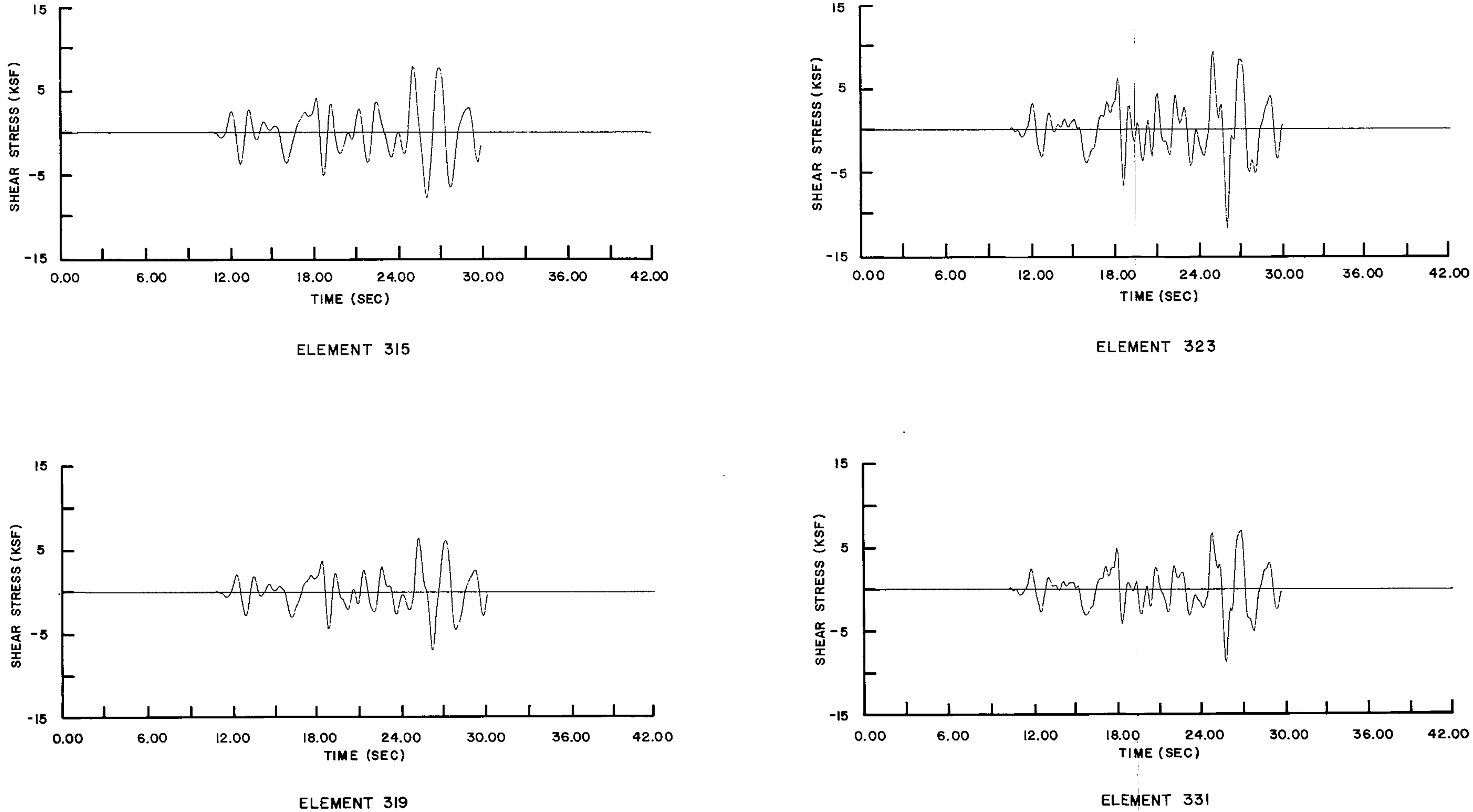
ACRES



DYNAMIC RUN STIFF CORE

SHEAR STRESS TIME HISTORY PLOTS

FIGURE B6.33

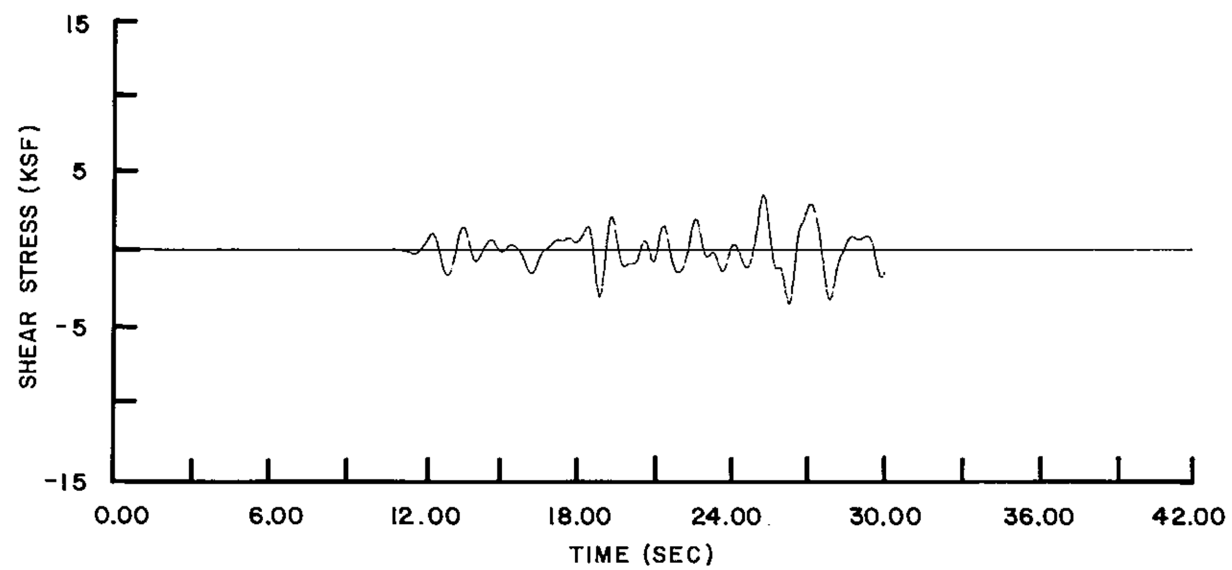


DYNAMIC RUN STIFF CORE

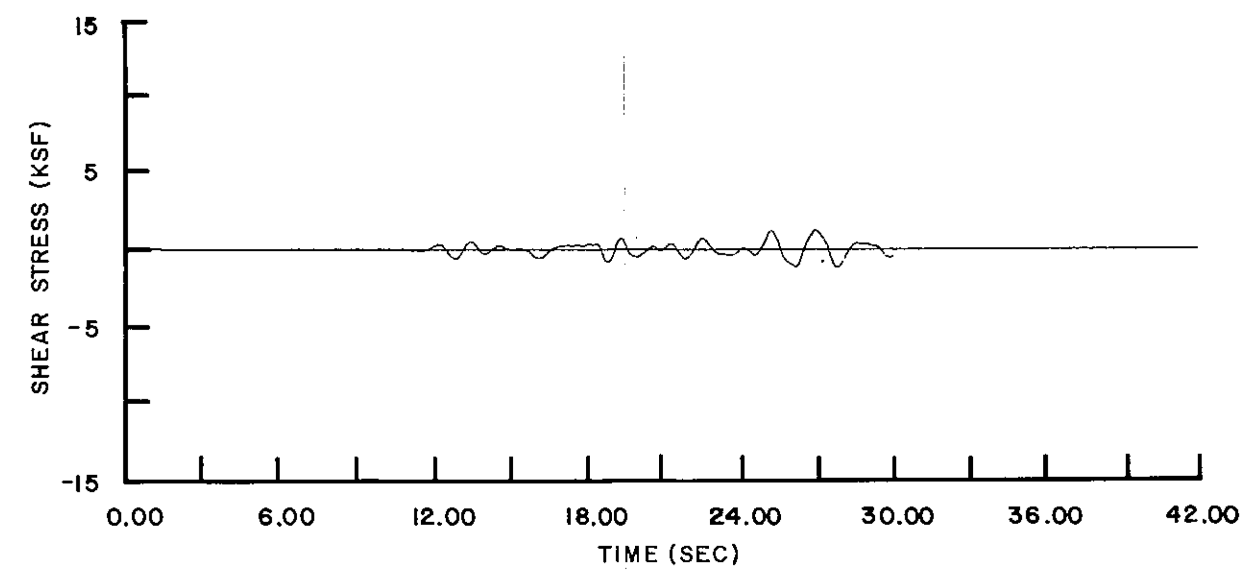
SHEAR STRESS TIME HISTORY PLOTS

FIGURE B6.34

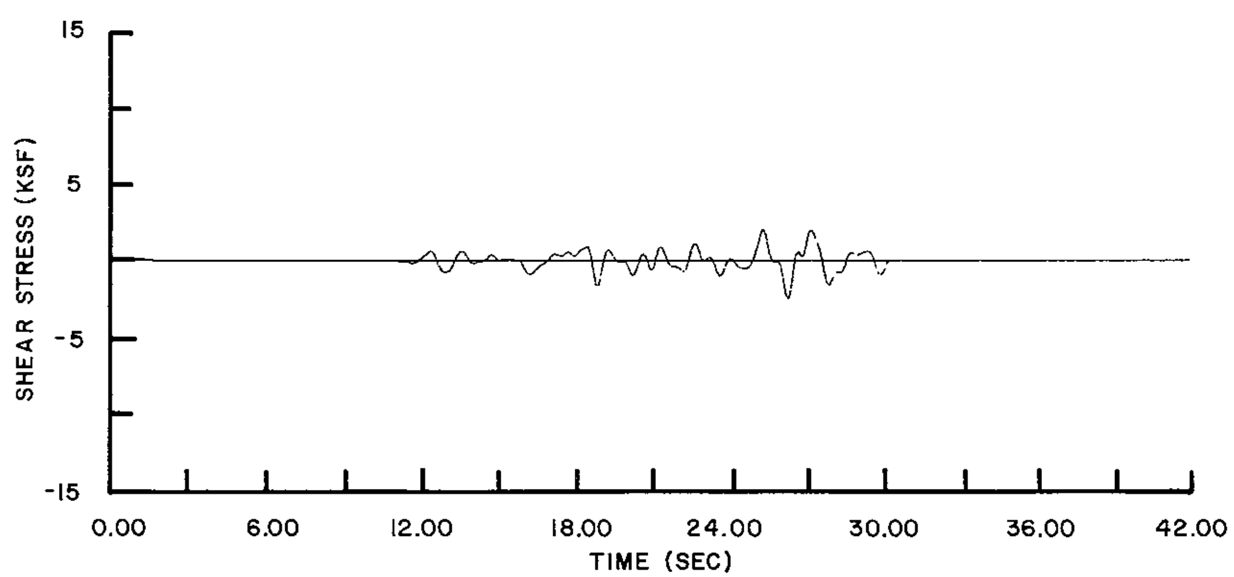
ACRES



ELEMENT 483



ELEMENT 491



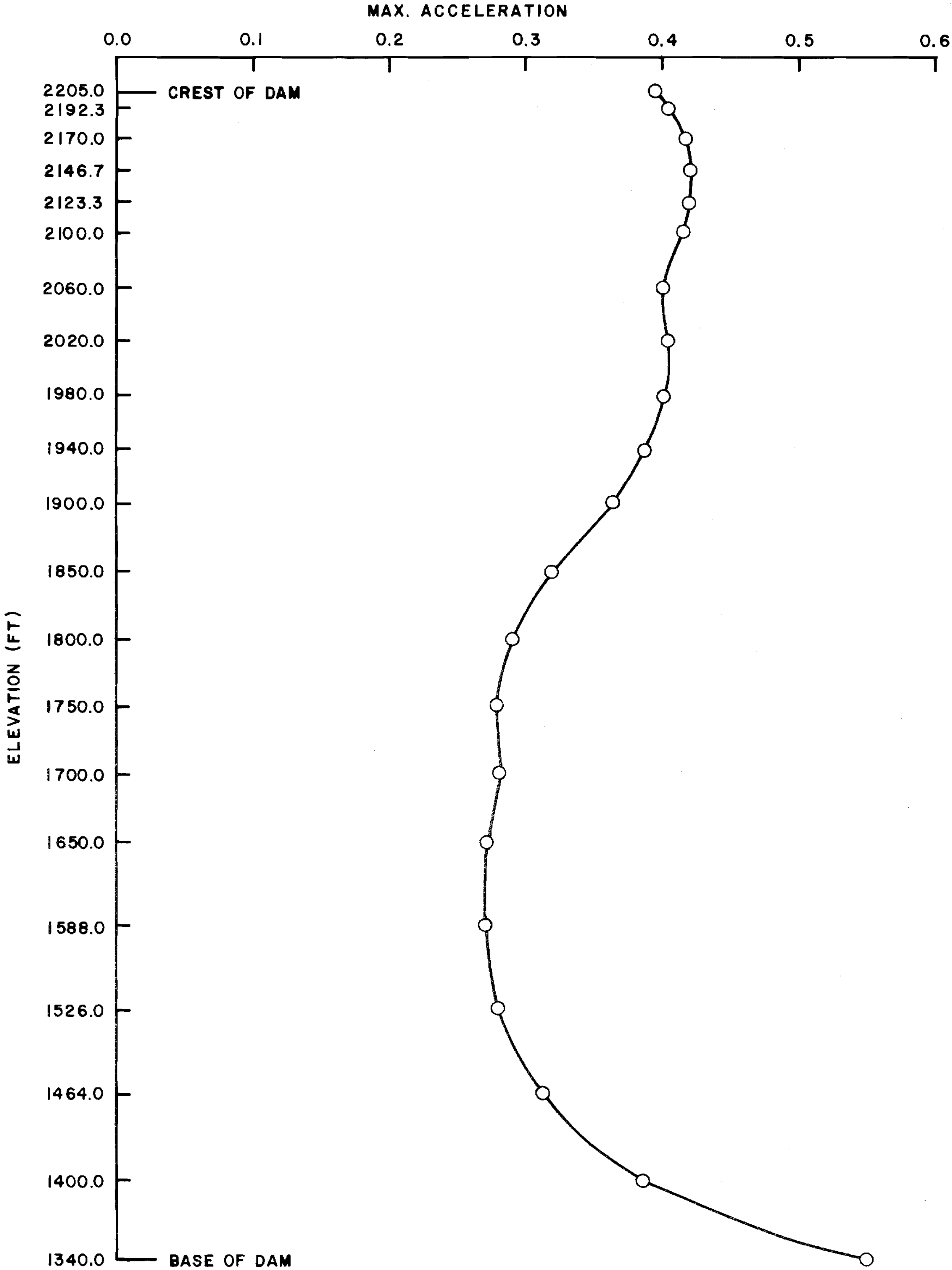
ELEMENT 487

DYNAMIC RUN STIFF CORE

SHEAR STRESS TIME HISTORY PLOTS

FIGURE B6.35

ACRES



DYNAMIC RUN STIFF CORE

MAXIMUM ACCELERATION VS. HEIGHT

ACRES

FIGURE B6.36

APPENDIX B7

ACCESS AND CAMP FACILITIES

1 - INTRODUCTION

The construction of the Watana and Devil Canyon power developments will require various facilities to support the construction activities throughout the entire construction period. Following construction, the operation of the power development will require certain facilities to support the permanent operation and maintenance of the power facility.

The concept adopted for project planning and feasibility and cost assessment purposes is based on completely self-contained and comprehensive community facilities. Variations in this concept are possible in which families are located elsewhere and appropriate transportation and other facilities are provided. The overall cost of such arrangements is not, however, expected to be significantly different.

The largest item among the proposed site facilities is a combination camp/village that will be constructed and operated at the project site. The camp/village will be an entire community, complete within itself, designed to house and maintain living facilities for the work force and supporting population of up to 4,000 people during the peak construction period of the Watana power development, and up to 1,900 people during the peak construction period at the Devil Canyon power development. The camp/village includes the services required to maintain the facilities.

The camp/village will be a major entity within itself, with buildings, roads, utilities, recreation facilities, etc. On completion of the project, it is planned to dismantle and demobilize the construction camp facility. Upon demobilizing the site, the area will be reclaimed. It is additionally planned to utilize as much as possible, dismantled buildings and other items in the Watana camp/village for the Devil Canyon development.

Permanent facilities required for project operation include a permanent town or small community for approximately 130 staff members and their families. The permanent town has been conceptualized; however, it is recommended that preliminary design and final design be delayed until the late 1980s when more information as to the physical parameters of design are better known and, more importantly, the human requirements and preferences are better defined.

The damsites are located on the Susitna River in an area presently accessible only by air or rolligons in winter. The sites are approximately 115 miles north-northeast of Anchorage and 140 miles south of Fairbanks.

The proposed location of the Watana camp and village is on the north bank of the Susitna River between Deadman and Tsusena Creek, approximately 2-1/2 miles northeast of Watana. The location of the camp and village is presented on Plate 36.

REQUIRED SYSTEM CAPACITIES	90 gpcd*
CAMP (3,600 PEOPLE)	
ESTIMATED DAILY DEMAND (MAX.)	745,200 gal.
ESTIMATED HOURLY DEMAND (MAX.)	60,750 gal.
ESTIMATED DAILY DEMAND (AVG.)	324,000 gal.
FIRE DEMAND (3 HOURS DURATION)	3,000 gpm.
VILLAGE (1,120 PEOPLE)	
ESTIMATED DAILY DEMAND (MAX.)	231,840 gal.
ESTIMATED HOURLY DEMAND (MAX.)	18,900 gal.
ESTIMATED DAILY DEMAND (AVG.)	100,800 gal.
FIRE DEMAND (3 HOURS DURATION)	3,000 gpm.
DISTRIBUTION SYSTEM PRESSURE	50 psi. (MINIMUM)

* BASED ON CONSUMPTION OF 68 gpcd AT THE ALYESKA CONSTRUCTION CAMP, INCREASED BY 1/3 TO TAKE INTO ACCOUNT THE LONG TERM NATURE OF THE CAMP AND TO MEET THE NEEDS OF THE FAMILIES IN THE VILLAGE.

WATANA WATER SYSTEM DESIGN PARAMETERS

FIGURE B7.2

ACRES

3 - DESIGN CONSIDERATIONS

3.1 - Alternative Camp Concepts

In the process of conceptualizing the design of the camps two alternative types emerged and were evaluated. The two types of camps were: the single status, army barracks type; and the family status, village type. The single status type is the most economical to construct and maintain. The first concept for the camp was a single status camp primarily for this reason. In addition to the economic advantage of the single status camp, historically on Alaskan construction projects the major construction camps usually have been single status.

Investigations of previous, large, hydroelectric projects on the North American continent showed that, where construction camps were a necessary part of the project, a percentage of the workers' families lived in a portion of the camp or in what evolved into a family status village.

Family status facilities are required on large hydroelectric projects because of the length of the construction schedule. They are also more suited to a single main construction area, which is not the case in say, pipeline construction. Considering the length of time some management and supervisory personnel will be working at the project site (five years or more), family status facilities were considered desirable to attract and retain the personnel necessary for the project. Family status facilities for the entire workforce would not be practical and would be prohibitively expensive. An assessment of previous projects of a similar nature showed family status facilities for 10 percent of the workforce to be appropriate. The family status facilities are planned to serve management and supervisory staff of the owner, its agents and the contractors.

3.2 - Camp Policies

Prior to commencing construction of the Watana and Devil Canyon sites, policies regarding operating rules and regulations at the camp will have to be finalized. These policies include transportation, alcohol, firearms, and work schedules. Assumptions regarding these policies have been established for the conceptual design of the camps and for purposes of estimating costs associated with the camps. These assumptions are:

(a) Transportation

Ninety percent of the workforce will be provided bus transportation round trip from Anchorage or Fairbanks, by the owner. The other 10 percent will drive their personal vehicles or find their own transportation to the jobsite. All the workers will be bussed from the construction camps to work areas. Private vehicles will not be allowed at Watana until the access road has reached continuous access status. Continual access status is presently scheduled for mid-1986. Devil Canyon will be accessible by privately owned vehicles from the start of development of the Devil Canyon site. Private vehicles will not be allowed inside the main camp. A parking area will be provided outside the main camp for private vehicles. The residents of the family village will be allowed private vehicles within the village area.

(b) Alcohol

The construction camp layout is based on a semi-dry camp concept. Alcohol will be allowed in private rooms; it will not be allowed in public areas (i.e., dining halls, recreation buildings, offices, etc.). The camp and village layout makes no provision for taverns or beer halls. The assumption is that beer will be available at the retail stores in camp and village in accordance with state law. Drunken behavior will constitute grounds for termination.

(c) Firearms

No firearms will be permitted inside the construction camp. Workers who bring personal firearms with them will be able to check them in a secured storage facility. Hunting and fishing will be regulated by members of Alaskan Fish and Game Department stationed at the camp.

(d) Work Schedules

In order to develop a work force manning schedule to allow designing the construction camps, a work schedule was assumed. Construction will be accomplished with 2 shifts working six 9 hour days each. Workers will be permitted 2 weeks leave every 12 weeks.

3.3 - Design Criteria

Several criteria were and/or will be utilized in the design of the camp and village. Selection of the site included consideration of closeness to the project site to minimize travel time to and from work.

Consideration was also given to locating the site far enough away from the main work areas to allow privacy and segregation of living areas and work areas. In selecting the sites south facing slopes were used. This is an important criteria due to the northern location of the project site. The south facing slopes maximize daylight available to the site and also aids in heating efficiency.

The design of construction camp and village buildings will conform to the requirements of applicable sections of the latest issues of the following standards:

(a) Alaska Building Code

- Uniform Building Code - International Conference of Building Officials;
- Nationa Electrical Code - NFPA; and
- National Plumbing Code - Coordinating Committee for National Plumbing Code.

(b) U.S. Department of the Interior

- EPA - Requirements for Water Treatment/Discharge;
- Alaska Division of Natural Resources - Water Treatment/Discharge; and
- Alaska Department of Transportation - Roads, Heliports, Airfields.

The design, materials, and workmanship shall be such that the completed work will withstand the following climatic conditions:

- Winter design temperature (1 percent basis):	-34°F
- Annual total degree days below 65°F:	14,000
- Cooling degree days;	7
- Maximum wind speed (mph):	120
- Maximum 24-hour rainfall (inches):	3.1
- Annual total precipitation in inches:.	30
- Average annual snowfall (inches):	120

4 - CONSTRUCTION CAMP AND VILLAGE - WATANA

4.1 - Site Preparation

(a) Clearing

The construction camp area will be cleared to a distance of 50 feet beyond the perimeter fence line shown on Plate 37. The construction village area will be similarly cleared, except that selected areas within the site will be left with natural vegetation intact.

Large brush, trees, and other unsuitable material shall be transported to a suitable disposal area.

(b) Slopes and Grades

Both the camp and village sites have been selected to provide well drained land with natural slopes between 2 and 3 percent.

(c) Granular Pad

Upon completion of the clearing operation a layer of filter fabric will be placed over the existing ground. A 4-foot-thick layer of nonfrost susceptible granular material will be placed over the filter cloth, and graded to provide a uniform surface for construction of buildings, utilities and roads. In the village area, the filter cloth and 4 foot granular pad will be installed except in green areas left uncleared.

(d) Roads and Parking Areas

All roads in camp and village will be gravel surfaced for two-way traffic. Main roads will provide a 34 foot travel surface and secondary roads a 24 foot surface. Parking areas within the camp and village will also be gravel surfaced. However, the parking area provided outside the camp for private automobiles will consist of a layer of NFS subbase material of the least thickness required to support the vehicles.

(e) Drainage

In general, drainage at the camp and village sites will be accomplished by a network of ditches. Peripheral ditches will intercept overland flows from adjacent uncleared land and route it around the sites, while ditches flanking roadways within the camp and village collect onsite runoff and convey it to existing water courses. Corrugated metal pipe culverts will be installed as required to convey drainage across roadways and driveways.

(f) Rehabilitation

Upon completion of construction activities at Watana, the camp and village buildings will be dismantled and removed from the site. Using topsoil stripped from the adjacent Borrow Area D, a 12-inch thick layer of soil will be spread over the pad, graded and seeded.

4.2 - Buildings

(a) General

Construction camp and village buildings will be of two types. Where practical, the buildings will be prefabricated, wood frame, factory-built, modular units, transported to the site, then assembled to provide the size and shape necessary. The modules will be fabricated, complete with heating, lighting and plumbing services, interior finishes, furnishings and equipment. All the housing units will be of this type.

In general, building spans exceeding 20 feet will be pre-engineered steel-frame structures supported by concrete slab foundations. The gymnasiums, warehouses, and ice rink are buildings of this type.

Both building types will be finished with metal cladding. Insulation will be installed to provide the following resistances to heat flow:

	Prefab Buildings	Steel-Frame Buildings
Roof	R20	R20
Walls	R20	R12
Floor	R20	N/A

The prefab buildings will be supported approximately two feet above grade by timber cribbing placed directly on the 4 foot thick granular pad. During placement of the granular pad, areas which will underlie concrete slabs will be excavated to remove frost susceptible material, then backfilled with nonfrost susceptible granular material before placing the 4 foot thick granular pad. The minimum depth of nonfrost susceptible material beneath concrete slabs shall be the thickness of the annual freeze/thaw layer.

The work force at the site is anticipated to average 10 percent female. To accommodate female residents 15 percent of the dormitory units will be designed to allow toilet/washroom facilities to be furnished with either male or female fixtures.

(b) Bachelor Dormitory

(i) Requirement

Living accommodation for 108 single-status workers.

(ii) Building Type

A two story, prefab building to accommodate 108 persons in double bedrooms providing 60 square feet per person.

Washroom and toilet facilities to include two each coin-operated washers and dryers on each floor.

(iii) Utilities

- Domestic water;
- Fire protection water with stand-pipes and hose racks;
- Sanitary sewerage facilities;
- Electrical power for lighting; and
- Fuel oil for heating and hot water.

(c) Bachelor Housing - Management - Type A

(i) Requirement

Living accommodations for 20 single-status personnel.

(ii) Building Type

A trailer-type complex for 20 persons in single-room accommodations of approximately 120 square feet per room, with a shared bathroom for every 2 rooms.

Provide a room to accommodate a coin-operated washer and dryer, and a recreation lounge with snack preparation area (sink, refrigerator, hot plate and counter).

(iii) Utilities

- Domestic water;
- Fire protection water with stand-pipes and hose racks;
- Sanitary sewerage facilities;
- Electric power for hot water and lighting;
- Pay telephone in lounge; and
- Fuel oil for heating.

(d) Bachelor Housing - Management - Type B

(i) Requirement

Living accommodations for 20 single-status personnel.

(ii) Building Type

A trailer-type complex for 20 persons in single-room accommodations of approximately 100 square feet per room.

Washroom and toilet facilities to include two each coin-operated washer and dryer.

Recreation lounge with snack preparation area (sink, refrigerator, hot plate and counter).

(iii) Utilities

- Domestic water;
- Fire protection water with stand-pipes and hose racks;
- Sanitary sewerage facilities;
- Electrical power for lighting and hot water;
- Fuel oil for heating; and
- Telephone.

(e) Manager's Office

(i) Requirement

An office facility to house the project management, engineering, and administrative staff.

(ii) Building Type

A trailer-type complex with the following facilities:

- APA office;
- Resident Manager's office;
- Deputy Resident Manager's office;
- Resident Civil Engineer's office;
- Resident Mechanical Engineer's office;
- Resident Electrical Engineer's office;
- Secretarial area for Resident Manager and Assistant (2 persons);
- Offices for 30 engineers;
- Offices for surveyors (10);
- Office Engineer's office;
- Cost Controller's office;
- Cost control staff office (3 persons);
- Draftsmens' and technicians' office (8 persons);
- Reproduction room;
- Secretarial office for Engineers (10);
- Conference room;
- Male and female washrooms; and
- Fireproof vault.

(iii) Utilities

- Domestic water;
- Fire protection water with stand pipes and hose racks;
- Sanitary sewerage facilities;
- Electrical power for hot water, lighting, utility outlets for office machines and janitorial services;
- Telephones; and
- Oil fuel heating.

(f) Camp Manager's Office

(i) Requirement

An office building to house the construction camp manager's office staff (including catering, housekeeping, warehousing, and maintenance personnel, record keeping and administration).

(ii) Building Type

A trailer-type complex to provide offices for camp manager and staff. The building to consist of one private office (150 ft^2), male and female washrooms, and open office space for 10 desks.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electrical power for hot water, lighting, utility outlets for office machines;
- Telephone; and
- Fuel oil heating.

(g) Dining Hall

(i) Requirement

To provide a combination kitchen/dining facility.

(ii) Building Type

A trailer-type complex capable of providing meals for 1,800 persons per day and of seating 900 simultaneously. The kitchen area shall include preparation, cooking/baking, serving, garbage handling, and dishwashing facilities. The dining area shall include coat hanging areas for 300 people. The facility shall be so designed that it is capable of serving three lines simultaneously with a separate area for dispensing box lunches. The facility shall also be designed to be operated at one-half the capacity, or at one-quarter capacity without undue loss of efficiency.

(iii) Utilities

- Domestic water;
- Fire protection water with stand-pipe and hose racks;
- Dry pipe sprinkler system;
- Sanitary sewerage facilities;
- Fuel oil heating and hot water;
- Telephone;
- Electrical power for lighting, food preparation, and storage; and
- Ventilation equipment for kitchen and dining areas.

(h) Recreation Hall

(i) Requirement

To provide a central recreational facility.

(ii) Building Type

A trailer-type complex 120 feet by 120 feet to accommodate the following:

- 3 chair barber shop;
- Snack bar to include facilities for food preparation, serving and dishwashing;
- A large-screen TV viewing room to accommodate 250 persons;
- A TV viewing room for 25 people;
- Post office station;
- Video game room;
- General recreation area for pool tables and ping pong;
- Lounge for table games (cards, chess, etc.) to accommodate 25 tables;
- Toilet facilities for males and females;
- Janitorial facilities; and
- Coat hanging area for 300 people.

(iii) Utilities

- Domestic water;
- Dry pipe sprinkler system;
- Sanitary sewerage facilities;
- Fire protection water with stand-pipes and hose stations;
- Fuel oil heating and hot water;
- Telephone;
- Pay telephones; and
- Electrical power for lighting, and recreation equipment.

(i) Staff Clubhouse

(i) Requirement

To provide a recreation center for management and professional personnel.

(ii) Building Type

A pre-engineered, insulated, steel-frame building with a concrete slab foundation. Clear headroom to be 10 feet with approximately 4000 square feet of floor area. Provide complete snack preparation area to include food storage, preparation areas and dishwashing facility. Provide one office of 100 square feet, and male and female washrooms.

Include a TV viewing lounge for 50 persons and table game area for 15 tables.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electrical power for lighting, hot water and kitchen equipment;
- Fuel oil heating; and
- Telephone.

(j) Gymnasium

(i) Requirements

To provide an all-weather sports facility to include basketball, handball and volleyball courts, an indoor track, fitness center, sauna and weight lifting room with shower and washrooms.

(ii) Building Type

A pre-engineered, insulated, steel-frame building with a concrete slab foundation. Provide minimum overhead clearance of 24 feet.

The building layout will provide for:

- Basketball courts - 1
- Volleyball courts - 3
- Badminton court - 1
- Track - 1
- Handball court (4 wall) - 2
- Fitness center - 1
- Male and female shower rooms
- Sauna - 1
- Equipment storage room - 1
- Office - 1

(iii) Utilities

- Domestic water;
- Fire protection water with stand-pipes and hose stations;
- Sanitary sewerage facilities;
- Electrical power for lighting;
- Telephone; and
- Fuel oil for hot water and for heating.

(k) Soils and Concrete Testing Laboratory

(i) Requirement

A combined soils and concrete testing laboratory building with office accommodation and washroom.

(ii) Building Type

A pre-engineered, insulated, steel-frame building with a concrete slab foundation for heavy loading testing equipment. Provide office space, washroom, and space for testing equipment. Provide a 10 foot by 10 foot overhead door facing the main street.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electrical power for lighting, hot water and for testing equipment
- Telephone; and
- Fuel oil heating.

(l) Site Security Building

(i) Requirement

Shelter for site security force, 1 state trooper, 2 fish and game police, 3 security cells, and secure storage rooms to hold 500 rifles, shotguns, and pistols.

(ii) Building Type

A trailer-type module with windows on three sides and security cell and storage rooms along back wall. Provide a toilet facility, a key cabinet, 2 offices (10 feet by 12 feet), 1 office (12 feet by 15 feet), front counter, 3 security cells (8 feet by 10 feet), an arms storage room totaling 400 square feet with gun storage lockers or shelves, and an area for luggage while arriving personnel are processed in.

(iii) Utilities

- Electrical power for lighting, hot water;
- Fuel oil heating;
- Telephone;
- Sanitary sewerage facilities; and
- Domestic water.

(m) Fire Station

(i) Requirement

To provide garage-type accommodations for 1 pick-up truck, 1 fire truck and an oil spill vehicle, with storage and maintenance areas for fire fighting and oil spill equipment to include hoses, extinguishers, brush and forest fire fighting equipment, and extinguisher recharging. Include a washroom and space for fire alarm control and annunciator panel.

(ii) Building Type

A pre-engineered, insulated, steel-frame building with a concrete slab foundation. Clear headroom to be 12 feet. Provide five 10 feet by 10 feet overhead doors facing main road and one man-door in side wall.

(iii) Utilities

- Domestic water;
- Telephone;
- Electrical power for lighting, hot water and fire control system;
- Sanitary sewerage facilities; and
- Fuel oil heating.

(n) Maintenance Building

(i) Requirement

To provide a facility to house and maintain road maintenance equipment, plows, front-end loader for fire protection, Alaska Department of Transportation road maintenance equipment, and to provide space for camp maintenance shops (carpentry, plumbing, and electrical).

(ii) Building Type

A pre-engineered, insulated, steel-frame building with concrete slab foundation. Clear headroom to be 12 feet minimum. Provide 6 vehicle doors facing main road, 5 to be 12-foot-wide by 12-foot-high, 1 to be 14 foot by 14 foot. Provide 600 square feet carpentry shop, 600 square feet plumbing shop, 400 square feet electrical shop, 200 square feet office and washrooms, male and female. Include a 6-ton hydraulic lift in one bay of garage area.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electrical power for lighting, hot water, machinery;
- Telephone;
- Fuel oil heating; and
- Fire protection water with stand-pipes and hose stations.

(o) Communications Building

(i) Requirement

A facility for providing television and radio broadcasting, internal phone communication, and a microwave phone connection to the ALASCOM phone system.

(ii) Building Type

A trailer-type complex providing 600 square feet of floor area for an automatic phone switching station for 600 phones, for reception and broadcast equipment for multi-channel radio and television coverage, and for a 100 channel microwave phone center. Provide one washroom.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electrical power for lighting, hot water, and to operate equipment;
- Telephone; and
- Fuel oil heating.

(p) Generating Station

(i) Requirement

A building to house the diesel powered generators and auxiliary equipment.

(ii) Building Type

A pre-engineered, insulated, steel-frame building with concrete slab foundation. Clear headroom to be 12 feet minimum. Provide a 10 foot by 10 foot overhead door on the side of building facing main road.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electrical power for lighting and equipment; and
- Ventilation units.

(q) Hospital

(i) Requirement

A ten-bed capacity hospital capable of providing complete medical service both for the construction camp and the village.

(ii) Building Type

A trailer-type complex to provide:

- 8 beds, semi-private;
- 2 beds - private;
- operating room;
- emergency room;
- drug storage locker;
- reception area;
- offices - administrative;
- radiology room;
- opthalmology unit;
- resident doctor's office;
- nurses room;
- washrooms, male and female;
- obstetrics;
- dental care unit;
- physiotherapy room; and
- electrocardiography unit.

(iii) Utilities

- Domestic water;
- Fire protection water with stand-pipe and hose stations;
- Sanitary sewerage facilities;
- Wet-pipe sprinkler system;
- Electrical power for lighting, hot water, equipment;
- Fuel oil heating;
- Telephone; and
- Emergency generator.

(r) Food Service Warehouse

(i) Requirement

Warehouse space for food storage to supply 4,000 man population. Warehouses to provide cold rooms, freezers, lockers and palletized dry goods storage. Office space shall be provided for a warehouse manager.

(ii) Building Type

A pre-engineered, insulated, steel-frame building with a concrete slab foundation to accommodate fork lift operation. Provide a 100-foot-wide truck dock across north elevation of building with three 10 foot by 8 foot overhead doors connecting to building. Minimum overhead clearance shall be 12 foot. The warehouse will directly adjoin Dining Halls 1 and 2 to allow simultaneous provisioning for both kitchens.

(iii) Utilities

- Domestic water;
- Fire protection water with stand-pipe and hose station;
- Sanitary sewerage facilities;
- Electrical power for lighting and cold storage equipment;
- Telephone; and
- Fuel oil heating.

(s) Warehouse

(i) Requirement

A storage facility to hold construction and equipment items purchased by manager for issue to contractors for installation in the permanent works. Office accommodation to be provided for a stores supervisor and records. Washroom accommodation required for warehouse.

(ii) Building Type

A pre-engineered, insulated, steel-frame building with a concrete slab foundation. Clear headroom to be 12 feet. One vehicle door facing main road to be 10 feet by 10 feet overhead type. Approximate area to be 12,000 square feet.

Office area to be approximately 150 square feet with adjoining washroom containing 1 water closet and 1 lavatory basin.

(iii) Utilities

- Domestic water;
- Fire protection water with stand-pipe and hose station;
- Sanitary sewerage facilities;
- Electric power for lighting;
- Telephone; and
- Fuel oil heating.

(t) Store

(i) Requirement

A general store to provide an outlet for food, dry goods, clothing, personnel effect, beer, etc.

(ii) Building Type

A trailer-type complex to provide 1,000 square feet of floor space for retail display, 700 square feet for storage, a washroom and small office.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electrical power for lighting and hot water;
- Fuel oil heating; and
- Telephone.

(u) Laundry

(i) Requirement

To provide space for a commercial laundry for use by manager's housekeeping staff.

(ii) Building Type

A trailer-type complex to accommodate 10 washers and dryers of the commercial type, with space for a 150 gallon high recovery water heater, and with 4 built-in work counters (each 3 feet by 5 feet).

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electric power for lighting, hot water and to supply power to washers and dryers;
- Telephone;
- Fuel oil heating.

(v) Bank

(i) Requirement

To provide a commercial banking facility for 4,000 people. The bank will also serve the 320 family village.

(ii) Building Type

A trailer-type complex to provide 3,000 square feet of floor space. Include 2 offices of 150 square feet each, male and female washrooms, safety deposit boxes for 500, and a compartment to accommodate an 8 foot by 8 foot steel safe. Also, provide six teller stations.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electrical power for lighting, hot water, and office equipment;
- Telephone; and
- Fuel oil heating.

(w) Guest House

(i) Requirement

To provide living accommodation for 20 single-status persons.

(ii) Building Type

A trailer-type complex for 20 persons in single-room accommodation of approximately 120 square feet per room.

Toilet and shower facilities for each two bedrooms.

One kitchen/dining area to seat 12 persons, equipped with refrigerator, stove, sink, counter, and cupboard units.

Lounge area to accommodate up to 20 persons.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electric power for lighting, hot water;
- Telephone;
- Fuel oil heating; and
- Fire protection water with stand-pipe and hose station.

(x) Family Housing Units

(i) Requirement

To provide single family dwelling units providing a range of space and finish.

(ii) Building Type

Mobile homes in five configurations as follows:

- A trailer-type home 24 feet by 50 feet with 2 bedrooms, 2 baths, living room, dinette, kitchen and utility room.
- A trailer-type home 24 feet by 50 feet with 3 bedrooms, 2 baths, living room, dinette, kitchen and utility room.
- A trailer-type home 28 feet by 50 feet with 4 bedrooms, 2 baths, living room, dinette, kitchen and utility room.
- A trailer-type home 14 feet by 60 feet with 2 bedrooms, 1 bath, living room, dinette, kitchen and utility room.
- A trailer-type home 14 feet by 60 feet with 3 bedrooms, 1 bath, living room, dinette, kitchen and utility room.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electric power for lighting, cooking, hot water, laundry;
- Fuel oil heating; and
- Telephone.

(y) School

(i) Requirement

To provide a facility for the education of the children of family status personnel.

(ii) Building Type

A trailer-type complex of 24,000 square feet to provide 12 classrooms and administrative offices for the education of 315 children in levels kindergarten to grade 12. Provide lavatory facilities, cafeteria with small kitchen, faculty room and boiler room.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Fire protection water with stand-pipes and hose stations;
- Electric power for lighting, hot water, and office equipment;
- Telephones;
- Fuel oil heating; and
- Dry pipe sprinkler system.

(z) Gymnasium

(i) Requirement

To provide an indoor facility to be used by the village school for gym classes and by village residents, when school not in session, as a sports center. Include an office (100 square feet) and an equipment storage room (150 square feet).

(ii) Building Type

A pre-engineered, insulated, steel-frame building with a concrete slab foundation. Provide a minimum overhead clearance of 24 feet and a floor area of 10,000 square feet. The main room will be sized to accommodate a basketball court. In addition, provide shower rooms for men and women.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electrical power for lighting, hot water;
- Telephone; and
- Fuel oil heating.

(aa) Swimming Pool

(i) Requirements

To provide a swimming pool to serve for community recreation and school instructional use. The pool also serves as an emergency reservoir for fire protection.

(ii) Building Type

A pre-engineered, insulated, steel-frame building with concrete slab foundation and concrete pool. Provide showers and washrooms for males and females.

(iii) Utilities

- Domestic water;
- Fire protection water with stand-pipes and hose stations;
- Sanitary sewerage facilities;
- Electrical power for lighting;
- Telephone; and
- Fuel oil for heating pool water, hot water, and space heating.

(bb) Recreation Center

(i) Requirement

To provide a central recreational facility to serve essentially village residents with provision for use of bowling alleys by camp personnel.

(ii) Building Type

A pre-engineered, insulated, steel-frame building with a concrete slab foundation. Clear headroom to be 10 feet, with 8,000 square feet of floor area. Provide six bowling alleys with automatic pin setters, a snack bar with provision for food storage, preparation and serving, dishwashing equipment and dining area. Provide one office of 120 square feet and washrooms for both sexes, video games area and pool table area.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Fire protection water with stand-pipes and hose stations;
- Electrical power for lighting, recreational games, and food preparation;
- Telephone;
- Fuel oil heating and hot water;
- Pay telephones.

(cc) Shopping Center

(i) Requirement

An all purpose shopping mart, providing a food supermarket, department store, and small shops for specialty items.

(ii) Building Type

A pre-engineered, insulated, steel-frame building with concrete slab foundation. Provide minimum headroom of 12 feet and floor area of 16,000 square feet. The supermarket area (10,000 square feet) will include a warehouse area with truck dock and an 8 foot by 10 foot overhead door in building wall adjacent to dock. Include male and female washrooms for employees.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Fire protection water with stand-pipes and hose stations;
- Electrical power for lighting, refrigeration and display equipment;
- Telephone; and
- Fuel oil heating and hot water.

(dd) Gas Station

(i) Requirement

A retail service station for private automobiles.

(ii) Building Type

A pre-engineered, insulated, steel-frame building with concrete slab foundation. Clear headroom to be 12 foot. Provide three vehicle doors (10 square feet) and storage area of 150 square feet for automotive repair and POL products. Include washrooms for both sexes, and provision for three hydraulic lifts with 6,000 lb. capacity each.

Provide underground storage tanks of 10,000 gallons capacity for 2 gasoline products and pumps to accommodate 6 vehicles simultaneously.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electrical power for lighting, hot water, lifts, service equipment and gas pumps;
- Telephone; and
- Fuel oil heating.

(ee) Generating Station

(i) Requirements

To accommodate the generating plant provided for the village.

(ii) Building Type

A pre-engineered, insulated, steel-frame building with concrete slab foundation. Clear headroom to be 12 feet. Provide a 10 foot by 10 foot overhead door facing main road and washroom.

(iii) Utilities

- Domestic water;
- Sanitary sewerage facilities;
- Electrical power for lighting, hot water; and
- Ventilation units.

4.3 - Utilities

(a) Water Supply

(i) General

The water supply system will provide for domestic water and fire protection at both construction camp and the village. The estimated peak population to be served is 4,030 (3,070 in the construction camp and 960 in the village).

A local stream will be the principal source of water. Wells tapping the local ground water will be used as a backup source.

Water treatment will bring the water from either source into compliance with Environmental Protection Agency's (EPAs) National Interim Primary Drinking Water Regulations in Part 40 of the Code of Federal Regulations, Chapter 141 (40 CFR 141) and EPAs National Secondary Drinking Water Regulations, in Part 40 of the Code of Federal Regulations Chaper 143 (40 CFR 143). The water will then be pumped to

3 storage tanks, 2 at the construction camp and 1 at the village. The tanks will provide 2 days' supply at maximum demand. The tanks will be covered and insulated to prevent freezup. Pump stations at the village and camp will supply the water to users through insulated pipes located in utilidors. The distribution system will be designed with loops to allow continuous circulation.

(ii) <u>Demand</u>

Figure B7.2 lists the parameters used for preliminary design of the water supply system. The system provides for the estimated population plus 10 percent.

(iii) <u>Source</u>

Tsusena Creek has been selected as the main source of water for the camp and the village. The creek flows all year with minimum rates in winter in excess of 500 gpm. A pool constructed in Borrow Area F will provide the withdrawal point from Tsusena Creek. The pool will be of sufficient depth to insure an ice freeze intake near the bottom.

As a backup water supply, wells will be drilled in the alluvium underlying Tsusena Creek adjacent to the water intake.

Water from Tsusena Creek will be pumped through a heat-traced pipeline to the treatment plant.

The pump station at the Tsusena Creek will be electrically operated. A backup diesel generator will also be provided.

(iv) <u>Transmission</u> (Figure B7.1)

- <u>Intake to Treatment Plant</u>

  Required capacity = 1,000,000 gal/day = 700 gpm.

  Due to the wide seasonal fluctuation in demands, a single line sized for the maximum summer demand would have a very low velocity during winters (less than 1 ft/s) and would be subject to freezing. Therefore, a system of two pipes was selected to convey water from the source to the treatment plant.

  A 6-inch pipe will be utilized to provide continuous service to the water treatment plant. When the demand increases during the construction season a 4-inch pipeline will be activated.

  This system of two pipes provides an adequate supply at all times. The velocities are sufficient to prevent freezing during periods of low demand, and the head losses are acceptable at maximum flows.

The two pipes will be heat-treated within an insulated utilidor parallel to the access road. The utilidor will be located on the surface, with an earth mounded on either side for insulation and protection.

The total distance from the intake to the treatment plant is approximately two miles.

- Treatment Plant to Main Camp

The treated water from the treatment plant clear well will be pumped to the main camp through parallel 6-inch and 4-inch lines installed in a utilidor similar to the utilidor from the source to the treatment plant.

- Treatment Plant to the Village

The treated water for the village will be pumped through a single 4-inch line located in an insulated surface utilidor covered by an earth berm. The lines will be heat traced. A single pipe is adequate since the winter and summer demands for the village will be approximately the same.

(v) Water Treatment

Water for both domestic consumption and fire service will be treated potable water to avoid interconnection problems. Water conveyed to the treatment plant through the transmission line from Tsusena Creek will be treated by chemical addition, flocculation, settling, filtration, and disinfection. If required, demineralization and aeration will also be provided before storage in the clearwell.

The treatment plant will be of modular design to facilitate shipment and setup and to permit staging the plant capacity to meet population changes.

(vi) Storage and Distribution

Water will be stored at both the camp and village in embankment-supported fabric tank reservoirs. The camp will have 2 reservoirs and the village will have 1. One reservoir at the camp will be taken out of service during the winter because of lower demands. The reservoirs will be fully insulated, covered, and heated.

Pump stations will be located adjacent to the reservoirs. Pump station flexibility will be achieved by manifolding multiple pumps and by the use of variable speed drives. The primary system will utilize electrically and driven pumps, with diesel generators or diesel engine drives as backup. Line pressures will be automatically maintained by utilizing a constant pressure control system with the variable speed drives to match changes in demand.

The distribution systems within the main camp and village will comprise insulated pipelines located inside utilidors. These systems will incorporate continual recirculation to prevent freezing without the need for extensive heat tracing. Pressure for domestic service will be maintained at 50 psi minimum.

(vii) Fire Protection

Fire flow requirements are based on the recommendations presented in the Guide for Determination of Required Fire Flow, by the Insurance Service Office (ISO) New York, New York. These requirements can be met by providing 3,000 gpm for a 3 hour duration to protect the wood frame residential and dormitory construction and the fire-resistant construction of the larger buildings.

Hydrants will be capable of supply 1,500 gpm pumpers. Hydrant spacing will vary to accommodate the arrangement of the buildings and the fire rating classifications. Hydrants will be the self-draining type and will be located on loops to prevent dead-end freezeup. Heat tracing will be used where hydrants might be located on dead-end lines.

All buildings will be supplied with hose racks at regular intervals, as well as wall-mounted chemical extinguishers. Buildings will be equipped with smoke and heat detectors wired into a central control office. These units will be located in every room and in hallways and major storage areas. Fire walls will also be utilized. These features keep the fire demand flows down to 3,000 gpm.

(b) Wastewater Collection and Treatment

(i) General

The main camp and village will be served by one waste treatment plant located at the camp. This plant will treat all sanitary waste that originates from the dorms, residences, kitchens, and laundries and from the chemical toilets at various locations on the construction site. The sanitary waste from the camp and the village will be collected and transported to the treatment plant through a system of sewers.

The capacities of the collection system and the treatment plant are based on the potable water requirements. With new tight water and sewer systems, and no industrial demand, lawn maintenance or residential swimming pools, nearly all the potable water used will be returned to the sewage systems.

(ii) Collection System

Gravity sewers with lift stations will collect the waste discharges from all the camp and village facilities. The collection systems will be installed in the permawalks and utilidors for protection from the elements.

The collector sewers at the main camp will be connected to a main trunk sewer which will discharge directly to the treatment plant.

At the village the sewage will be collected in an aerated collection basin which will serve to balance out the diurnal variation in flows. The sewage will be pumped from this collection basin to the waste treatment plant through a force main which will be routed in the utilidors from the village to the water treatment plant, and from the water treatment plant to the main camp. At the main camp, the force main will discharge into the main trunk sewer from the camp to the waste treatment plant.

The chemical toilets scattered around the construction site will be serviced by septage hauling trucks, which will discharge directly at the sewage treatment plant.

(iii) Receiving Stream

The treated effluent from the waste water treatment plant will be discharged to Deadman Creek approximately one-half mile upstream of the confluence with the Susitna River. There is no data available regarding the quality of water in the receiving stream in this area.

(iv) Treatment Plant

- Influent Characteristics

Daily Flows

Maximum: 1.0 million gallons per day (mgd)

Average: 435,000 gallons per day (gpd)

*5 day biological oxygen demand (BOD): 440 milligrams per liter (mg/l)

**Suspended Solids (SS): 485 mg/l

(v) Effluent Characteristics

- Design Considerations

  - The plant is to be used for 12 years, with subsequent use of most components at Devil Canyon;

* U.S. EPA "Cold Climate Utilities Delivery Design Manual EPA600/8-79-027 September 1979 - Chapter 9.

**ASCE Conference Proceedings on "Applied Techniques for Cold Environments", Vol. 1, pp 319-329.

- The plant operation should be made simple, with minimal control and monitoring functions;
- As a minimum level of treatment the treated plant effluent may not exceed the following constituent concentrations as listed in the Alaskan State Water Secondary Treatment Standards:

  BOD_5 < 30 mg/l
  SS < 30 mg/l
  pH > 6.0 < 9.0

  Other effluent concentration limitations, methods of testing and allowable variations are outlined in the standards.

- The plant should be modular to provide gradual expansion and reduction in capacity to match population changes.
- Chemical use should be kept to a minimum and confined to readily available chemicals.
- Heat entering the plant in the sewage should be considered a resource.
- Freezing and moisture can create serious operational problems.
- The flows are highly cyclic, corresponding to shift changes.
- The plant must be enclosed, insulated, and heated to maintain the influent at a temperature to permit the processes to work effectively.
- Instrumentation must be protected from moisture by providing separate humidity-controlled rooms.
- Complete laboratory facilities are required for all testing and analyses of plant process operations required by the EPA.

- <u>Selection of Treatment Processes</u>

  - Biological treatment will be used. This is a simple process which has been in used for many years, and has been employed successfully at installations in similar environments. It has an operational advantage of generating less sludge than a total physical/chemical system.
  - Lagoons will balance the diurnal variations in flow, reduce the BOD to about 150 mg/l to prevent RBC overloading, remove grit and some solids, and provide sludge storage.
  - Rotating biological contactors (RBCs) will reduce the BOD to secondary standards.

- Clarifiers will reduce the suspended solids concentration to acceptable levels;

- Ozone will serve as the primary means of disinfecting the effluent. Chlorine will be used as a back-up.

- A heat pump will extract heat from the effluent for use in heating the influent sewage. However, effluent temperatures will be maintained at a sufficient level to prevent freezing before discharge to Deadman Creek.

- A back-up physical/chemical system will provide an acceptable level of treatment during times the primary treatment system may be out of service.

- <u>Sludge Handling</u>

A portion of the sludge from the clarifiers will be returned to the lagoons. The remainder will be disposed of by thickening at a gravity thickener, reducing solids at a wet air oxidation unit, removing excess moisture at a filter press and disposing of the filter cake at a sanitary landfill. Liquid overflow and filtrate from the thickener and filter press will be recycled to the lagoons.

- <u>Heat Pump</u>

A heat pump will extract heat from the effluent and heat the influent. An auxiliary boiler will be used to heat the plant and assist in maintaining desired influent temperatures.

- <u>Discharge</u>

The plant will discharge treated effluent to Deadman Creek through a heat-traced force main installed in an insulated utilidor.

- <u>Sludge Disposal</u>

All treated sludge will be disposed of in the solid waste sanitary landfill.

(vi) <u>Treatment Plant Unit Processees</u> (Figure B7.3)

- <u>Headworks</u>

  - A skimming tank will remove grease and other floating objects before they reach the lagoons. The skimmings will be disposed of in a landfill.

- <u>Chemical Toilet Dump</u>

  - The septage hauling trucks which service the chemical toilets will discharge into a receiving tank at the treatment plant where hydrogen peroxide will be added. This waste will be discharged into the lagoons at a rate which will not cause a shock loading.

- Lagoons

Lagoon No. 1 will contain one-third of the total volume and will be a complete mix, aerated lagoon. The remaining four lagoons will be partially mixed, aerated facultative lagoons of equal volume (1/6 the total) with provision for sludge storage. Lagoons 1 and 2 will be covered and heated for cold weather operation; the remaining lagoons will be shut down.

- Rotating Biological Contactors (RBCs)

The RBCs will reduce the 5-day BOD to 30 mg/l. Multiple units will be provided so that 2 units can be out of service at any 1 time and effluent quality can still be met.

- Clarifiers

Tube settler units will reduce the suspended solids to about 30 mg/l.

- Physical/Chemical Treatment

This will be a back-up treatment system to be utilized where the primary biological treatment system is out of service. Chemical flocculants will be added to the waste stream from the lagoons at the chemical addition units and mixed at the flocculating tanks to cause agglomeration of the sewage solids. The resulting flow will be removed through settling in the clarifiers. This process tends to produce large volumes of sludge.

- Disinfection

Ozone will be the principal disinfection agent with chlorine as a backup.

(c) Electrical System

(i) General

Electrical energy will be utilized for all power requirements except space and hot water heating in both the village and the camp. Hot water for dormitories and for the core service buildings will be heated by oil fired units, while family housing units and hot water heaters of 100-gallon capacity or less will be electrically heated.

(ii) Power Supply

Electrical power, initially, will be generated at the site by diesel powered generators. A generator station will be located near the village and another near the camp. Each will house several generators of like size and make, with total capacity sufficient to the needs of either the camp or the village. Generator commonality will simplify maintenance procedures and spare parts stockage.

Generator station output will be 4.6 kV, 3-phase, 4-wire power carried throughout camp and village on poles or in the utilidor network. Pole-mounted and/or ground-level transformers, suitably located, will reduce the power to 600 volt, 3-phase, or 120/240 volt single-phase for use in buildings, at treatment plants, pump stations, heat tracing networks, etc.

Not later than mid-1987 a power cable connected into the Railbelt intertie system will bring 138 kV power to the site, to a point adjacent to the north end of the proposed dam. A 20 MVA transformer will step the voltage down to 34.5 kV. The power will be supplied to the camp, the village and to construction users via a 34.5 kV loop. At both the camp and the village it will be further transformed to 4.16 kV and tied into the existing distribution systems. At this time the generating stations will become standby units for emergency service.

In both the camp and village, pole-mounted luminaires will be used to provide general illumination, with floodlights installed in selected areas for security purposes.

(iii) Fuel

Fifty thousand gallon fuel bladders will be located adjacent to each generating station (one each). Diesel fuel will be pumped into day tanks before being fed to the generators.

(d) Fuel Oil Distribution System

(i) Camp

A pipeline system, carried primarily within the utilidors, will convey fuel oil to the furnaces and hot water heaters of the major buildings, and of the dormitories. The fuel will be pumped out of the fuel bladder supplying fuel to the generator station and into the pipeline distribution network.

(ii) Village

In the village, ground level tanks of 1,000 gallon capacity will provide fuel to four houses each. Larger tanks will be used at the school, gymnasium, swimming pool, recreation building and shopping center.

(e) Communications System

(i) Telephone

- A microwave system will provide the link between the wire conducted phone system at the site and Alascom. This wireless system will consist of two terminal and several repeater stations, housing 100 channel transmitting and receiving units. One of the repeating stations will be located such, that upon completion of the Watana hydroelectric project, it will be able to be redirected to a new terminal at the Devil Canyon site.

- The site phone system will utilize pole supported cables to tie together all housing units in the village, main activity centers in both camp and village, contractors work and office areas, and the owner/manager office complex.

(ii) Radio and Television

Parabolic dish antenna located at the camp will receive radio and TV signals from either satellite or microwave transmission. The signals will be channeled to a transmitting station located between the village and camp and rebroadcast for reception within a 3-mile radius. Records, discs and tapes will supplement the broadcast program.

(f) Solid Waste Disposal

(i) General

Solid waste will be collected on a daily basis and disposed of in a landfill operated by owner. The sludge by-product of the wastewater treatment plant will also be disposed of in the same landfill.

(ii) Location

The landfill will be located in a non-permafrost area above the water table (both existing and projected).

(iii) Operation

To avoid the problems of animal attraction, the landfill will be entirely fenced. Wastes will be emplaced in compartments, with not less than 1-foot of cover over all waste products at end of each day's operation. This landfill will not be utilized for the disposal of the by-product of clearing and grubbing operations, nor for the burial of scrap machinery and equipment.

(iv) Reclamation

Upon discontinuance of operation of a landfill, the area will be reclaimed in accordance with requirements of 18 ACC 60.050. Some of the requirements of Title 18 code are a final cap of not less than two feet of earth over all waste material, and final site grading to channel surface runoff around or away from the landfill.

5 - CONSTRUCTION CAMP AND VILLAGE - DEVIL CANYON

5.1 - Site Preparation

(a) General

The sites chosen for the construction camp and village are in a non-permafrost area where the bedrock lies an average of 3 to 4 feet below the surface. The site has a low density tree cover, with well drained land sloping between 3 and 5 percent to the south.

(b) Clearing and Grubbing

Both the camp and village sites will be cleared and grubbed to a distance of 15 feet beyond the perimeter fence line. Brush, trees, roots, and other unsuitable materials will be transported to a suitable disposal area.

(c) Stripping

The cleared organic material shall be stripped and stockpiled outside the camp and village for use in rehabilitation activities. In areas which will underly concrete slab foundations, additional excavation to bedrock, to a non-frost susceptible material, or to a depth of 8 feet (whichever comes first) will be accomplished. These areas will be backfilled to original grade using non-frost susceptible material. After stripping the sites shall be rough graded preparatory to placement of pad.

(d) Granular Pad

Both the camp and village sites will be covered using a 1-foot-layer of non-frost susceptible material from the saddle dam excavation, followed by a 1-foot-layer of gravel from Borrow Area G.

(e) Road and Parking Areas

Roads in camp and village will carry two-way traffic on gravel surfaces 34 feet wide for primary streets and 24 feet wide for secondary streets. Parking areas inside camp and village will be gravel surfaced. The four acre area for private vehicles outside the camp will be cleared and provided a 1-foot layer of NFS material.

(f) Drainage

A system of ditches will intercept surface runoff and channel it to existing watercourses off the sites. Roadway and driveway crossings will be accomplished through installation of CMP culverts. Drainage water from adjacent land will be intercepted by peripheral ditches and routed around the site.

5.2 - Buildings

(a) General

The construction camp and village at Devil Canyon will be built using components from the Watana construction camp. Prefabricated wood frame buildings will be broken down into their original elements, transported to Devil Canyon, reassembled, then rehabilitated as necessary. Pre-engineered, steel-frame buildings will be dismantled, moved to Devil Canyon and reconstructed on new concrete slab foundations. The reconstructed buildings will be refurbished before occupancy.

Most of the buildings are reerected to their original shape and dimension, however, a few are reduced in size. Those requiring size reduction are listed in Table B7.2. The buildings will be reconstructed to the same specification for that building in Section 4.2 of this report.

Rehabilitation of the structures will be to put them in like new condition. The only design changes necessary will be the modification of furnaces and building wiring to provide for electrical heating.

Buildings requiring layout changes are listed below.

(b) Staff Clubhouse

(i) Requirement

To provide a recreation center for management and professional personnel.

(ii) Building Type

A pre-engineered, insulated, steel-frame building with a concrete slab foundation. Clear headroom to be 10 feet, with approximately 2,500 square feet of floor area. Provide a complete snack preparation area to include food storage, preparation, and dish washing facilities. Provide an office of 100 square feet, and male and female washrooms. Include a room for TV viewing for 30 people, a pool table, ping pong table, and 5 card tables.

(iii) Utilities

- Domestic water;
- Fire protection water with stand-pipes and hose stations;
- Sanitary sewerage facilities;
- Electrical power for lighting, heating, kitchen equipment and hot water; and
- Telephone.

(c) Gymnasium

(i) Requirement

To provide an indoor sports area for use by construction camp residents.

(ii) Building Type

A pre-engineered, steel-frame building with a concrete slab foundation. Provide a minimum overhead clearance of 24 feet and a floor area of 14,400 square feet. In addition to a basketball court, provide a fitness room and sauna.

Provide shower rooms for males and females, an office of 100 square feet and an equipment storage room of 100 square feet.

(iii) Utilities

- Domestic water,
- Sanitary sewerage facilities;
- Electrical power for lighting, heating and hot water; and
- Telephone.

(d) Maintenance Building

(i) Requirement

To provide a facility for the housing and maintaining of camp vehicles, and to provide space for camp maintenance shops (carpentry, electrical, plumbing, welding).

(ii) Building Type

A pre-engineered, steel-frame building with a concrete slab foundation. Clear headroom shall be 12 foot minimum. Provide 3 overhead doors, two 12 feet by 12 feet and one 14 feet by 14 feet. Inclue a 6-ton hydraulic lift in 1 of the garage bays.

Provide a 400 square foot carpentry shop, a 400 square foot plumbing/welding shop and a 200 square foot electrical shop.

(iii) Utilities

- Domestic water;
- Fire protection water with stand-pipes and hose stations;
- Sanitary sewerage facilities;
- Electric power for lighting, heating and hot water; and
- Telephone.

(e) Food Service Warehouse

(i) Requirement

To provide food storage space for the camp kitchen/dining facility. Separate areas will provide meat lockers, freezers and shelf areas for dry goods storage.

(ii) Building Type

A pre-engineered, steel-frame building with a concrete slab foundation to accommodate forklift operation. Provide a 40-foot-wide truck dock across one end with two 8 by 10 foot overhead doors opening onto it. Minimum overhead clearance shall be 12 foot.

(iii) Utilities

- Domestic water;
- Fire protection water with stand-pipe and hose station;
- Sanitary sewerage facilities;
- Electric power for lighting and storage equipment; and
- Telephone.

5.3 - Utilities

(a) General

The water treatment and wastewater treatment plants used at Watana will be reduced in size, then moved to Devil Canyon and reconstructed there.

(b) Water Treatment

An intake in the Susitna River will be the source of domestic water for the camp and village at Devil Canyon. Figures B7.4 and B7.5 present the design parameters and transmission scheme for the potable water system.

(c) Wastewater Treatment

The wastewater treatment facility at Devil Canyon will be sized to treat 500,000 gallons daily. Figure B7.3 depicts the plant layout. Except for size reduction, the system will be similar to the one used at the Watana site.

The plant will discharge to the Susitna River 1,000 feet downstream from the potable water intake.

APPENDIX B8

WATANA PLANT SIMULATION STUDIES

1 - SCOPE

The objective of the plant simulation studies is to present performance studies of the selected Watana plant with six 170 MW units. The studies demonstrate the improved performance of the six 170 MW plants in comparison with four 250 MW plants. The simulation program was arranged to:

- Study the operation and load following characteristics of the Watana power plant with different number and rating of units;

- Determine the effect of minimum and maximum loading constraints of the units;

- Determine the effect of critical single or double contingency outages of units on the amount and type of spinning reserves available in the system;

- Study the effects of maintenance outages and its impact on generation scheduling and system security; and

- Check the operation of gas turbines and peaking plant.

The simulation studies were done for the typical year 2000, a few years before the Devil Canyon plant is put into operation. The load demand data used are from the medium load forecast.

2 - COMPUTER SIMULATION MODEL

To achieve the stated objectives, a computer simulation program was used to simulate Watana power plant and system operation. The Watana turbines and reservoir are modeled in detail to simulate closely the reservoir regulation and load-following characteristics of the turbines.

The model includes the following principal features:

- Turbine characteristics as a function of head, gate opening (flow), and efficiency are used in the model;

- Minimum loading limitations of the turbine due to rough zone of operation up to 50 percent of the gate openings are constraints for turbine loading and operation;

- Maximum continuous rating (MCR) of the generators constitutes the maximum loading of the units. Higher turbine capability at higher heads is blocked at the generator MCR rating;

- Predicted daily system load demand curves are used for two typical load shapes for winter and summer, respectively. Monthly peak load variation of the load is taken into account;

- Average reservoir inflows are input in the program. Allowable monthly maximum and minimum reservoir levels are constraints for reservoir regulation and operation;

- Unit by unit loading and deloading of Watana generators according to load demand (load-following) is done taking into account all constraints mentioned above. The program loads the units equally for maximum efficiency of operation;

- Steam plants are loaded as base-load plants and gas turbines as peaking plants; and

- The maintenance scheduling is done for the generating units.

The turbine characteristic curves used in the simulation model are for typical Francis turbines of similar specific speeds as the Watana turbines. These curves have been computed from turbine "hill" charts and are normalized to unit head, flow and power. The turbine characteristics include allowances for generator efficiency and are shown in Figure B8.1 for the Watana units. Figure B8.2 shows the efficiency curves for operation of one to six units. The data from the turbine curves are stored in the computer model in per-unit normalized form, and are calculated for each turbine rating in dimensions of feet, cfs, and kW for the head, flow and time are interpolated by the program. Hydraulic losses in the intake and waterways are taken into account.

The Watana reservoir characteristics are shown in Plate 5 in Volume 3. Curve interpolation is again utilized during the program simulation. Figure 15.1 (Volume 1) presents the load demand curves showing daily and monthly variations in load. Weekend load demands are factored into the simulation.

The program loads coal plants, combined cycle plants, gas turbines, and hydro plants generally in accordance with the optimized generation planning program output. Watana generators are allowed to perform load following operations. High merit-order plants such as coal plants are run as base plants. Gas turbines and diesel generators, being low-merit order plants, are generally brought on by the program automatically only when the specified constraints prohibit the loading of higher merit-order plants.

The program takes into account the maintenance scheduling of the generating plants. An outage of one unit for one month is assumed for Watana in the month of July.

The integration routes used for the solution of the differential equations is the Rune Kutta Fourth Order method. A time step size of 0.002 of a day (approximately a 3 minute step) is used for the calculation with a printout time interval of one hour.

3 - RESULTS OF THE SIMULATIONS

Printouts of the results of the plant simulations are included in this appendix for the six x 170 MW units and the four x 250 MW unit cases, respectively. For each run, printouts are presented for the following outputs in a typical day in each month of the year 2000 (January to December):

- Watana plant kW output;
- Watana turbine kW output, with flow and efficiency for each unit;
- Watana turbine utilization, showing number of units loaded;
- Watana reservoir level;
- kW output of thermal, small hydro and peaking plants;
- Total system load kW demand;
- Total system reserve capacity, including maintenance outage;
- Watana reserve capacity;
- Annual energy output of Watana, thermal plant, small hydro, and gas turbine plants; and
- System annual energy.

A typical December 2000 simulation output is shown in Figure 15.5 (Volume 1). The printout intervals are for each hour of a typical December day. The legend for the printout variables is given in this figure.

In the December daily load demand curve, the system peak load of 1084 MW occurs in the evening at 1700 hours. The Watana plant output of 804 MW, the thermal plant output of 200 MW, and small hydro plant output of 80 MW supplies the total system load of 1084. The total system reserve capacity is 447 MW.

The Watana six x 170 MW plant has, at this peak hour, a reserve capacity of 270 MW, with one unit on spinning reserve and the remaining five units operating at a part-gate loading of 160 MW each. The reserve capacity available at Watana plant is therefore adequate to meet a single contingency outage of one unit. A subsequent double contingency outage can be met by the reserves available in the system.

The simulation results for the alternative four 250 MW plant shows that sufficient reserve capacity is not available for double contingency unit outages for the December 2000 peak load demand.

4 - CONCLUSIONS

The following is a summary of the conclusions of the simulation studies:

- The simulations indicate that the six unit Watana plant (six x 170 MW) has superior overall performance in terms of load following, improved overall efficiency and minimum loading constraints of the units over the four unit (four x 250 MW) plant.

- The overall reliability of the six unit Watana plant is better than that of the four unit plant. During maintenance the six unit plant has a planned outage of 170 MW versus 250 MW for the four unit plant.

- The minimum loading constraints mentioned above are due to the turbine rough zone operation arising from draft tube hydraulic surging. A fairly conservative constraint of 50 percent of gate opening has been assumed in these studies which does not allow the unit to be loaded below 50 percent of its load output at a particular head. The simulations show that constraints on the 250 MW units are much greater than the 170 MW units requiring consequently greater operation of lower merit-order plants.

- The simulations indicate that sufficient spinning reserve of a minimum of one Watana unit is available for all peak day loadings for the selected six unit Watana plant.

- During peak December loading for a double contingency outage of two units, there is adequate system reserve for the year 2000 for the six x 170 MW plant but not for the four x 250 MW plant.

SUSITNA SIMULATION STUDY

INPUT DATA

```
*** CSMP Simulation Data ***

CONSTANT NWUNIT=4.,HTRH=680.,TURMIN=0.5,...
THERMX=200000.,SMHYDR=80000.,DVLCMX=0.,...
WHWLST=2153.,WTWLST=1455.,WHWLMX=2185.,WVOLO=357.0E9,...
PRATED=267000.,GENMAX=287500.,...
GROWTH=1.0,TRLOSS=0.00,PKLOAD=1084000.
CONSTANT OUTTH=50000.0,INSTAL=1531000.
CONSTANT OUTSH=20000.,OUTDV=0.
CONSTANT IN1=1157.,IN2=979.,IN3=898.,IN4=1113.,IN5=10398.,...
IN6=22922.,IN7=20778.,IN8=18431.,IN9=10670.,IN10=4513.,...
IN11=2052.,IN12=1405.
CONSTANT HM1=2135.,HM2=2119.,HM3=2105.,HM4=2095.,HM5=2145.,...
HM6=2160.,HM7=2170.,HM8=2180.,HM9=2190.,HM10=2185.,...
HM11=2172.,HM12=2153.
CONSTANT LC1=.914,LC2=.864,LC3=.783,LC4=.696,LC5=.638,...
LC6=.621,LC7=.607,LC8=.646,LC9=.696,LC10=.795,...
LC11=.922,LC12=1.0
FUNCTION ECURVE=(.4,.8),(.5,.85),(.6,.88),(.7,.905),...
(.8,.92),(.9,.915),(1.,.89),(1.1,.86),(1.15,.855)
FUNCTION VCURVE=(111.,1900.),(185.,2000.),(235.,2050.),...
(290.,2100.),(375.,2150.),(405.,2175.),(435.,2200.),...
(450.,2225),(580.,2275.)
FUNCTION LCURVE=(0.,.71),(.125,.64),(.25,.7),(.375,.92),...
(.5,.92),(.625,.93),...
(.708,1.0),(.75,.99),(.875,.92),(1.,.72)
FUNCTION LSCURV=(.0,.7),(.125,.59),(.25,.59),(.333,.84),...
(.375,.9),(.417,.96),(.5,1.),(.625,.97),(.75,.99),...
(.875,.92),(.9167,.91),(1.,.76)
TITLE SUSITNA PROJECT SIMULATION
TIMER DELT=0.002,FINTIM=12.0,...
OUTDEL=0.041667,PRDEL=0.041667,DELMIN=1.0E-10
PRINT WTWHWL,WATANA,KWHWT,KWHTH,KWHSH,KWHPK,KWHSYS
```

```
LABEL SUSITNA PROJECT SIMULATION :  2000(MED.LOAD): WATANA 4-250

PRTPLOT WATANA (N,GENKW,EFF)

LABEL SUSITNA PROJECT SIMULATION :  2000(MED.LOAD): WATANA 4-250

PRTPLOT KWLOAD(THERML,SMHY,PEAKPL)

LABEL SUSITNA PROJECT SIMULATION :  2000(MED.LOAD): WATANA 4-250

PRTPLOT RESERV (INSTAL,KWLOAD,WATRES)

END


Timer Variables
 DELT   = 1.9841E-03
 DELMIN= 1.0000E-10
 FINTIM= 1.1958E+01
 PRDEL  = 4.1667E-02
 OUTDEL= 4.1667E-02
```

SUSITNA PROJECT SIMULATION RKS integration

TIME	MTWHWL	WATANA	KWHWT	KWHTH	KWHSH	KWHPK	KWHSYS
WATANA	0.0000E+00	5.1010E+00	8.0389E+05	1.1708E+01			
KWLOAD	3.8821E+05	6.1250E+00	1.0839E+06	1.1708E+01			
RESERV	4.4711E+05	1.1708E+01	1.1428E+06	6.1250E+00			

SUSITNA SIMULATION WITH

SIX 170 MW UNITS AT WATANA

Minimum 1.0821E+05 WATANA verses TIME Maximum 8.0389E+05

TIME	WATANA	N	GENKW	EFF
0.0000E+00	4.2345E+05	3.0000E+00	1.4115E+05	9.1515E-01
4.1667E-02	4.0033E+05	3.0000E+00	1.3344E+05	9.0886E-01
8.3334E-02	3.7721E+05	3.0000E+00	1.2574E+05	9.0095E-01
1.2500E-01	3.5410E+05	2.0000E+00	1.7705E+05	8.9930E-01
1.6667E-01	3.7391E+05	3.0000E+00	1.2464E+05	8.9945E-01
2.0833E-01	3.9373E+05	3.0000E+00	1.3124E+05	9.0705E-01
2.5000E-01	4.1355E+05	3.0000E+00	1.3785E+05	9.1244E-01
2.9167E-01	4.8620E+05	3.0000E+00	1.6207E+05	9.1594E-01
3.3334E-01	5.5886E+05	4.0000E+00	1.3972E+05	9.1395E-01
3.7500E-01	6.3151E+05	4.0000E+00	1.5788E+05	9.1708E-01
4.1667E-01	6.3151E+05	4.0000E+00	1.5788E+05	9.1708E-01
4.5834E-01	6.3151E+05	4.0000E+00	1.5788E+05	9.1708E-01
5.0000E-01	6.3151E+05	4.0000E+00	1.5788E+05	9.1709E-01
5.4167E-01	6.3482E+05	4.0000E+00	1.5870E+05	9.1686E-01
5.8334E-01	6.3812E+05	4.0000E+00	1.5953E+05	9.1664E-01
6.2501E-01	6.4143E+05	4.0000E+00	1.6036E+05	9.1642E-01
6.6667E-01	6.7624E+05	4.0000E+00	1.6906E+05	9.1029E-01
7.0834E-01	7.1070E+05	4.0000E+00	1.7767E+05	8.9860E-01
7.5001E-01	7.0086E+05	4.0000E+00	1.7522E+05	9.0195E-01
7.9167E-01	6.7775E+05	4.0000E+00	1.6944E+05	9.0981E-01
8.3334E-01	6.5463E+05	4.0000E+00	1.6366E+05	9.1554E-01
8.7501E-01	6.3150E+05	4.0000E+00	1.5788E+05	9.1711E-01
9.1667E-01	5.6545E+05	4.0000E+00	1.4136E+05	9.1521E-01
9.5834E-01	4.9940E+05	3.0000E+00	1.6647E+05	9.1389E-01
1.0000E+00	4.3496E+05	3.0000E+00	1.4499E+05	9.1816E-01
1.0417E+00	4.1311E+05	3.0000E+00	1.3770E+05	9.1222E-01
1.0833E+00	3.9126E+05	3.0000E+00	1.3042E+05	9.0628E-01
1.1250E+00	3.6941E+05	3.0000E+00	1.2314E+05	8.9723E-01
1.1667E+00	3.8814E+05	3.0000E+00	1.2938E+05	9.0542E-01
1.2083E+00	4.0688E+05	3.0000E+00	1.3563E+05	9.1051E-01
1.2500E+00	4.2562E+05	3.0000E+00	1.4187E+05	9.1560E-01
1.2917E+00	4.9430E+05	3.0000E+00	1.6477E+05	9.1525E-01
1.3333E+00	5.6299E+05	4.0000E+00	1.4075E+05	9.1467E-01
1.3750E+00	6.3165E+05	4.0000E+00	1.5791E+05	9.1712E-01
1.4167E+00	6.3165E+05	4.0000E+00	1.5791E+05	9.1712E-01
1.4583E+00	6.3165E+05	4.0000E+00	1.5791E+05	9.1712E-01
1.5000E+00	6.3165E+05	4.0000E+00	1.5791E+05	9.1712E-01
1.5417E+00	6.3477E+05	4.0000E+00	1.5869E+05	9.1691E-01
1.5833E+00	6.3789E+05	4.0000E+00	1.5947E+05	9.1670E-01
1.6250E+00	6.4103E+05	4.0000E+00	1.6026E+05	9.1649E-01
1.6667E+00	6.7394E+05	4.0000E+00	1.6848E+05	9.1132E-01
1.7083E+00	7.0650E+05	4.0000E+00	1.7662E+05	9.0028E-01
1.7500E+00	6.9720E+05	4.0000E+00	1.7430E+05	9.0345E-01
1.7917E+00	6.7535E+05	4.0000E+00	1.6884E+05	9.1088E-01
1.8333E+00	6.5350E+05	4.0000E+00	1.6337E+05	9.1566E-01
1.8750E+00	6.3163E+05	4.0000E+00	1.5791E+05	9.1715E-01
1.9167E+00	5.6919E+05	4.0000E+00	1.4230E+05	9.1585E-01
1.9583E+00	5.0675E+05	3.0000E+00	1.6892E+05	9.1082E-01
2.0000E+00	3.7262E+05	3.0000E+00	1.2421E+05	8.9852E-01
2.0417E+00	3.5282E+05	2.0000E+00	1.7641E+05	9.0067E-01
2.0833E+00	3.3301E+05	2.0000E+00	1.6651E+05	9.1411E-01

TIME	WATANA	Minimum 1.0821E+05 : WATANA verses TIME Maximum 8.0389E+05 :	N	GENKW	EFF
2.1250E+00	3.1322E+05	--------------+	2.0000E+00	1.5661E+05	9.1751E-01
2.1667E+00	3.3020E+05	---------------+	2.0000E+00	1.6510E+05	9.1521E-01
2.2084E+00	3.4717E+05	-----------------+	2.0000E+00	1.7359E+05	9.0452E-01
2.2500E+00	3.6417E+05	------------------+	3.0000E+00	1.2139E+05	8.9467E-01
2.2917E+00	4.2641E+05	----------------------+	3.0000E+00	1.4214E+05	9.1568E-01
2.3334E+00	4.8865E+05	---------------------------+	3.0000E+00	1.6288E+05	9.1581E-01
2.3750E+00	5.5087E+05	-------------------------------+	4.0000E+00	1.3772E+05	9.1208E-01
2.4167E+00	5.5087E+05	-------------------------------+	4.0000E+00	1.3772E+05	9.1207E-01
2.4584E+00	5.5087E+05	-------------------------------+	4.0000E+00	1.3772E+05	9.1207E-01
2.5000E+00	5.5087E+05	-------------------------------+	4.0000E+00	1.3772E+05	9.1206E-01
2.5417E+00	5.5370E+05	--------------------------------+	4.0000E+00	1.3843E+05	9.1263E-01
2.5834E+00	5.5653E+05	--------------------------------+	4.0000E+00	1.3913E+05	9.1320E-01
2.6250E+00	5.5937E+05	--------------------------------+	4.0000E+00	1.3984E+05	9.1378E-01
2.6667E+00	5.8920E+05	----------------------------------+	4.0000E+00	1.4730E+05	9.1984E-01
2.7084E+00	6.1870E+05	------------------------------------+	4.0000E+00	1.5468E+05	9.1806E-01
2.7500E+00	6.1027E+05	------------------------------------+	4.0000E+00	1.5257E+05	9.1863E-01
2.7917E+00	5.9047E+05	----------------------------------+	4.0000E+00	1.4762E+05	9.1997E-01
2.8334E+00	5.7066E+05	---------------------------------+	4.0000E+00	1.4267E+05	9.1605E-01
2.8750E+00	5.5084E+05	-------------------------------+	4.0000E+00	1.3771E+05	9.1201E-01
2.9167E+00	4.9425E+05	---------------------------+	3.0000E+00	1.6475E+05	9.1533E-01
2.9584E+00	4.3767E+05	-----------------------+	3.0000E+00	1.4589E+05	9.1865E-01
3.0000E+00	2.7566E+05	------------+	2.0000E+00	1.3783E+05	9.1210E-01
3.0417E+00	2.5805E+05	----------+	2.0000E+00	1.2903E+05	9.0489E-01
3.0834E+00	2.4045E+05	---------+	2.0000E+00	1.2023E+05	8.9296E-01
3.1250E+00	2.2287E+05	--------+	2.0000E+00	1.1143E+05	8.8104E-01
3.1667E+00	2.3796E+05	---------+	2.0000E+00	1.1898E+05	8.9126E-01
3.2084E+00	2.5304E+05	----------+	2.0000E+00	1.2652E+05	9.0148E-01
3.2500E+00	2.6816E+05	-----------+	2.0000E+00	1.3408E+05	9.0903E-01
3.2917E+00	3.2349E+05	---------------+	2.0000E+00	1.6174E+05	9.1616E-01
3.3334E+00	3.7881E+05	-------------------+	3.0000E+00	1.2627E+05	9.0113E-01
3.3750E+00	4.3411E+05	-----------------------+	3.0000E+00	1.4470E+05	9.1766E-01
3.4167E+00	4.3411E+05	-----------------------+	3.0000E+00	1.4470E+05	9.1766E-01
3.4584E+00	4.3411E+05	-----------------------+	3.0000E+00	1.4470E+05	9.1766E-01
3.5000E+00	4.3411E+05	-----------------------+	3.0000E+00	1.4470E+05	9.1765E-01
3.5417E+00	4.3662E+05	-----------------------+	3.0000E+00	1.4554E+05	9.1833E-01
3.5834E+00	4.3914E+05	-----------------------+	3.0000E+00	1.4638E+05	9.1901E-01
3.6250E+00	4.4167E+05	-----------------------+	3.0000E+00	1.4722E+05	9.1969E-01
3.6667E+00	4.6818E+05	-------------------------+	3.0000E+00	1.5606E+05	9.1771E-01
3.7084E+00	4.9440E+05	----------------------------+	3.0000E+00	1.6480E+05	9.1534E-01
3.7500E+00	4.8691E+05	----------------------------+	3.0000E+00	1.6230E+05	9.1602E-01
3.7917E+00	4.6930E+05	-------------------------+	3.0000E+00	1.5643E+05	9.1761E-01
3.8334E+00	4.5170E+05	------------------------+	3.0000E+00	1.5057E+05	9.1921E-01
3.8750E+00	4.3407E+05	-----------------------+	3.0000E+00	1.4469E+05	9.1760E-01
3.9167E+00	3.8377E+05	-------------------+	3.0000E+00	1.2792E+05	9.0329E-01
3.9584E+00	3.3347E+05	----------------+	2.0000E+00	1.6674E+05	9.1414E-01
4.0000E+00	2.2409E+05	--------+	2.0000E+00	1.1205E+05	8.8178E-01
4.0417E+00	1.9874E+05	------+	2.0000E+00	9.9368E+04	8.6153E-01
4.0834E+00	1.7338E+05	----+	1.0000E+00	1.7338E+05	9.0513E-01
4.1250E+00	1.4804E+05	--+	1.0000E+00	1.4804E+05	9.1989E-01
4.1667E+00	1.4804E+05	--+	1.0000E+00	1.4804E+05	9.1989E-01
4.2084E+00	1.4804E+05	--+	1.0000E+00	1.4804E+05	9.1989E-01

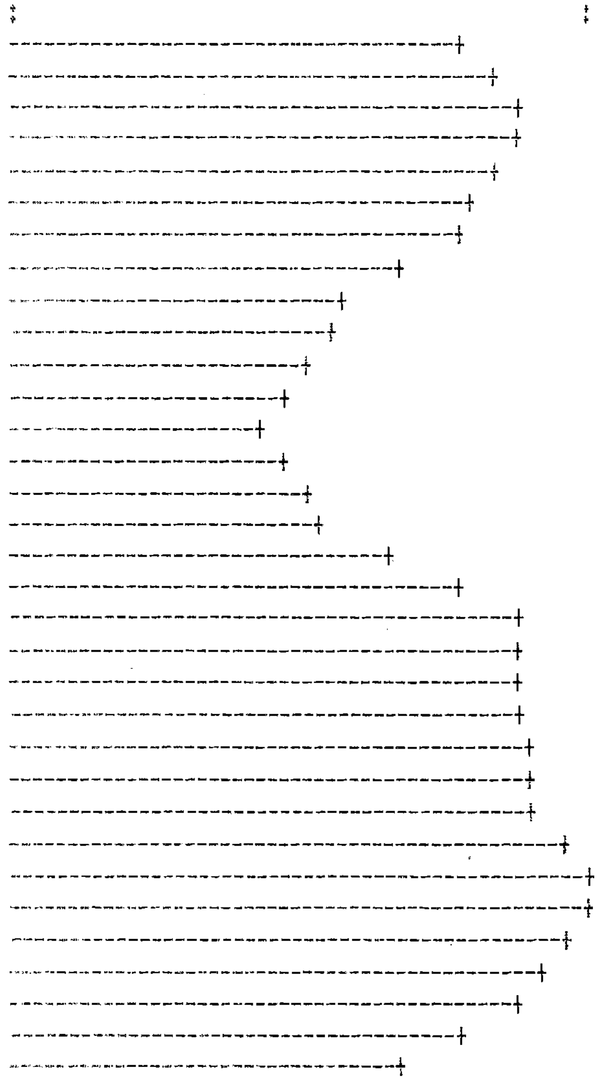
	Minimum	WATANA verses TIME	Maximum			
	1.0821E+05		8.0389E+05			
TIME	WATANA	:	:	N	GENKW	EFF
4.2500E+00	1.4811E+05	--+		1.0000E+00	1.4811E+05	9.1987E-01
4.2917E+00	2.3491E+05	---------+		2.0000E+00	1.1745E+05	8.8914E-01
4.3334E+00	3.2130E+05	---------------+		2.0000E+00	1.6065E+05	9.1646E-01
4.3750E+00	3.6247E+05	-----------------+		3.0000E+00	1.2082E+05	8.9371E-01
4.4167E+00	4.0363E+05	--------------------+		3.0000E+00	1.3454E+05	9.0938E-01
4.4584E+00	4.1772E+05	---------------------+		3.0000E+00	1.3924E+05	9.1320E-01
4.5000E+00	4.3159E+05	----------------------+		3.0000E+00	1.4386E+05	9.1696E-01
4.5417E+00	4.2467E+05	---------------------+		3.0000E+00	1.4156E+05	9.1509E-01
4.5834E+00	4.1775E+05	---------------------+		3.0000E+00	1.3925E+05	9.1322E-01
4.6250E+00	4.1085E+05	--------------------+		3.0000E+00	1.3695E+05	9.1135E-01
4.6667E+00	4.1546E+05	---------------------+		3.0000E+00	1.3849E+05	9.1260E-01
4.7084E+00	4.2007E+05	---------------------+		3.0000E+00	1.4002E+05	9.1385E-01
4.7500E+00	4.2466E+05	---------------------+		3.0000E+00	1.4155E+05	9.1509E-01
4.7917E+00	4.0852E+05	--------------------+		3.0000E+00	1.3617E+05	9.1072E-01
4.8334E+00	3.9239E+05	-------------------+		3.0000E+00	1.3080E+05	9.0635E-01
4.8750E+00	3.7626E+05	------------------+		3.0000E+00	1.2542E+05	8.9996E-01
4.9167E+00	3.6934E+05	-----------------+		3.0000E+00	1.2311E+05	8.9684E-01
4.9584E+00	3.1745E+05	---------------+		2.0000E+00	1.5872E+05	9.1698E-01
5.0000E+00	1.9119E+05	-----+		2.0000E+00	9.5595E+04	8.5548E-01
5.0417E+00	1.6651E+05	----+		1.0000E+00	1.6651E+05	9.1431E-01
5.0834E+00	1.4182E+05	--+		1.0000E+00	1.4182E+05	9.1535E-01
5.1250E+00	1.1717E+05	+		1.0000E+00	1.1717E+05	8.8884E-01
5.1667E+00	1.1717E+05	+		1.0000E+00	1.1717E+05	8.8886E-01
5.2084E+00	1.1717E+05	+		1.0000E+00	1.1717E+05	8.8887E-01
5.2500E+00	1.1725E+05	+		1.0000E+00	1.1725E+05	8.8901E-01
5.2917E+00	2.0174E+05	------+		2.0000E+00	1.0087E+05	8.6416E-01
5.3334E+00	2.8582E+05	------------+		2.0000E+00	1.4291E+05	9.1630E-01
5.3750E+00	3.2589E+05	---------------+		2.0000E+00	1.6294E+05	9.1580E-01
5.4167E+00	3.6596E+05	-----------------+		3.0000E+00	1.2199E+05	8.9548E-01
5.4584E+00	3.7966E+05	------------------+		3.0000E+00	1.2655E+05	9.0169E-01
5.5000E+00	3.9316E+05	-------------------+		3.0000E+00	1.3105E+05	9.0668E-01
5.5417E+00	3.8643E+05	------------------+		3.0000E+00	1.2881E+05	9.0477E-01
5.5834E+00	3.7969E+05	------------------+		3.0000E+00	1.2656E+05	9.0174E-01
5.6250E+00	3.7297E+05	------------------+		3.0000E+00	1.2432E+05	8.9871E-01
5.6667E+00	3.7746E+05	------------------+		3.0000E+00	1.2582E+05	9.0075E-01
5.7084E+00	3.8195E+05	------------------+		3.0000E+00	1.2732E+05	9.0280E-01
5.7500E+00	3.8641E+05	------------------+		3.0000E+00	1.2880E+05	9.0483E-01
5.7917E+00	3.7071E+05	-----------------+		3.0000E+00	1.2357E+05	8.9774E-01
5.8334E+00	3.5500E+05	----------------+		2.0000E+00	1.7750E+05	8.9904E-01
5.8750E+00	3.3930E+05	---------------+		2.0000E+00	1.6965E+05	9.0968E-01
5.9167E+00	3.3256E+05	---------------+		2.0000E+00	1.6628E+05	9.1424E-01
5.9584E+00	2.8205E+05	------------+		2.0000E+00	1.4103E+05	9.1489E-01
6.0000E+00	1.8056E+05	-----+		2.0000E+00	9.0282E+04	8.5000E-01
6.0417E+00	1.5644E+05	---+		1.0000E+00	1.5644E+05	9.1751E-01
6.0834E+00	1.3231E+05	-+		1.0000E+00	1.3231E+05	9.0782E-01
6.1250E+00	1.0821E+05	+		1.0000E+00	1.0821E+05	8.7638E-01
6.1667E+00	1.0821E+05	+		1.0000E+00	1.0821E+05	8.7640E-01
6.2084E+00	1.0821E+05	+		1.0000E+00	1.0821E+05	8.7641E-01
6.2501E+00	1.0831E+05	+		1.0000E+00	1.0831E+05	8.7659E-01
6.2917E+00	1.9089E+05	-----+		2.0000E+00	9.5447E+04	8.5563E-01
6.3334E+00	2.7307E+05	-----------+		2.0000E+00	1.3654E+05	9.1132E-01

Minimum 1.0821E+05 WATANA verses TIME Maximum 8.0389E+05

TIME	WATANA	: :	N	GENKW	EFF
6.3751E+00	3.1224E+05	--------------+	2.0000E+00	1.5612E+05	9.1757E-01
6.4167E+00	3.5140E+05	---------------+	2.0000E+00	1.7570E+05	9.0121E-01
6.4584E+00	3.6479E+05	------------------+	3.0000E+00	1.2160E+05	8.9527E-01
6.5001E+00	3.7798E+05	-------------------+	3.0000E+00	1.2599E+05	9.0125E-01
6.5417E+00	3.7140E+05	------------------+	3.0000E+00	1.2380E+05	8.9828E-01
6.5834E+00	3.6482E+05	------------------+	3.0000E+00	1.2161E+05	8.9531E-01
6.6251E+00	3.5825E+05	-----------------+	2.0000E+00	1.7913E+05	8.9648E-01
6.6667E+00	3.6264E+05	------------------+	3.0000E+00	1.2088E+05	8.9434E-01
6.7084E+00	3.6703E+05	------------------+	3.0000E+00	1.2234E+05	8.9634E-01
6.7501E+00	3.7139E+05	------------------+	3.0000E+00	1.2380E+05	8.9833E-01
6.7917E+00	3.5603E+05	-----------------+	2.0000E+00	1.7802E+05	8.9793E-01
6.8334E+00	3.4068E+05	----------------+	2.0000E+00	1.7034E+05	9.0835E-01
6.8751E+00	3.2534E+05	---------------+	2.0000E+00	1.6267E+05	9.1575E-01
6.9167E+00	3.1874E+05	---------------+	2.0000E+00	1.5937E+05	9.1665E-01
6.9584E+00	2.6937E+05	-----------+	2.0000E+00	1.3469E+05	9.0992E-01
7.0001E+00	2.1015E+05	-------+	2.0000E+00	1.0507E+05	8.7152E-01
7.0417E+00	1.8447E+05	-----+	2.0000E+00	9.2237E+04	8.5057E-01
7.0834E+00	1.5880E+05	---+	1.0000E+00	1.5880E+05	9.1679E-01
7.1251E+00	1.3316E+05	-+	1.0000E+00	1.3316E+05	9.0870E-01
7.1667E+00	1.3316E+05	-+	1.0000E+00	1.3316E+05	9.0871E-01
7.2084E+00	1.3316E+05	-+	1.0000E+00	1.3316E+05	9.0872E-01
7.2501E+00	1.3328E+05	-+	1.0000E+00	1.3328E+05	9.0883E-01
7.2917E+00	2.2116E+05	--------+	2.0000E+00	1.1058E+05	8.8050E-01
7.3334E+00	3.0861E+05	--------------+	2.0000E+00	1.5431E+05	9.1800E-01
7.3751E+00	3.5030E+05	-----------------+	2.0000E+00	1.7515E+05	9.0160E-01
7.4167E+00	3.9198E+05	--------------------+	3.0000E+00	1.3066E+05	9.0671E-01
7.4584E+00	4.0622E+05	---------------------+	3.0000E+00	1.3541E+05	9.1059E-01
7.5001E+00	4.2025E+05	----------------------+	3.0000E+00	1.4008E+05	9.1442E-01
7.5417E+00	4.1325E+05	---------------------+	3.0000E+00	1.3775E+05	9.1252E-01
7.5834E+00	4.0625E+05	---------------------+	3.0000E+00	1.3542E+05	9.1062E-01
7.6251E+00	3.9926E+05	--------------------+	3.0000E+00	1.3309E+05	9.0872E-01
7.6667E+00	4.0393E+05	---------------------+	3.0000E+00	1.3464E+05	9.1000E-01
7.7084E+00	4.0860E+05	---------------------+	3.0000E+00	1.3620E+05	9.1127E-01
7.7501E+00	4.1324E+05	---------------------+	3.0000E+00	1.3775E+05	9.1254E-01
7.7917E+00	3.9690E+05	--------------------+	3.0000E+00	1.3230E+05	9.0810E-01
7.8334E+00	3.8056E+05	-------------------+	3.0000E+00	1.2685E+05	9.0276E-01
7.8751E+00	3.6423E+05	------------------+	3.0000E+00	1.2141E+05	8.9535E-01
7.9167E+00	3.5720E+05	-----------------+	2.0000E+00	1.7860E+05	8.9674E-01
7.9584E+00	3.0466E+05	--------------+	2.0000E+00	1.5233E+05	9.1850E-01
8.0001E+00	3.0564E+05	--------------+	2.0000E+00	1.5282E+05	9.1837E-01
8.0417E+00	2.8804E+05	------------+	2.0000E+00	1.4402E+05	9.1770E-01
8.0834E+00	2.7043E+05	-----------+	2.0000E+00	1.3522E+05	9.1051E-01
8.1251E+00	2.5288E+05	----------+	2.0000E+00	1.2644E+05	9.0224E-01
8.1667E+00	2.6797E+05	-----------+	2.0000E+00	1.3399E+05	9.0951E-01
8.2084E+00	2.8306E+05	------------+	2.0000E+00	1.4153E+05	9.1568E-01
8.2501E+00	2.9821E+05	-------------+	2.0000E+00	1.4911E+05	9.1937E-01
8.2917E+00	3.5354E+05	-----------------+	2.0000E+00	1.7677E+05	8.9918E-01
8.3334E+00	4.0887E+05	---------------------+	3.0000E+00	1.3629E+05	9.1141E-01
8.3751E+00	4.6411E+05	-------------------------+	3.0000E+00	1.5470E+05	9.1785E-01
8.4167E+00	4.6411E+05	-------------------------+	3.0000E+00	1.5470E+05	9.1785E-01
8.4584E+00	4.6411E+05	-------------------------+	3.0000E+00	1.5470E+05	9.1785E-01

TIME	WATANA	Minimum 1.0821E+05 : WATANA verses TIME Maximum 8.0389E+05 :	N	GENKW	EFF
8.5001E+00	4.6411E+05	-------------------------+	3.0000E+00	1.5470E+05	9.1785E-01
8.5417E+00	4.6663E+05	-------------------------+	3.0000E+00	1.5554E+05	9.1762E-01
8.5834E+00	4.6914E+05	-------------------------+	3.0000E+00	1.5638E+05	9.1739E-01
8.6251E+00	4.7170E+05	--------------------------+	3.0000E+00	1.5723E+05	9.1716E-01
8.6667E+00	4.9821E+05	----------------------------+	3.0000E+00	1.6607E+05	9.1374E-01
8.7084E+00	5.2439E+05	-----------------------------+	3.0000E+00	1.7480E+05	9.0185E-01
8.7501E+00	5.1689E+05	-----------------------------+	3.0000E+00	1.7230E+05	9.0525E-01
8.7917E+00	4.9929E+05	----------------------------+	3.0000E+00	1.6643E+05	9.1325E-01
8.8334E+00	4.8168E+05	--------------------------+	3.0000E+00	1.6056E+05	9.1625E-01
8.8751E+00	4.6402E+05	-------------------------+	3.0000E+00	1.5467E+05	9.1785E-01
8.9167E+00	4.1372E+05	---------------------+	3.0000E+00	1.3791E+05	9.1274E-01
8.9584E+00	3.6342E+05	------------------+	3.0000E+00	1.2114E+05	8.9506E-01
9.0001E+00	3.8183E+05	-------------------+	3.0000E+00	1.2728E+05	9.0341E-01
9.0417E+00	3.6172E+05	------------------+	3.0000E+00	1.2057E+05	8.9428E-01
9.0834E+00	3.4161E+05	----------------+	2.0000E+00	1.7081E+05	9.0728E-01
9.1251E+00	3.2157E+05	---------------+	2.0000E+00	1.6078E+05	9.1619E-01
9.1667E+00	3.3881E+05	----------------+	2.0000E+00	1.6940E+05	9.0920E-01
9.2084E+00	3.5604E+05	-----------------+	2.0000E+00	1.7802E+05	8.9746E-01
9.2501E+00	3.7336E+05	-------------------+	3.0000E+00	1.2445E+05	8.9956E-01
9.2917E+00	4.3656E+05	-----------------------+	3.0000E+00	1.4552E+05	9.1895E-01
9.3334E+00	4.9975E+05	----------------------------+	3.0000E+00	1.6658E+05	9.1305E-01
9.3751E+00	5.6284E+05	--------------------------------+	4.0000E+00	1.4071E+05	9.1502E-01
9.4167E+00	5.6284E+05	--------------------------------+	4.0000E+00	1.4071E+05	9.1501E-01
9.4584E+00	5.6284E+05	--------------------------------+	4.0000E+00	1.4071E+05	9.1501E-01
9.5001E+00	5.6284E+05	--------------------------------+	4.0000E+00	1.4071E+05	9.1501E-01
9.5417E+00	5.6572E+05	--------------------------------+	4.0000E+00	1.4143E+05	9.1559E-01
9.5834E+00	5.6859E+05	---------------------------------+	4.0000E+00	1.4215E+05	9.1617E-01
9.6251E+00	5.7151E+05	---------------------------------+	4.0000E+00	1.4288E+05	9.1677E-01
9.6667E+00	6.0180E+05	-----------------------------------+	4.0000E+00	1.5045E+05	9.1902E-01
9.7084E+00	6.3170E+05	-------------------------------------+	4.0000E+00	1.5792E+05	9.1698E-01
9.7501E+00	6.2312E+05	-------------------------------------+	4.0000E+00	1.5578E+05	9.1757E-01
9.7917E+00	6.0302E+05	-----------------------------------+	4.0000E+00	1.5075E+05	9.1894E-01
9.8334E+00	5.8291E+05	----------------------------------+	4.0000E+00	1.4573E+05	9.1908E-01
9.8751E+00	5.6273E+05	--------------------------------+	4.0000E+00	1.4068E+05	9.1495E-01
9.9167E+00	5.0527E+05	----------------------------+	3.0000E+00	1.6842E+05	9.1064E-01
9.9584E+00	4.4782E+05	------------------------+	3.0000E+00	1.4927E+05	9.1934E-01
1.0000E+01	4.2956E+05	-----------------------+	3.0000E+00	1.4319E+05	9.1699E-01
1.0042E+01	4.0624E+05	---------------------+	3.0000E+00	1.3541E+05	9.1064E-01
1.0083E+01	3.8292E+05	-------------------+	3.0000E+00	1.2764E+05	9.0380E-01
1.0125E+01	3.5969E+05	------------------+	3.0000E+00	1.1990E+05	8.9325E-01
1.0167E+01	3.7968E+05	-------------------+	3.0000E+00	1.2656E+05	9.0232E-01
1.0208E+01	3.9966E+05	--------------------+	3.0000E+00	1.3322E+05	9.0883E-01
1.0250E+01	4.1976E+05	----------------------+	3.0000E+00	1.3992E+05	9.1430E-01
1.0292E+01	4.9305E+05	---------------------------+	3.0000E+00	1.6435E+05	9.1525E-01
1.0333E+01	5.6635E+05	--------------------------------+	4.0000E+00	1.4159E+05	9.1566E-01
1.0375E+01	6.3949E+05	--------------------------------------+	4.0000E+00	1.5987E+05	9.1647E-01
1.0417E+01	6.3949E+05	--------------------------------------+	4.0000E+00	1.5987E+05	9.1647E-01
1.0458E+01	6.3949E+05	--------------------------------------+	4.0000E+00	1.5987E+05	9.1647E-01
1.0500E+01	6.3950E+05	--------------------------------------+	4.0000E+00	1.5987E+05	9.1648E-01
1.0542E+01	6.4283E+05	--------------------------------------+	4.0000E+00	1.6071E+05	9.1625E-01
1.0583E+01	6.4616E+05	--------------------------------------+	4.0000E+00	1.6154E+05	9.1603E-01

Minimum 1.0821E+05 — WATANA verses TIME — Maximum 8.0389E+05



TIME	WATANA	N	GENKW	EFF
1.0625E+01	6.4956E+05	4.0000E+00	1.6239E+05	9.1580E-01
1.0667E+01	6.8468E+05	4.0000E+00	1.7117E+05	9.0705E-01
1.0708E+01	7.1935E+05	5.0000E+00	1.4387E+05	9.1747E-01
1.0750E+01	7.0940E+05	4.0000E+00	1.7735E+05	8.9866E-01
1.0792E+01	6.8608E+05	4.0000E+00	1.7152E+05	9.0661E-01
1.0833E+01	6.6276E+05	4.0000E+00	1.6569E+05	9.1455E-01
1.0875E+01	6.3935E+05	4.0000E+00	1.5984E+05	9.1651E-01
1.0917E+01	5.7272E+05	4.0000E+00	1.4318E+05	9.1688E-01
1.0958E+01	5.0609E+05	3.0000E+00	1.6870E+05	9.1049E-01
1.1000E+01	4.8959E+05	3.0000E+00	1.6320E+05	9.1560E-01
1.1042E+01	4.6429E+05	3.0000E+00	1.5476E+05	9.1789E-01
1.1083E+01	4.3900E+05	3.0000E+00	1.4633E+05	9.1944E-01
1.1125E+01	4.1381E+05	3.0000E+00	1.3794E+05	9.1258E-01
1.1167E+01	4.3549E+05	3.0000E+00	1.4516E+05	9.1847E-01
1.1208E+01	4.5717E+05	3.0000E+00	1.5239E+05	9.1854E-01
1.1250E+01	4.7897E+05	3.0000E+00	1.5966E+05	9.1657E-01
1.1292E+01	5.5847E+05	4.0000E+00	1.3962E+05	9.1393E-01
1.1333E+01	6.3796E+05	4.0000E+00	1.5949E+05	9.1662E-01
1.1375E+01	7.1728E+05	5.0000E+00	1.4346E+05	9.1706E-01
1.1417E+01	7.1728E+05	5.0000E+00	1.4346E+05	9.1705E-01
1.1458E+01	7.1728E+05	5.0000E+00	1.4346E+05	9.1704E-01
1.1500E+01	7.1729E+05	5.0000E+00	1.4346E+05	9.1704E-01
1.1542E+01	7.2090E+05	5.0000E+00	1.4418E+05	9.1762E-01
1.1583E+01	7.2451E+05	5.0000E+00	1.4490E+05	9.1820E-01
1.1625E+01	7.2821E+05	5.0000E+00	1.4564E+05	9.1880E-01
1.1667E+01	7.6630E+05	5.0000E+00	1.5326E+05	9.1833E-01
1.1708E+01	8.0389E+05	5.0000E+00	1.6078E+05	9.1629E-01
1.1750E+01	7.9310E+05	5.0000E+00	1.5862E+05	9.1688E-01
1.1792E+01	7.6781E+05	5.0000E+00	1.5356E+05	9.1826E-01
1.1833E+01	7.4252E+05	5.0000E+00	1.4850E+05	9.1963E-01
1.1875E+01	7.1711E+05	5.0000E+00	1.4342E+05	9.1695E-01
1.1917E+01	6.4485E+05	4.0000E+00	1.6121E+05	9.1619E-01
1.1958E+01	5.7258E+05	4.0000E+00	1.4315E+05	9.1671E-01

Minimum 3.8821E+05 KWLOAD verses TIME Maximum 1.0839E+06

TIME	KWLOAD	! !	THERML	SMHY	PEAKPL
0.0000E+00	7.0345E+05	----------------------+	2.0000E+05	8.0000E+04	0.0000E+00
4.1667E-02	6.8033E+05	--------------------+	2.0000E+05	8.0000E+04	0.0000E+00
8.3334E-02	6.5721E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
1.2500E-01	6.3410E+05	-----------------+	2.0000E+05	8.0000E+04	0.0000E+00
1.6667E-01	6.5391E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
2.0833E-01	6.7373E+05	--------------------+	2.0000E+05	8.0000E+04	0.0000E+00
2.5000E-01	6.9355E+05	---------------------+	2.0000E+05	8.0000E+04	0.0000E+00
2.9167E-01	7.6620E+05	---------------------------+	2.0000E+05	8.0000E+04	0.0000E+00
3.3334E-01	8.3886E+05	--------------------------------+	2.0000E+05	8.0000E+04	0.0000E+00
3.7500E-01	9.1151E+05	-------------------------------------+	2.0000E+05	8.0000E+04	0.0000E+00
4.1667E-01	9.1151E+05	-------------------------------------+	2.0000E+05	8.0000E+04	0.0000E+00
4.5834E-01	9.1151E+05	-------------------------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.0000E-01	9.1151E+05	-------------------------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.4167E-01	9.1482E+05	-------------------------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.8334E-01	9.1812E+05	--------------------------------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.2501E-01	9.2143E+05	--------------------------------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.6667E-01	9.5624E+05	--+	2.0000E+05	8.0000E+04	0.0000E+00
7.0834E-01	9.9070E+05	---+	2.0000E+05	8.0000E+04	0.0000E+00
7.5001E-01	9.8086E+05	--+	2.0000E+05	8.0000E+04	0.0000E+00
7.9167E-01	9.5775E+05	--+	2.0000E+05	8.0000E+04	0.0000E+00
8.3334E-01	9.3463E+05	---------------------------------------+	2.0000E+05	8.0000E+04	0.0000E+00
8.7501E-01	9.1150E+05	-------------------------------------+	2.0000E+05	8.0000E+04	0.0000E+00
9.1667E-01	8.4545E+05	--------------------------------+	2.0000E+05	8.0000E+04	0.0000E+00
9.5834E-01	7.7940E+05	----------------------------+	2.0000E+05	8.0000E+04	0.0000E+00
1.0000E+00	6.6496E+05	-------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.0417E+00	6.4311E+05	------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.0833E+00	6.2126E+05	----------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.1250E+00	5.9941E+05	---------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.1667E+00	6.1814E+05	----------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.2083E+00	6.3688E+05	-----------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.2500E+00	6.5562E+05	-------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.2917E+00	7.2430E+05	------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.3333E+00	7.9299E+05	-----------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.3750E+00	8.6165E+05	----------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.4167E+00	8.6165E+05	----------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.4583E+00	8.6165E+05	----------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.5000E+00	8.6165E+05	----------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.5417E+00	8.6477E+05	----------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.5833E+00	8.6789E+05	----------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.6250E+00	8.7103E+05	----------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.6667E+00	9.0394E+05	-------------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.7083E+00	9.3650E+05	---------------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.7500E+00	9.2720E+05	--------------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.7917E+00	9.0535E+05	-------------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.8333E+00	8.8350E+05	-----------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.8750E+00	8.6163E+05	----------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.9167E+00	7.9919E+05	-----------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
1.9583E+00	7.3675E+05	-------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.0000E+00	6.0262E+05	---------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.0417E+00	5.8282E+05	-------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.0833E+00	5.6301E+05	------------+	1.5000E+05	8.0000E+04	0.0000E+00

	Minimum 3.8821E+05	KWLOAD verses TIME	Maximum 1.0839E+06		
TIME	KWLOAD	: :	THERML	SMHY	PEAKPL
2.1250E+00	5.4322E+05	------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.1667E+00	5.6020E+05	-------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.2084E+00	5.7717E+05	--------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.2500E+00	5.9417E+05	---------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.2917E+00	6.5641E+05	--------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.3334E+00	7.1865E+05	------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.3750E+00	7.8087E+05	-----------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.4167E+00	7.8087E+05	-----------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.4584E+00	7.8087E+05	-----------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.5000E+00	7.8087E+05	-----------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.5417E+00	7.8370E+05	-----------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.5834E+00	7.8653E+05	-----------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.6250E+00	7.8937E+05	-----------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.6667E+00	8.1920E+05	-------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.7084E+00	8.4870E+05	----------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.7500E+00	8.4027E+05	---------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.7917E+00	8.2047E+05	--------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.8334E+00	8.0066E+05	------------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.8750E+00	7.8084E+05	-----------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.9167E+00	7.2425E+05	-------------------------+	1.5000E+05	8.0000E+04	0.0000E+00
2.9584E+00	6.6767E+05	---------------------+	1.5000E+05	8.0000E+04	0.0000E+00
3.0000E+00	5.3566E+05	-----------+	2.0000E+05	6.0000E+04	0.0000E+00
3.0417E+00	5.1805E+05	----------+	2.0000E+05	6.0000E+04	0.0000E+00
3.0834E+00	5.0045E+05	--------+	2.0000E+05	6.0000E+04	0.0000E+00
3.1250E+00	4.8287E+05	------+	2.0000E+05	6.0000E+04	0.0000E+00
3.1667E+00	4.9796E+05	-------+	2.0000E+05	6.0000E+04	0.0000E+00
3.2084E+00	5.1304E+05	--------+	2.0000E+05	6.0000E+04	0.0000E+00
3.2500E+00	5.2816E+05	----------+	2.0000E+05	6.0000E+04	0.0000E+00
3.2917E+00	5.8349E+05	---------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.3334E+00	6.3881E+05	-------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.3750E+00	6.9411E+05	----------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.4167E+00	6.9411E+05	----------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.4584E+00	6.9411E+05	----------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.5000E+00	6.9411E+05	----------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.5417E+00	6.9662E+05	-----------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.5834E+00	6.9914E+05	-----------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.6250E+00	7.0167E+05	-----------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.6667E+00	7.2818E+05	-------------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.7084E+00	7.5440E+05	---------------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.7500E+00	7.4691E+05	--------------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.7917E+00	7.2930E+05	-------------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.8334E+00	7.1170E+05	------------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.8750E+00	6.9407E+05	----------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.9167E+00	6.4377E+05	-------------------+	2.0000E+05	6.0000E+04	0.0000E+00
3.9584E+00	5.9347E+05	---------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.0000E+00	4.8409E+05	------+	2.0000E+05	6.0000E+04	0.0000E+00
4.0417E+00	4.5874E+05	-----+	2.0000E+05	6.0000E+04	0.0000E+00
4.0834E+00	4.3338E+05	---+	2.0000E+05	6.0000E+04	0.0000E+00
4.1250E+00	4.0804E+05	-+	2.0000E+05	6.0000E+04	0.0000E+00
4.1667E+00	4.0804E+05	-+	2.0000E+05	6.0000E+04	0.0000E+00
4.2084E+00	4.0804E+05	-+	2.0000E+05	6.0000E+04	0.0000E+00

Minimum 3.8821E+05 KWLOAD verses TIME Maximum 1.0839E+06

TIME	KWLOAD	: :	THERML	SMHY	PEAKPL
4.2500E+00	4.0811E+05	-+	2.0000E+05	6.0000E+04	0.0000E+00
4.2917E+00	4.9491E+05	-------+	2.0000E+05	6.0000E+04	0.0000E+00
4.3334E+00	5.8130E+05	-------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.3750E+00	6.2247E+05	----------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.4167E+00	6.6363E+05	-------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.4584E+00	6.7772E+05	--------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.5000E+00	6.9159E+05	---------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.5417E+00	6.8467E+05	---------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.5834E+00	6.7775E+05	--------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.6250E+00	6.7085E+05	--------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.6667E+00	6.7546E+05	--------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.7084E+00	6.8007E+05	--------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.7500E+00	6.8466E+05	---------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.7917E+00	6.6852E+05	--------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.8334E+00	6.5239E+05	------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.8750E+00	6.3626E+05	-----------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.9167E+00	6.2934E+05	-----------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.9584E+00	5.7745E+05	-------------+	2.0000E+05	6.0000E+04	0.0000E+00
5.0000E+00	4.7119E+05	-----+	2.0000E+05	8.0000E+04	0.0000E+00
5.0417E+00	4.4651E+05	----+	2.0000E+05	8.0000E+04	0.0000E+00
5.0834E+00	4.2182E+05	--+	2.0000E+05	8.0000E+04	0.0000E+00
5.1250E+00	3.9717E+05	+	2.0000E+05	8.0000E+04	0.0000E+00
5.1667E+00	3.9717E+05	+	2.0000E+05	8.0000E+04	0.0000E+00
5.2084E+00	3.9717E+05	+	2.0000E+05	8.0000E+04	0.0000E+00
5.2500E+00	3.9725E+05	+	2.0000E+05	8.0000E+04	0.0000E+00
5.2917E+00	4.8174E+05	------+	2.0000E+05	8.0000E+04	0.0000E+00
5.3334E+00	5.6582E+05	------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.3750E+00	6.0589E+05	---------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.4167E+00	6.4596E+05	------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.4584E+00	6.5966E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.5000E+00	6.7316E+05	--------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.5417E+00	6.6643E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.5834E+00	6.5969E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.6250E+00	6.5297E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.6667E+00	6.5746E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.7084E+00	6.6195E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.7500E+00	6.6641E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.7917E+00	6.5071E+05	------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.8334E+00	6.3500E+05	-----------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.8750E+00	6.1930E+05	----------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.9167E+00	6.1256E+05	----------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.9584E+00	5.6205E+05	------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.0000E+00	4.6056E+05	-----+	2.0000E+05	8.0000E+04	0.0000E+00
6.0417E+00	4.3644E+05	---+	2.0000E+05	8.0000E+04	0.0000E+00
6.0834E+00	4.1231E+05	-+	2.0000E+05	8.0000E+04	0.0000E+00
6.1250E+00	3.8821E+05	+	2.0000E+05	8.0000E+04	0.0000E+00
6.1667E+00	3.8821E+05	+	2.0000E+05	8.0000E+04	0.0000E+00
6.2084E+00	3.8821E+05	+	2.0000E+05	8.0000E+04	0.0000E+00
6.2501E+00	3.8831E+05	+	2.0000E+05	8.0000E+04	0.0000E+00
6.2917E+00	4.7089E+05	-----+	2.0000E+05	8.0000E+04	0.0000E+00
6.3334E+00	5.5307E+05	-----------+	2.0000E+05	8.0000E+04	0.0000E+00

		Minimum 3.8821E+05 — KWLOAD verses TIME — Maximum 1.0839E+06			
TIME	KWLOAD	: :	THERML	SMHY	PEAKPL
6.3751E+00	5.9224E+05	--------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.4167E+00	6.3140E+05	-----------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.4584E+00	6.4479E+05	------------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.5001E+00	6.5798E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.5417E+00	6.5140E+05	------------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.5834E+00	6.4482E+05	------------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.6251E+00	6.3825E+05	-----------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.6667E+00	6.4264E+05	------------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.7084E+00	6.4703E+05	------------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.7501E+00	6.5139E+05	------------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.7917E+00	6.3603E+05	-----------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.8334E+00	6.2068E+05	----------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.8751E+00	6.0534E+05	---------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.9167E+00	5.9874E+05	---------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.9584E+00	5.4937E+05	-----------+	2.0000E+05	8.0000E+04	0.0000E+00
7.0001E+00	4.9015E+05	-------+	2.0000E+05	8.0000E+04	0.0000E+00
7.0417E+00	4.6447E+05	-----+	2.0000E+05	8.0000E+04	0.0000E+00
7.0834E+00	4.3880E+05	---+	2.0000E+05	8.0000E+04	0.0000E+00
7.1251E+00	4.1316E+05	-+	2.0000E+05	8.0000E+04	0.0000E+00
7.1667E+00	4.1316E+05	-+	2.0000E+05	8.0000E+04	0.0000E+00
7.2084E+00	4.1316E+05	-+	2.0000E+05	8.0000E+04	0.0000E+00
7.2501E+00	4.1328E+05	-+	2.0000E+05	8.0000E+04	0.0000E+00
7.2917E+00	5.0116E+05	--------+	2.0000E+05	8.0000E+04	0.0000E+00
7.3334E+00	5.8861E+05	--------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.3751E+00	6.3030E+05	-----------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.4167E+00	6.7198E+05	--------------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.4584E+00	6.8622E+05	---------------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.5001E+00	7.0025E+05	----------------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.5417E+00	6.9325E+05	---------------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.5834E+00	6.8625E+05	---------------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.6251E+00	6.7926E+05	--------------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.6667E+00	6.8393E+05	---------------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.7084E+00	6.8860E+05	---------------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.7501E+00	6.9324E+05	---------------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.7917E+00	6.7690E+05	--------------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.8334E+00	6.6056E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.8751E+00	6.4423E+05	------------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.9167E+00	6.3720E+05	-----------------+	2.0000E+05	8.0000E+04	0.0000E+00
7.9584E+00	5.8466E+05	--------------+	2.0000E+05	8.0000E+04	0.0000E+00
8.0001E+00	5.3564E+05	----------+	1.5000E+05	8.0000E+04	0.0000E+00
8.0417E+00	5.1804E+05	---------+	1.5000E+05	8.0000E+04	0.0000E+00
8.0834E+00	5.0043E+05	--------+	1.5000E+05	8.0000E+04	0.0000E+00
8.1251E+00	4.8288E+05	------+	1.5000E+05	8.0000E+04	0.0000E+00
8.1667E+00	4.9797E+05	-------+	1.5000E+05	8.0000E+04	0.0000E+00
8.2084E+00	5.1306E+05	--------+	1.5000E+05	8.0000E+04	0.0000E+00
8.2501E+00	5.2821E+05	----------+	1.5000E+05	8.0000E+04	0.0000E+00
8.2917E+00	5.8354E+05	--------------+	1.5000E+05	8.0000E+04	0.0000E+00
8.3334E+00	6.3887E+05	------------------+	1.5000E+05	8.0000E+04	0.0000E+00
8.3751E+00	6.9411E+05	---------------------+	1.5000E+05	8.0000E+04	0.0000E+00
8.4167E+00	6.9411E+05	---------------------+	1.5000E+05	8.0000E+04	0.0000E+00
8.4584E+00	6.9411E+05	---------------------+	1.5000E+05	8.0000E+04	0.0000E+00

Minimum 3.8821E+05 KWLOAD verses TIME Maximum 1.0839E+06

TIME	KWLOAD	THERML	SMHY	PEAKPL
8.5001E+00	6.9411E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.5417E+00	6.9663E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.5834E+00	6.9914E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.6251E+00	7.0170E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.6667E+00	7.2821E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.7084E+00	7.5439E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.7501E+00	7.4689E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.7917E+00	7.2929E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.8334E+00	7.1168E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.8751E+00	6.9402E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.9167E+00	6.4372E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.9584E+00	5.9342E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.0001E+00	6.1183E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.0417E+00	5.9172E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.0834E+00	5.7161E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.1251E+00	5.5157E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.1667E+00	5.6881E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.2084E+00	5.8604E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.2501E+00	6.0336E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.2917E+00	6.6656E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.3334E+00	7.2975E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.3751E+00	7.9284E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.4167E+00	7.9284E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.4584E+00	7.9284E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.5001E+00	7.9284E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.5417E+00	7.9572E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.5834E+00	7.9859E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.6251E+00	8.0151E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.6667E+00	8.3180E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.7084E+00	8.6170E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.7501E+00	8.5312E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.7917E+00	8.3302E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.8334E+00	8.1291E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.8751E+00	7.9273E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.9167E+00	7.3527E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.9584E+00	6.7782E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.0000E+01	7.0956E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0042E+01	6.8624E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0083E+01	6.6292E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0125E+01	6.3969E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0167E+01	6.5968E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0208E+01	6.7966E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0250E+01	6.9976E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0292E+01	7.7305E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0333E+01	8.4635E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0375E+01	9.1949E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0417E+01	9.1949E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0458E+01	9.1949E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0500E+01	9.1950E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0542E+01	9.2283E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0583E+01	9.2616E+05	2.0000E+05	8.0000E+04	0.0000E+00

KWLOAD verses TIME

Minimum 3.8821E+05 Maximum 1.0839E+06

TIME	KWLOAD	THERML	SMHY	PEAKPL
1.0625E+01	9.2956E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0667E+01	9.6468E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0708E+01	9.9935E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0750E+01	9.8940E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0792E+01	9.6608E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0833E+01	9.4276E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0875E+01	9.1935E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0917E+01	8.5272E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0958E+01	7.8609E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1000E+01	7.6959E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1042E+01	7.4429E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1083E+01	7.1900E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1125E+01	6.9381E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1167E+01	7.1549E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1208E+01	7.3717E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1250E+01	7.5897E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1292E+01	8.3847E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1333E+01	9.1796E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1375E+01	9.9728E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1417E+01	9.9728E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1458E+01	9.9728E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1500E+01	9.9729E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1542E+01	1.0009E+06	2.0000E+05	8.0000E+04	0.0000E+00
1.1583E+01	1.0045E+06	2.0000E+05	8.0000E+04	0.0000E+00
1.1625E+01	1.0082E+06	2.0000E+05	8.0000E+04	0.0000E+00
1.1667E+01	1.0463E+06	2.0000E+05	8.0000E+04	0.0000E+00
1.1708E+01	1.0839E+06	2.0000E+05	8.0000E+04	0.0000E+00
1.1750E+01	1.0731E+06	2.0000E+05	8.0000E+04	0.0000E+00
1.1792E+01	1.0478E+06	2.0000E+05	8.0000E+04	0.0000E+00
1.1833E+01	1.0225E+06	2.0000E+05	8.0000E+04	0.0000E+00
1.1875E+01	9.9711E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1917E+01	9.2485E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.1958E+01	8.5258E+05	2.0000E+05	8.0000E+04	0.0000E+00

Minimum 4.4711E+05 — RESERV verses TIME — Maximum 1.1428E+06

TIME	RESERV	: :	INSTAL	KWLOAD	WATRES
0.0000E+00	8.2755E+05	----------------------------------+	1.5310E+06	7.0345E+05	6.5152E+05
4.1667E-02	8.5067E+05	------------------------------------+	1.5310E+06	6.8033E+05	6.7460E+05
8.3334E-02	8.7379E+05	---------------------------------------+	1.5310E+06	6.5721E+05	6.9769E+05
1.2500E-01	8.9690E+05	---+	1.5310E+06	6.3410E+05	7.2077E+05
1.6667E-01	8.7709E+05	---------------------------------------+	1.5310E+06	6.5391E+05	7.0093E+05
2.0833E-01	8.5727E+05	-------------------------------------+	1.5310E+06	6.7373E+05	6.8108E+05
2.5000E-01	8.3745E+05	-----------------------------------+	1.5310E+06	6.9355E+05	6.6123E+05
2.9167E-01	7.6480E+05	-----------------------------+	1.5310E+06	7.6620E+05	5.8854E+05
3.3334E-01	6.9214E+05	----------------------+	1.5310E+06	8.3886E+05	5.1583E+05
3.7500E-01	6.1949E+05	----------------+	1.5310E+06	9.1151E+05	4.4313E+05
4.1667E-01	6.1949E+05	----------------+	1.5310E+06	9.1151E+05	4.4308E+05
4.5834E-01	6.1949E+05	----------------+	1.5310E+06	9.1151E+05	4.4302E+05
5.0000E-01	6.1949E+05	----------------+	1.5310E+06	9.1151E+05	4.4297E+05
5.4167E-01	6.1618E+05	---------------+	1.5310E+06	9.1482E+05	4.3961E+05
5.8334E-01	6.1288E+05	---------------+	1.5310E+06	9.1812E+05	4.3625E+05
6.2501E-01	6.0957E+05	---------------+	1.5310E+06	9.2143E+05	4.3289E+05
6.6667E-01	5.7476E+05	------------+	1.5310E+06	9.5624E+05	3.9802E+05
7.0834E-01	5.4030E+05	--------+	1.5310E+06	9.9070E+05	3.6350E+05
7.5001E-01	5.5014E+05	---------+	1.5310E+06	9.8086E+05	3.7327E+05
7.9167E-01	5.7325E+05	-----------+	1.5310E+06	9.5775E+05	3.9633E+05
8.3334E-01	5.9637E+05	-------------+	1.5310E+06	9.3463E+05	4.1939E+05
8.7501E-01	6.1950E+05	----------------+	1.5310E+06	9.1150E+05	4.4246E+05
9.1667E-01	6.8555E+05	----------------------+	1.5310E+06	8.4545E+05	5.0846E+05
9.5834E-01	7.5160E+05	----------------------------+	1.5310E+06	7.7940E+05	5.7447E+05
1.0000E+00	8.1604E+05	---------------------------------+	1.5310E+06	6.6496E+05	6.3886E+05
1.0417E+00	8.3789E+05	-----------------------------------+	1.5310E+06	6.4311E+05	6.6068E+05
1.0833E+00	8.5974E+05	-------------------------------------+	1.5310E+06	6.2126E+05	6.8250E+05
1.1250E+00	8.8159E+05	---------------------------------------+	1.5310E+06	5.9941E+05	7.0431E+05
1.1667E+00	8.6286E+05	--------------------------------------+	1.5310E+06	6.1814E+05	6.8555E+05
1.2083E+00	8.4412E+05	------------------------------------+	1.5310E+06	6.3688E+05	6.6678E+05
1.2500E+00	8.2538E+05	----------------------------------+	1.5310E+06	6.5562E+05	6.4800E+05
1.2917E+00	7.5670E+05	----------------------------+	1.5310E+06	7.2430E+05	5.7928E+05
1.3333E+00	6.8801E+05	----------------------+	1.5310E+06	7.9299E+05	5.1055E+05
1.3750E+00	6.1935E+05	----------------+	1.5310E+06	8.6165E+05	4.4184E+05
1.4167E+00	6.1935E+05	----------------+	1.5310E+06	8.6165E+05	4.4178E+05
1.4583E+00	6.1935E+05	----------------+	1.5310E+06	8.6165E+05	4.4173E+05
1.5000E+00	6.1935E+05	----------------+	1.5310E+06	8.6165E+05	4.4167E+05
1.5417E+00	6.1623E+05	---------------+	1.5310E+06	8.6477E+05	4.3849E+05
1.5833E+00	6.1311E+05	---------------+	1.5310E+06	8.6789E+05	4.3532E+05
1.6250E+00	6.0997E+05	---------------+	1.5310E+06	8.7103E+05	4.3213E+05
1.6667E+00	5.7706E+05	------------+	1.5310E+06	9.0394E+05	3.9916E+05
1.7083E+00	5.4450E+05	---------+	1.5310E+06	9.3650E+05	3.6654E+05
1.7500E+00	5.5380E+05	----------+	1.5310E+06	9.2720E+05	3.7577E+05
1.7917E+00	5.7565E+05	------------+	1.5310E+06	9.0535E+05	3.9756E+05
1.8333E+00	5.9750E+05	--------------+	1.5310E+06	8.8350E+05	4.1936E+05
1.8750E+00	6.1937E+05	----------------+	1.5310E+06	8.6163E+05	4.4117E+05
1.9167E+00	6.8181E+05	---------------------+	1.5310E+06	7.9919E+05	5.0355E+05
1.9583E+00	7.4425E+05	---------------------------+	1.5310E+06	7.3675E+05	5.6595E+05
2.0000E+00	8.7838E+05	---------------------------------------+	1.5310E+06	6.0262E+05	7.0004E+05
2.0417E+00	8.9818E+05	---+	1.5310E+06	5.8282E+05	7.1981E+05
2.0833E+00	9.1799E+05	---+	1.5310E+06	5.6301E+05	7.3959E+05

```
                    Minimum              RESERV verses TIME            Maximum
                  4.4711E+05                                        1.1428E+06
 TIME          RESERV     :                                                 :       INSTAL      KWLOAD      WATRES
2.1250E+00  9.3778E+05  -----------------------------------+                      1.5310E+06  5.4322E+05  7.5935E+05
2.1667E+00  9.2080E+05  ----------------------------------+                       1.5310E+06  5.6020E+05  7.4235E+05
2.2084E+00  9.0383E+05  --------------------------------+                         1.5310E+06  5.7717E+05  7.2535E+05
2.2500E+00  8.8683E+05  -------------------------------+                          1.5310E+06  5.9417E+05  7.0832E+05
2.2917E+00  8.2459E+05  ---------------------------+                              1.5310E+06  6.5641E+05  6.4605E+05
2.3334E+00  7.6235E+05  ----------------------+                                   1.5310E+06  7.1865E+05  5.8376E+05
2.3750E+00  7.0013E+05  ------------------+                                       1.5310E+06  7.8087E+05  5.2150E+05
2.4167E+00  7.0013E+05  ------------------+                                       1.5310E+06  7.8087E+05  5.2145E+05
2.4584E+00  7.0013E+05  ------------------+                                       1.5310E+06  7.8087E+05  5.2141E+05
2.5000E+00  7.0013E+05  ------------------+                                       1.5310E+06  7.8087E+05  5.2136E+05
2.5417E+00  6.9730E+05  -----------------+                                        1.5310E+06  7.8370E+05  5.1848E+05
2.5834E+00  6.9447E+05  -----------------+                                        1.5310E+06  7.8653E+05  5.1560E+05
2.6250E+00  6.9163E+05  -----------------+                                        1.5310E+06  7.8937E+05  5.1271E+05
2.6667E+00  6.6180E+05  ---------------+                                          1.5310E+06  8.1920E+05  4.8283E+05
2.7084E+00  6.3230E+05  -------------+                                            1.5310E+06  8.4870E+05  4.5328E+05
2.7500E+00  6.4073E+05  -------------+                                            1.5310E+06  8.4027E+05  4.6165E+05
2.7917E+00  6.6053E+05  ---------------+                                          1.5310E+06  8.2047E+05  4.8140E+05
2.8334E+00  6.8034E+05  ----------------+                                         1.5310E+06  8.0066E+05  5.0116E+05
2.8750E+00  7.0016E+05  ------------------+                                       1.5310E+06  7.8084E+05  5.2093E+05
2.9167E+00  7.5675E+05  ----------------------+                                   1.5310E+06  7.2425E+05  5.7747E+05
2.9584E+00  8.1333E+05  --------------------------+                               1.5310E+06  6.6767E+05  6.3402E+05
3.0000E+00  9.7534E+05  -------------------------------------+                    1.5310E+06  5.3566E+05  7.9600E+05
3.0417E+00  9.9295E+05  ---------------------------------------+                  1.5310E+06  5.1805E+05  8.1359E+05
3.0834E+00  1.0105E+06  ----------------------------------------+                 1.5310E+06  5.0045E+05  8.3117E+05
3.1250E+00  1.0281E+06  -----------------------------------------+                1.5310E+06  4.8287E+05  8.4874E+05
3.1667E+00  1.0130E+06  ----------------------------------------+                 1.5310E+06  4.9796E+05  8.3363E+05
3.2084E+00  9.9796E+05  ---------------------------------------+                  1.5310E+06  5.1304E+05  8.1853E+05
3.2500E+00  9.8284E+05  --------------------------------------+                   1.5310E+06  5.2816E+05  8.0339E+05
3.2917E+00  9.2751E+05  ----------------------------------+                       1.5310E+06  5.8349E+05  7.4804E+05
3.3334E+00  8.7219E+05  ------------------------------+                           1.5310E+06  6.3881E+05  6.9268E+05
3.3750E+00  8.1689E+05  --------------------------+                               1.5310E+06  6.9411E+05  6.3736E+05
3.4167E+00  8.1689E+05  --------------------------+                               1.5310E+06  6.9411E+05  6.3732E+05
3.4584E+00  8.1689E+05  --------------------------+                               1.5310E+06  6.9411E+05  6.3729E+05
3.5000E+00  8.1689E+05  --------------------------+                               1.5310E+06  6.9411E+05  6.3725E+05
3.5417E+00  8.1438E+05  --------------------------+                               1.5310E+06  6.9662E+05  6.3470E+05
3.5834E+00  8.1186E+05  --------------------------+                               1.5310E+06  6.9914E+05  6.3215E+05
3.6250E+00  8.0933E+05  --------------------------+                               1.5310E+06  7.0167E+05  6.2958E+05
3.6667E+00  7.8282E+05  ------------------------+                                 1.5310E+06  7.2818E+05  6.0303E+05
3.7084E+00  7.5660E+05  ----------------------+                                   1.5310E+06  7.5440E+05  5.7677E+05
3.7500E+00  7.6409E+05  ----------------------+                                   1.5310E+06  7.4691E+05  5.8422E+05
3.7917E+00  7.8170E+05  ------------------------+                                 1.5310E+06  7.2930E+05  6.0179E+05
3.8334E+00  7.9930E+05  -------------------------+                                1.5310E+06  7.1170E+05  6.1935E+05
3.8750E+00  8.1693E+05  --------------------------+                               1.5310E+06  6.9407E+05  6.3695E+05
3.9167E+00  8.6723E+05  ------------------------------+                           1.5310E+06  6.4377E+05  6.8721E+05
3.9584E+00  9.1753E+05  ---------------------------------+                        1.5310E+06  5.9347E+05  7.3748E+05
4.0000E+00  1.0269E+06  -----------------------------------------+                1.5310E+06  4.8409E+05  8.4688E+05
4.0417E+00  1.0523E+06  -------------------------------------------+              1.5310E+06  4.5874E+05  8.7227E+05
4.0834E+00  1.0776E+06  ---------------------------------------------+            1.5310E+06  4.3338E+05  8.9766E+05
4.1250E+00  1.1030E+06  -----------------------------------------------+          1.5310E+06  4.0804E+05  9.2304E+05
4.1667E+00  1.1030E+06  -----------------------------------------------+          1.5310E+06  4.0804E+05  9.2307E+05
4.2084E+00  1.1030E+06  -----------------------------------------------+          1.5310E+06  4.0804E+05  9.2311E+05
```

Minimum 4.4711E+05 — RESERV verses TIME — Maximum 1.1428E+06

TIME	RESERV	INSTAL	KWLOAD	WATRES
4.2500E+00	1.1029E+06	1.5310E+06	4.0811E+05	9.2308E+05
4.2917E+00	1.0161E+06	1.5310E+06	4.9491E+05	8.3631E+05
4.3334E+00	9.2970E+05	1.5310E+06	5.8130E+05	7.4995E+05
4.3750E+00	8.8853E+05	1.5310E+06	6.2247E+05	7.0880E+05
4.4167E+00	8.4737E+05	1.5310E+06	6.6363E+05	6.6765E+05
4.4584E+00	8.3328E+05	1.5310E+06	6.7772E+05	6.5358E+05
4.5000E+00	8.1941E+05	1.5310E+06	6.9159E+05	6.3972E+05
4.5417E+00	8.2633E+05	1.5310E+06	6.8467E+05	6.4665E+05
4.5834E+00	8.3325E+05	1.5310E+06	6.7775E+05	6.5357E+05
4.6250E+00	8.4015E+05	1.5310E+06	6.7085E+05	6.6049E+05
4.6667E+00	8.3554E+05	1.5310E+06	6.7546E+05	6.5589E+05
4.7084E+00	8.3093E+05	1.5310E+06	6.8007E+05	6.5129E+05
4.7500E+00	8.2634E+05	1.5310E+06	6.8466E+05	6.4671E+05
4.7917E+00	8.4248E+05	1.5310E+06	6.6852E+05	6.6286E+05
4.8334E+00	8.5861E+05	1.5310E+06	6.5239E+05	6.7901E+05
4.8750E+00	8.7474E+05	1.5310E+06	6.3626E+05	6.9516E+05
4.9167E+00	8.8166E+05	1.5310E+06	6.2934E+05	7.0209E+05
4.9584E+00	9.3355E+05	1.5310E+06	5.7745E+05	7.5400E+05
5.0000E+00	8.8122E+05	1.5310E+06	4.7119E+05	7.0176E+05
5.0417E+00	9.0589E+05	1.5310E+06	4.4651E+05	7.2652E+05
5.0834E+00	9.3055E+05	1.5310E+06	4.2182E+05	7.5129E+05
5.1250E+00	9.5519E+05	1.5310E+06	3.9717E+05	7.7603E+05
5.1667E+00	9.5518E+05	1.5310E+06	3.9717E+05	7.7611E+05
5.2084E+00	9.5516E+05	1.5310E+06	3.9717E+05	7.7620E+05
5.2500E+00	9.5506E+05	1.5310E+06	3.9725E+05	7.7620E+05
5.2917E+00	8.7056E+05	1.5310E+06	4.8174E+05	6.9180E+05
5.3334E+00	7.8646E+05	1.5310E+06	5.6582E+05	6.0779E+05
5.3750E+00	7.4637E+05	1.5310E+06	6.0589E+05	5.6779E+05
5.4167E+00	7.0629E+05	1.5310E+06	6.4596E+05	5.2779E+05
5.4584E+00	6.9258E+05	1.5310E+06	6.5966E+05	5.1415E+05
5.5000E+00	6.7907E+05	1.5310E+06	6.7316E+05	5.0072E+05
5.5417E+00	6.8579E+05	1.5310E+06	6.6643E+05	5.0752E+05
5.5834E+00	6.9251E+05	1.5310E+06	6.5969E+05	5.1431E+05
5.6250E+00	6.9921E+05	1.5310E+06	6.5297E+05	5.2110E+05
5.6667E+00	6.9471E+05	1.5310E+06	6.5746E+05	5.1667E+05
5.7084E+00	6.9021E+05	1.5310E+06	6.6195E+05	5.1225E+05
5.7500E+00	6.8573E+05	1.5310E+06	6.6641E+05	5.0785E+05
5.7917E+00	7.0143E+05	1.5310E+06	6.5071E+05	5.2362E+05
5.8334E+00	7.1712E+05	1.5310E+06	6.3500E+05	5.3939E+05
5.8750E+00	7.3280E+05	1.5310E+06	6.1930E+05	5.5516E+05
5.9167E+00	7.3953E+05	1.5310E+06	6.1256E+05	5.6197E+05
5.9584E+00	7.9003E+05	1.5310E+06	5.6205E+05	6.1255E+05
6.0000E+00	1.0704E+06	1.5310E+06	4.6056E+05	8.9305E+05
6.0417E+00	1.0946E+06	1.5310E+06	4.3644E+05	9.1726E+05
6.0834E+00	1.1187E+06	1.5310E+06	4.1231E+05	9.4148E+05
6.1250E+00	1.1428E+06	1.5310E+06	3.8821E+05	9.6567E+05
6.1667E+00	1.1428E+06	1.5310E+06	3.8821E+05	9.6576E+05
6.2084E+00	1.1428E+06	1.5310E+06	3.8821E+05	9.6585E+05
6.2501E+00	1.1427E+06	1.5310E+06	3.8831E+05	9.6584E+05
6.2917E+00	1.0601E+06	1.5310E+06	4.7089E+05	8.8335E+05
6.3334E+00	9.7793E+05	1.5310E+06	5.5307E+05	8.0126E+05

Minimum 4.4711E+05 RESERV verses TIME Maximum 1.1428E+06

TIME	RESERV	INSTAL	KWLOAD	WATRES
6.3751E+00	9.3876E+05	1.5310E+06	5.9224E+05	7.6217E+05
6.4167E+00	8.9960E+05	1.5310E+06	6.3140E+05	7.2307E+05
6.4584E+00	8.8621E+05	1.5310E+06	6.4479E+05	7.0975E+05
6.5001E+00	8.7302E+05	1.5310E+06	6.5798E+05	6.9663E+05
6.5417E+00	8.7960E+05	1.5310E+06	6.5140E+05	7.0328E+05
6.5834E+00	8.8618E+05	1.5310E+06	6.4482E+05	7.0993E+05
6.6251E+00	8.9275E+05	1.5310E+06	6.3825E+05	7.1656E+05
6.6667E+00	8.8836E+05	1.5310E+06	6.4264E+05	7.1224E+05
6.7084E+00	8.8397E+05	1.5310E+06	6.4703E+05	7.0792E+05
6.7501E+00	8.7961E+05	1.5310E+06	6.5139E+05	7.0363E+05
6.7917E+00	8.9497E+05	1.5310E+06	6.3603E+05	7.1905E+05
6.8334E+00	9.1032E+05	1.5310E+06	6.2068E+05	7.3448E+05
6.8751E+00	9.2566E+05	1.5310E+06	6.0534E+05	7.4989E+05
6.9167E+00	9.3226E+05	1.5310E+06	5.9874E+05	7.5656E+05
6.9584E+00	9.8163E+05	1.5310E+06	5.4937E+05	8.0600E+05
7.0001E+00	1.0409E+06	1.5310E+06	4.9015E+05	8.6531E+05
7.0417E+00	1.0665E+06	1.5310E+06	4.6447E+05	8.9106E+05
7.0834E+00	1.0922E+06	1.5310E+06	4.3880E+05	9.1681E+05
7.1251E+00	1.1178E+06	1.5310E+06	4.1316E+05	9.4253E+05
7.1667E+00	1.1178E+06	1.5310E+06	4.1316E+05	9.4261E+05
7.2084E+00	1.1178E+06	1.5310E+06	4.1316E+05	9.4269E+05
7.2501E+00	1.1177E+06	1.5310E+06	4.1328E+05	9.4264E+05
7.2917E+00	1.0298E+06	1.5310E+06	5.0116E+05	8.5483E+05
7.3334E+00	9.4239E+05	1.5310E+06	5.8861E+05	7.6745E+05
7.3751E+00	9.0070E+05	1.5310E+06	6.3030E+05	7.2582E+05
7.4167E+00	8.5902E+05	1.5310E+06	6.7198E+05	6.8420E+05
7.4584E+00	8.4478E+05	1.5310E+06	6.8622E+05	6.7001E+05
7.5001E+00	8.3075E+05	1.5310E+06	7.0025E+05	6.5603E+05
7.5417E+00	8.3775E+05	1.5310E+06	6.9325E+05	6.6308E+05
7.5834E+00	8.4475E+05	1.5310E+06	6.8625E+05	6.7014E+05
7.6251E+00	8.5174E+05	1.5310E+06	6.7926E+05	6.7718E+05
7.6667E+00	8.4707E+05	1.5310E+06	6.8393E+05	6.7256E+05
7.7084E+00	8.4240E+05	1.5310E+06	6.8860E+05	6.6795E+05
7.7501E+00	8.3776E+05	1.5310E+06	6.9324E+05	6.6336E+05
7.7917E+00	8.5410E+05	1.5310E+06	6.7690E+05	6.7976E+05
7.8334E+00	8.7044E+05	1.5310E+06	6.6056E+05	6.9615E+05
7.8751E+00	8.8677E+05	1.5310E+06	6.4423E+05	7.1253E+05
7.9167E+00	8.9380E+05	1.5310E+06	6.3720E+05	7.1962E+05
7.9584E+00	9.4634E+05	1.5310E+06	5.8466E+05	7.7222E+05
8.0001E+00	9.4536E+05	1.5310E+06	5.3564E+05	7.7126E+05
8.0417E+00	9.6296E+05	1.5310E+06	5.1804E+05	7.8889E+05
8.0834E+00	9.8057E+05	1.5310E+06	5.0043E+05	8.0652E+05
8.1251E+00	9.9812E+05	1.5310E+06	4.8288E+05	8.2410E+05
8.1667E+00	9.8303E+05	1.5310E+06	4.9797E+05	8.0904E+05
8.2084E+00	9.6794E+05	1.5310E+06	5.1306E+05	7.9398E+05
8.2501E+00	9.5279E+05	1.5310E+06	5.2821E+05	7.7885E+05
8.2917E+00	8.9746E+05	1.5310E+06	5.8354E+05	7.2355E+05
8.3334E+00	8.4213E+05	1.5310E+06	6.3887E+05	6.6823E+05
8.3751E+00	7.8689E+05	1.5310E+06	6.9411E+05	6.1301E+05
8.4167E+00	7.8689E+05	1.5310E+06	6.9411E+05	6.1302E+05
8.4584E+00	7.8689E+05	1.5310E+06	6.9411E+05	6.1303E+05

RESERV verses TIME

Minimum 4.4711E+05 Maximum 1.1428E+06

TIME	RESERV	INSTAL	KWLOAD	WATRES
8.5001E+00	7.8689E+05	1.5310E+06	6.9411E+05	6.1303E+05
8.5417E+00	7.8437E+05	1.5310E+06	6.9663E+05	6.1053E+05
8.5834E+00	7.8186E+05	1.5310E+06	6.9914E+05	6.0802E+05
8.6251E+00	7.7930E+05	1.5310E+06	7.0170E+05	6.0547E+05
8.6667E+00	7.5279E+05	1.5310E+06	7.2821E+05	5.7897E+05
8.7084E+00	7.2661E+05	1.5310E+06	7.5439E+05	5.5279E+05
8.7501E+00	7.3411E+05	1.5310E+06	7.4689E+05	5.6029E+05
8.7917E+00	7.5171E+05	1.5310E+06	7.2929E+05	5.7790E+05
8.8334E+00	7.6932E+05	1.5310E+06	7.1168E+05	5.9551E+05
8.8751E+00	7.8698E+05	1.5310E+06	6.9402E+05	6.1318E+05
8.9167E+00	8.3728E+05	1.5310E+06	6.4372E+05	6.6349E+05
8.9584E+00	8.8758E+05	1.5310E+06	5.9342E+05	7.1380E+05
9.0001E+00	8.6917E+05	1.5310E+06	6.1183E+05	6.9539E+05
9.0417E+00	8.8928E+05	1.5310E+06	5.9172E+05	7.1548E+05
9.0834E+00	9.0939E+05	1.5310E+06	5.7161E+05	7.3558E+05
9.1251E+00	9.2943E+05	1.5310E+06	5.5157E+05	7.5561E+05
9.1667E+00	9.1219E+05	1.5310E+06	5.6881E+05	7.3837E+05
9.2084E+00	8.9496E+05	1.5310E+06	5.8604E+05	7.2112E+05
9.2501E+00	8.7764E+05	1.5310E+06	6.0336E+05	7.0379E+05
9.2917E+00	8.1444E+05	1.5310E+06	6.6656E+05	6.4057E+05
9.3334E+00	7.5125E+05	1.5310E+06	7.2975E+05	5.7735E+05
9.3751E+00	6.8816E+05	1.5310E+06	7.9284E+05	5.1424E+05
9.4167E+00	6.8816E+05	1.5310E+06	7.9284E+05	5.1421E+05
9.4584E+00	6.8816E+05	1.5310E+06	7.9284E+05	5.1418E+05
9.5001E+00	6.8816E+05	1.5310E+06	7.9284E+05	5.1414E+05
9.5417E+00	6.8528E+05	1.5310E+06	7.9572E+05	5.1124E+05
9.5834E+00	6.8241E+05	1.5310E+06	7.9859E+05	5.0834E+05
9.6251E+00	6.7949E+05	1.5310E+06	8.0151E+05	5.0538E+05
9.6667E+00	6.4920E+05	1.5310E+06	8.3180E+05	4.7506E+05
9.7084E+00	6.1930E+05	1.5310E+06	8.6170E+05	4.4513E+05
9.7501E+00	6.2788E+05	1.5310E+06	8.5312E+05	4.5366E+05
9.7917E+00	6.4798E+05	1.5310E+06	8.3302E+05	4.7373E+05
9.8334E+00	6.6809E+05	1.5310E+06	8.1291E+05	4.9381E+05
9.8751E+00	6.8827E+05	1.5310E+06	7.9273E+05	5.1396E+05
9.9167E+00	7.4573E+05	1.5310E+06	7.3527E+05	5.7138E+05
9.9584E+00	8.0318E+05	1.5310E+06	6.7782E+05	6.2881E+05
1.0000E+01	8.2144E+05	1.5310E+06	7.0956E+05	6.4705E+05
1.0042E+01	8.4476E+05	1.5310E+06	6.8624E+05	6.7034E+05
1.0083E+01	8.6808E+05	1.5310E+06	6.6292E+05	6.9363E+05
1.0125E+01	8.9131E+05	1.5310E+06	6.3969E+05	7.1684E+05
1.0167E+01	8.7132E+05	1.5310E+06	6.5968E+05	6.9683E+05
1.0208E+01	8.5134E+05	1.5310E+06	6.7966E+05	6.7681E+05
1.0250E+01	8.3124E+05	1.5310E+06	6.9976E+05	6.5669E+05
1.0292E+01	7.5795E+05	1.5310E+06	7.7305E+05	5.8336E+05
1.0333E+01	6.8465E+05	1.5310E+06	8.4635E+05	5.1003E+05
1.0375E+01	6.1151E+05	1.5310E+06	9.1949E+05	4.3684E+05
1.0417E+01	6.1151E+05	1.5310E+06	9.1949E+05	4.3678E+05
1.0458E+01	6.1151E+05	1.5310E+06	9.1949E+05	4.3673E+05
1.0500E+01	6.1150E+05	1.5310E+06	9.1950E+05	4.3668E+05
1.0542E+01	6.0817E+05	1.5310E+06	9.2283E+05	4.3329E+05
1.0583E+01	6.0484E+05	1.5310E+06	9.2616E+05	4.2991E+05

Minimum 4.4711E+05 — RESERV verses TIME — Maximum 1.1428E+06

TIME	RESERV	: (4.4711E+05 … 1.1428E+06)	INSTAL	KWLOAD	WATRES
1.0625E+01	6.0144E+05	-----------+	1.5310E+06	9.2956E+05	4.2646E+05
1.0667E+01	5.6632E+05	--------+	1.5310E+06	9.6468E+05	3.9129E+05
1.0708E+01	5.3165E+05	------+	1.5310E+06	9.9935E+05	3.5656E+05
1.0750E+01	5.4160E+05	------+	1.5310E+06	9.8940E+05	3.6645E+05
1.0792E+01	5.6492E+05	--------+	1.5310E+06	9.6608E+05	3.8971E+05
1.0833E+01	5.8824E+05	----------+	1.5310E+06	9.4276E+05	4.1298E+05
1.0875E+01	6.1165E+05	-----------+	1.5310E+06	9.1935E+05	4.3634E+05
1.0917E+01	6.7828E+05	----------------+	1.5310E+06	8.5272E+05	5.0292E+05
1.0958E+01	7.4491E+05	---------------------+	1.5310E+06	7.8609E+05	5.6951E+05
1.1000E+01	7.6141E+05	----------------------+	1.5310E+06	7.6959E+05	5.8598E+05
1.1042E+01	7.8671E+05	------------------------+	1.5310E+06	7.4429E+05	6.1123E+05
1.1083E+01	8.1200E+05	--------------------------+	1.5310E+06	7.1900E+05	6.3649E+05
1.1125E+01	8.3719E+05	----------------------------+	1.5310E+06	6.9381E+05	6.6165E+05
1.1167E+01	8.1551E+05	--------------------------+	1.5310E+06	7.1549E+05	6.3994E+05
1.1208E+01	7.9383E+05	------------------------+	1.5310E+06	7.3717E+05	6.1822E+05
1.1250E+01	7.7203E+05	-----------------------+	1.5310E+06	7.5897E+05	5.9638E+05
1.1292E+01	6.9253E+05	-----------------+	1.5310E+06	8.3847E+05	5.1684E+05
1.1333E+01	6.1304E+05	-----------+	1.5310E+06	9.1796E+05	4.3730E+05
1.1375E+01	5.3372E+05	------+	1.5310E+06	9.9728E+05	3.5792E+05
1.1417E+01	5.3372E+05	------+	1.5310E+06	9.9728E+05	3.5786E+05
1.1458E+01	5.3372E+05	------+	1.5310E+06	9.9728E+05	3.5780E+05
1.1500E+01	5.3371E+05	------+	1.5310E+06	9.9729E+05	3.5773E+05
1.1542E+01	5.3010E+05	-----+	1.5310E+06	1.0009E+06	3.5405E+05
1.1583E+01	5.2649E+05	-----+	1.5310E+06	1.0045E+06	3.5038E+05
1.1625E+01	5.2279E+05	-----+	1.5310E+06	1.0082E+06	3.4662E+05
1.1667E+01	4.8470E+05	--+	1.5310E+06	1.0463E+06	3.0847E+05
1.1708E+01	4.4711E+05	+	1.5310E+06	1.0839E+06	2.7081E+05
1.1750E+01	4.5790E+05	+	1.5310E+06	1.0731E+06	2.8153E+05
1.1792E+01	4.8319E+05	--+	1.5310E+06	1.0478E+06	3.0675E+05
1.1833E+01	5.0848E+05	----+	1.5310E+06	1.0225E+06	3.3198E+05
1.1875E+01	5.3389E+05	------+	1.5310E+06	9.9711E+05	3.5732E+05
1.1917E+01	6.0615E+05	-----------+	1.5310E+06	9.2485E+05	4.2953E+05
1.1958E+01	6.7842E+05	----------------+	1.5310E+06	8.5258E+05	5.0174E+05

SUSITNA SIMULATION WITH

FOUR 250 MW UNITS AT WATANA

Minimum 0.0000E+00 — WATANA verses TIME — Maximum 9.0389E+05

TIME	WATANA	H	GENKW	EFF
0.0000E+00	4.2345E+05	2.0000E+00	2.1173E+05	9.1741E-01
4.1667E-02	4.0033E+05	2.0000E+00	2.0017E+05	9.1100E-01
8.3334E-02	3.7721E+05	2.0000E+00	1.8861E+05	9.0431E-01
1.2500E-01	3.5410E+05	2.0000E+00	1.7705E+05	8.9363E-01
1.6667E-01	3.7391E+05	2.0000E+00	1.8696E+05	9.0278E-01
2.0833E-01	3.9373E+05	2.0000E+00	1.9686E+05	9.0916E-01
2.5000E-01	4.1355E+05	2.0000E+00	2.0677E+05	9.1465E-01
2.9167E-01	4.8620E+05	2.0000E+00	2.4310E+05	9.1507E-01
3.3334E-01	5.5886E+05	3.0000E+00	1.8629E+05	9.0214E-01
3.7500E-01	6.3151E+05	3.0000E+00	2.1050E+05	9.1670E-01
4.1667E-01	6.3151E+05	3.0000E+00	2.1050E+05	9.1670E-01
4.5834E-01	6.3151E+05	3.0000E+00	2.1050E+05	9.1669E-01
5.0000E-01	6.3151E+05	3.0000E+00	2.1050E+05	9.1668E-01
5.4167E-01	6.3482E+05	3.0000E+00	2.1161E+05	9.1729E-01
5.8334E-01	6.3812E+05	3.0000E+00	2.1271E+05	9.1789E-01
6.2501E-01	6.4143E+05	3.0000E+00	2.1381E+05	9.1850E-01
6.6667E-01	6.7624E+05	3.0000E+00	2.2541E+05	9.1836E-01
7.0834E-01	7.1070E+05	3.0000E+00	2.3690E+05	9.1624E-01
7.5001E-01	7.0086E+05	3.0000E+00	2.3362E+05	9.1685E-01
7.9167E-01	6.7775E+05	3.0000E+00	2.2592E+05	9.1827E-01
8.3334E-01	6.5463E+05	3.0000E+00	2.1821E+05	9.1970E-01
8.7501E-01	6.3150E+05	3.0000E+00	2.1050E+05	9.1663E-01
9.1667E-01	5.6545E+05	3.0000E+00	1.8848E+05	9.0404E-01
9.5834E-01	4.9940E+05	2.0000E+00	2.4970E+05	9.0945E-01
1.0000E+00	4.3496E+05	2.0000E+00	2.1748E+05	9.1984E-01
1.0417E+00	4.1311E+05	2.0000E+00	2.0656E+05	9.1442E-01
1.0833E+00	3.9126E+05	2.0000E+00	1.9563E+05	9.0837E-01
1.1250E+00	3.6941E+05	2.0000E+00	1.8471E+05	9.0052E-01
1.1667E+00	3.8814E+05	2.0000E+00	1.9407E+05	9.0750E-01
1.2083E+00	4.0688E+05	2.0000E+00	2.0344E+05	9.1268E-01
1.2500E+00	4.2562E+05	2.0000E+00	2.1281E+05	9.1787E-01
1.2917E+00	4.9430E+05	2.0000E+00	2.4715E+05	9.1186E-01
1.3333E+00	5.6299E+05	3.0000E+00	1.8766E+05	9.0322E-01
1.3750E+00	6.3165E+05	3.0000E+00	2.1055E+05	9.1660E-01
1.4167E+00	6.3165E+05	3.0000E+00	2.1055E+05	9.1660E-01
1.4583E+00	6.3165E+05	3.0000E+00	2.1055E+05	9.1659E-01
1.5000E+00	6.3165E+05	3.0000E+00	2.1055E+05	9.1658E-01
1.5417E+00	6.3477E+05	3.0000E+00	2.1159E+05	9.1715E-01
1.5833E+00	6.3789E+05	3.0000E+00	2.1263E+05	9.1772E-01
1.6250E+00	6.4103E+05	3.0000E+00	2.1368E+05	9.1830E-01
1.6667E+00	6.7394E+05	3.0000E+00	2.2465E+05	9.1855E-01
1.7083E+00	7.0650E+05	3.0000E+00	2.3550E+05	9.1655E-01
1.7500E+00	6.9720E+05	3.0000E+00	2.3240E+05	9.1712E-01
1.7917E+00	6.7535E+05	3.0000E+00	2.2512E+05	9.1847E-01
1.8333E+00	6.5350E+05	3.0000E+00	2.1783E+05	9.1981E-01
1.8750E+00	6.3163E+05	3.0000E+00	2.1054E+05	9.1652E-01
1.9167E+00	5.6919E+05	3.0000E+00	1.8973E+05	9.0500E-01
1.9583E+00	5.0675E+05	2.0000E+00	2.5337E+05	9.0631E-01
2.0000E+00	3.7262E+05	2.0000E+00	1.8631E+05	9.0183E-01
2.0417E+00	3.5282E+05	2.0000E+00	1.7641E+05	8.9269E-01
2.0833E+00	3.3301E+05	2.0000E+00	1.6651E+05	8.8356E-01

Minimum 0.0000E+00 — WATANA verses TIME — Maximum 8.0389E+05

TIME	WATANA	N	GENKW	EFF
2.1250E+00	3.1322E+05	2.0000E+00	1.5661E+05	8.7331E-01
2.1667E+00	3.3020E+05	2.0000E+00	1.6510E+05	8.8225E-01
2.2084E+00	3.4717E+05	2.0000E+00	1.7359E+05	8.9007E-01
2.2500E+00	3.6417E+05	2.0000E+00	1.8208E+05	8.9791E-01
2.2917E+00	4.2641E+05	2.0000E+00	2.1321E+05	9.1796E-01
2.3334E+00	4.8865E+05	2.0000E+00	2.4433E+05	9.1471E-01
2.3750E+00	5.5087E+05	3.0000E+00	1.8362E+05	8.9931E-01
2.4167E+00	5.5087E+05	3.0000E+00	1.8362E+05	8.9930E-01
2.4584E+00	5.5087E+05	3.0000E+00	1.8362E+05	8.9929E-01
2.5000E+00	5.5087E+05	3.0000E+00	1.8362E+05	8.9928E-01
2.5417E+00	5.5370E+05	3.0000E+00	1.8457E+05	9.0015E-01
2.5834E+00	5.5653E+05	3.0000E+00	1.8551E+05	9.0101E-01
2.6250E+00	5.5937E+05	3.0000E+00	1.8646E+05	9.0187E-01
2.6667E+00	5.8920E+05	3.0000E+00	1.9640E+05	9.0862E-01
2.7084E+00	6.1870E+05	3.0000E+00	2.0623E+05	9.1405E-01
2.7500E+00	6.1027E+05	3.0000E+00	2.0342E+05	9.1249E-01
2.7917E+00	5.9047E+05	3.0000E+00	1.9682E+05	9.0883E-01
2.8334E+00	5.7066E+05	3.0000E+00	1.9022E+05	9.0518E-01
2.8750E+00	5.5084E+05	3.0000E+00	1.8361E+05	8.9920E-01
2.9167E+00	4.9425E+05	2.0000E+00	2.4713E+05	9.1228E-01
2.9584E+00	4.3767E+05	2.0000E+00	2.1883E+05	9.1967E-01
3.0000E+00	2.7566E+05	2.0000E+00	1.3783E+05	8.5240E-01
3.0417E+00	2.5805E+05	1.0000E+00	2.5805E+05	9.0223E-01
3.0834E+00	2.4045E+05	1.0000E+00	2.4045E+05	9.1569E-01
3.1250E+00	2.2287E+05	1.0000E+00	2.2287E+05	9.1893E-01
3.1667E+00	2.3796E+05	1.0000E+00	2.3796E+05	9.1615E-01
3.2084E+00	2.5304E+05	1.0000E+00	2.5304E+05	9.0686E-01
3.2500E+00	2.6816E+05	2.0000E+00	1.3408E+05	8.5000E-01
3.2917E+00	3.2349E+05	2.0000E+00	1.6174E+05	8.7882E-01
3.3334E+00	3.7881E+05	2.0000E+00	1.8941E+05	9.0450E-01
3.3750E+00	4.3411E+05	2.0000E+00	2.1705E+05	9.1998E-01
3.4167E+00	4.3411E+05	2.0000E+00	2.1705E+05	9.1997E-01
3.4584E+00	4.3411E+05	2.0000E+00	2.1705E+05	9.1997E-01
3.5000E+00	4.3411E+05	2.0000E+00	2.1705E+05	9.1996E-01
3.5417E+00	4.3662E+05	2.0000E+00	2.1831E+05	9.1978E-01
3.5834E+00	4.3914E+05	2.0000E+00	2.1957E+05	9.1955E-01
3.6250E+00	4.4167E+05	2.0000E+00	2.2083E+05	9.1932E-01
3.6667E+00	4.6818E+05	2.0000E+00	2.3409E+05	9.1688E-01
3.7084E+00	4.9440E+05	2.0000E+00	2.4720E+05	9.1233E-01
3.7500E+00	4.8691E+05	2.0000E+00	2.4345E+05	9.1516E-01
3.7917E+00	4.6930E+05	2.0000E+00	2.3465E+05	9.1678E-01
3.8334E+00	4.5170E+05	2.0000E+00	2.2585E+05	9.1840E-01
3.8750E+00	4.3407E+05	2.0000E+00	2.1703E+05	9.1991E-01
3.9167E+00	3.8377E+05	2.0000E+00	1.9189E+05	9.0602E-01
3.9584E+00	3.3347E+05	2.0000E+00	1.6674E+05	8.8353E-01
4.0000E+00	2.2409E+05	1.0000E+00	2.2409E+05	9.1873E-01
4.0417E+00	1.9874E+05	1.0000E+00	1.9874E+05	9.0980E-01
4.0834E+00	1.7338E+05	1.0000E+00	1.7338E+05	8.8966E-01
4.1250E+00	1.4804E+05	1.0000E+00	1.4804E+05	8.6360E-01
4.1667E+00	1.4804E+05	1.0000E+00	1.4804E+05	8.6360E-01
4.2084E+00	1.4804E+05	1.0000E+00	1.4804E+05	8.6361E-01

Minimum 0.0000E+00 | WATANA verses TIME | Maximum 8.0389E+05

TIME	WATANA	: :	N	GENKW	EFF
4.2500E+00	1.4811E+05	---------+	1.0000E+00	1.4811E+05	8.6369E-01
4.2917E+00	2.3491E+05	--------------+	1.0000E+00	2.3491E+05	9.1673E-01
4.3334E+00	3.2130E+05	-------------------+	2.0000E+00	1.6065E+05	8.7756E-01
4.3750E+00	3.6247E+05	----------------------+	2.0000E+00	1.8123E+05	8.9693E-01
4.4167E+00	4.0363E+05	-------------------------+	2.0000E+00	2.0182E+05	9.1153E-01
4.4584E+00	4.1772E+05	-------------------------+	2.0000E+00	2.0886E+05	9.1543E-01
4.5000E+00	4.3159E+05	--------------------------+	2.0000E+00	2.1579E+05	9.1926E-01
4.5417E+00	4.2467E+05	--------------------------+	2.0000E+00	2.1233E+05	9.1735E-01
4.5834E+00	4.1775E+05	-------------------------+	2.0000E+00	2.0888E+05	9.1544E-01
4.6250E+00	4.1085E+05	-------------------------+	2.0000E+00	2.0542E+05	9.1353E-01
4.6667E+00	4.1546E+05	-------------------------+	2.0000E+00	2.0773E+05	9.1481E-01
4.7084E+00	4.2007E+05	--------------------------+	2.0000E+00	2.1003E+05	9.1608E-01
4.7500E+00	4.2466E+05	--------------------------+	2.0000E+00	2.1233E+05	9.1735E-01
4.7917E+00	4.0852E+05	-------------------------+	2.0000E+00	2.0426E+05	9.1290E-01
4.8334E+00	3.9239E+05	------------------------+	2.0000E+00	1.9619E+05	9.0844E-01
4.8750E+00	3.7626E+05	-----------------------+	2.0000E+00	1.8813E+05	9.0330E-01
4.9167E+00	3.6934E+05	----------------------+	2.0000E+00	1.8467E+05	9.0012E-01
4.9584E+00	3.1745E+05	-------------------+	2.0000E+00	1.5872E+05	8.7547E-01
5.0000E+00	1.9119E+05	-----------+	1.0000E+00	1.9119E+05	9.0569E-01
5.0417E+00	1.6651E+05	----------+	1.0000E+00	1.6651E+05	8.8342E-01
5.0834E+00	1.4182E+05	--------+	1.0000E+00	1.4182E+05	8.5682E-01
5.1250E+00	0.0000E+00	+	1.0000E+00	0.0000E+00	8.5000E-01
5.1667E+00	0.0000E+00	+	1.0000E+00	0.0000E+00	8.5000E-01
5.2084E+00	0.0000E+00	+	1.0000E+00	0.0000E+00	8.5000E-01
5.2500E+00	0.0000E+00	+	1.0000E+00	0.0000E+00	8.5000E-01
5.2917E+00	2.0174E+05	------------+	1.0000E+00	2.0174E+05	9.1159E-01
5.3334E+00	2.8582E+05	-----------------+	2.0000E+00	1.4291E+05	8.5812E-01
5.3750E+00	3.2589E+05	--------------------+	2.0000E+00	1.6294E+05	8.8025E-01
5.4167E+00	3.6596E+05	----------------------+	2.0000E+00	1.8298E+05	8.9874E-01
5.4584E+00	3.7966E+05	-----------------------+	2.0000E+00	1.8983E+05	9.0504E-01
5.5000E+00	3.9316E+05	------------------------+	2.0000E+00	1.9658E+05	9.0878E-01
5.5417E+00	3.8643E+05	------------------------+	2.0000E+00	1.9321E+05	9.0693E-01
5.5834E+00	3.7969E+05	-----------------------+	2.0000E+00	1.8985E+05	9.0507E-01
5.6250E+00	3.7297E+05	-----------------------+	2.0000E+00	1.8649E+05	9.0203E-01
5.6667E+00	3.7746E+05	-----------------------+	2.0000E+00	1.8873E+05	9.0412E-01
5.7084E+00	3.8195E+05	-----------------------+	2.0000E+00	1.9097E+05	9.0572E-01
5.7500E+00	3.8641E+05	------------------------+	2.0000E+00	1.9321E+05	9.0696E-01
5.7917E+00	3.7071E+05	-----------------------+	2.0000E+00	1.8535E+05	9.0104E-01
5.8334E+00	3.5500E+05	----------------------+	2.0000E+00	1.7750E+05	8.9380E-01
5.8750E+00	3.3930E+05	---------------------+	2.0000E+00	1.6965E+05	8.8657E-01
5.9167E+00	3.3256E+05	--------------------+	2.0000E+00	1.6628E+05	8.8347E-01
5.9584E+00	2.8205E+05	-----------------+	2.0000E+00	1.4103E+05	8.5621E-01
6.0000E+00	1.8056E+05	-----------+	1.0000E+00	1.8056E+05	8.9668E-01
6.0417E+00	1.5644E+05	---------+	1.0000E+00	1.5644E+05	8.7331E-01
6.0834E+00	1.3231E+05	--------+	1.0000E+00	1.3231E+05	8.5000E-01
6.1250E+00	0.0000E+00	+	1.0000E+00	0.0000E+00	8.5000E-01
6.1667E+00	0.0000E+00	+	1.0000E+00	0.0000E+00	8.5000E-01
6.2084E+00	0.0000E+00	+	1.0000E+00	0.0000E+00	8.5000E-01
6.2501E+00	0.0000E+00	+	1.0000E+00	0.0000E+00	8.5000E-01
6.2917E+00	1.9089E+05	-----------+	1.0000E+00	1.9089E+05	9.0580E-01
6.3334E+00	2.7307E+05	----------------+	2.0000E+00	1.3654E+05	8.5135E-01

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SUSITNA PROJECT SIMULATION :  2000(MED.LOAD); WATANA 4-250          Page   4

                         Minimum              WATANA verses TIME              Maximum
                       0.0000E+00                                           8.0389E+05
 TIME          WATANA          :                                                   :       N            GENKW         EFF
6.3751E+00    3.1224E+05    --------------------+                                      2.0000E+00   1.5612E+05   8.7307E-01
6.4167E+00    3.5140E+05    ----------------------+                                    2.0000E+00   1.7570E+05   8.9233E-01
6.4584E+00    3.6479E+05    -----------------------+                                   2.0000E+00   1.8240E+05   8.9853E-01
6.5001E+00    3.7798E+05    ------------------------+                                  2.0000E+00   1.8899E+05   9.0463E-01
6.5417E+00    3.7140E+05    ------------------------+                                  2.0000E+00   1.8570E+05   9.0160E-01
6.5834E+00    3.6482E+05    -----------------------+                                   2.0000E+00   1.8241E+05   8.9857E-01
6.6251E+00    3.5825E+05    -----------------------+                                   2.0000E+00   1.7913E+05   8.9555E-01
6.6667E+00    3.6264E+05    -----------------------+                                   2.0000E+00   1.8132E+05   8.9759E-01
6.7084E+00    3.6703E+05    -----------------------+                                   2.0000E+00   1.8351E+05   8.9962E-01
6.7501E+00    3.7139E+05    ------------------------+                                  2.0000E+00   1.8569E+05   9.0165E-01
6.7917E+00    3.5603E+05    -----------------------+                                   2.0000E+00   1.7802E+05   8.9456E-01
6.8334E+00    3.4068E+05    ----------------------+                                    2.0000E+00   1.7034E+05   8.8748E-01
6.8751E+00    3.2534E+05    ---------------------+                                     2.0000E+00   1.6267E+05   8.8040E-01
6.9167E+00    3.1874E+05    --------------------+                                      2.0000E+00   1.5937E+05   8.7683E-01
6.9584E+00    2.6937E+05    -----------------+                                         2.0000E+00   1.3469E+05   8.5000E-01
7.0001E+00    2.1015E+05    -------------+                                             1.0000E+00   2.1015E+05   9.1660E-01
7.0417E+00    1.8447E+05    ------------+                                              1.0000E+00   1.8447E+05   9.0060E-01
7.0834E+00    1.5880E+05    ----------+                                                1.0000E+00   1.5880E+05   8.7624E-01
7.1251E+00    1.3316E+05    --------+                                                  1.0000E+00   1.3316E+05   8.5000E-01
7.1667E+00    1.3316E+05    --------+                                                  1.0000E+00   1.3316E+05   8.5000E-01
7.2084E+00    1.3316E+05    --------+                                                  1.0000E+00   1.3316E+05   8.5000E-01
7.2501E+00    1.3328E+05    --------+                                                  1.0000E+00   1.3328E+05   8.5000E-01
7.2917E+00    2.2116E+05    -------------+                                             1.0000E+00   2.2116E+05   9.1908E-01
7.3334E+00    3.0861E+05    --------------------+                                      2.0000E+00   1.5431E+05   8.7133E-01
7.3751E+00    3.5030E+05    ----------------------+                                    2.0000E+00   1.7515E+05   8.9207E-01
7.4167E+00    3.9198E+05    -------------------------+                                 2.0000E+00   1.9599E+05   9.0882E-01
7.4584E+00    4.0622E+05    --------------------------+                                2.0000E+00   2.0311E+05   9.1278E-01
7.5001E+00    4.2025E+05    ---------------------------+                               2.0000E+00   2.1013E+05   9.1668E-01
7.5417E+00    4.1325E+05    --------------------------+                                2.0000E+00   2.0663E+05   9.1474E-01
7.5834E+00    4.0625E+05    --------------------------+                                2.0000E+00   2.0312E+05   9.1280E-01
7.6251E+00    3.9926E+05    -------------------------+                                 2.0000E+00   1.9963E+05   9.1087E-01
7.6667E+00    4.0393E+05    --------------------------+                                2.0000E+00   2.0197E+05   9.1217E-01
7.7084E+00    4.0860E+05    --------------------------+                                2.0000E+00   2.0430E+05   9.1347E-01
7.7501E+00    4.1324E+05    --------------------------+                                2.0000E+00   2.0662E+05   9.1476E-01
7.7917E+00    3.9690E+05    -------------------------+                                 2.0000E+00   1.9845E+05   9.1023E-01
7.8334E+00    3.8056E+05    ------------------------+                                  2.0000E+00   1.9028E+05   9.0570E-01
7.8751E+00    3.6423E+05    -----------------------+                                   2.0000E+00   1.8212E+05   8.9861E-01
7.9167E+00    3.5720E+05    -----------------------+                                   2.0000E+00   1.7860E+05   8.9537E-01
7.9584E+00    3.0466E+05    -------------------+                                       2.0000E+00   1.5233E+05   8.6926E-01
8.0001E+00    3.0564E+05    --------------------+                                      2.0000E+00   1.5282E+05   8.6981E-01
8.0417E+00    2.8804E+05    ------------------+                                        2.0000E+00   1.4402E+05   8.6003E-01
8.0834E+00    2.7043E+05    -----------------+                                         2.0000E+00   1.3522E+05   8.5026E-01
8.1251E+00    2.5288E+05    ----------------+                                          1.0000E+00   2.5288E+05   9.0582E-01
8.1667E+00    2.6797E+05    -----------------+                                         2.0000E+00   1.3399E+05   8.5000E-01
8.2084E+00    2.8306E+05    ------------------+                                        2.0000E+00   1.4153E+05   8.5728E-01
8.2501E+00    2.9821E+05    -------------------+                                       2.0000E+00   1.4911E+05   8.6571E-01
8.2917E+00    3.5354E+05    ----------------------+                                    2.0000E+00   1.7677E+05   8.9371E-01
8.3334E+00    4.0887E+05    --------------------------+                                2.0000E+00   2.0443E+05   9.1360E-01
8.3751E+00    4.6411E+05    -----------------------------+                             2.0000E+00   2.3205E+05   9.1702E-01
8.4167E+00    4.6411E+05    -----------------------------+                             2.0000E+00   2.3205E+05   9.1702E-01
8.4584E+00    4.6411E+05    -----------------------------+                             2.0000E+00   2.3205E+05   9.1702E-01
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Minimum 0.0000E+00 — WATANA verses TIME — Maximum 8.0389E+05

TIME	WATANA	: :	N	GENKW	EFF
8.5001E+00	4.6411E+05	----------------------------+	2.0000E+00	2.3206E+05	9.1702E-01
8.5417E+00	4.6663E+05	-----------------------------+	2.0000E+00	2.3331E+05	9.1678E-01
8.5834E+00	4.6914E+05	-----------------------------+	2.0000E+00	2.3457E+05	9.1655E-01
8.6251E+00	4.7170E+05	-----------------------------+	2.0000E+00	2.3585E+05	9.1631E-01
8.6667E+00	4.9821E+05	------------------------------+	2.0000E+00	2.4910E+05	9.0928E-01
8.7084E+00	5.2439E+05	--------------------------------+	2.0000E+00	2.6220E+05	8.9715E-01
8.7501E+00	5.1689E+05	--------------------------------+	2.0000E+00	2.5844E+05	9.0063E-01
8.7917E+00	4.9929E+05	-------------------------------+	2.0000E+00	2.4964E+05	9.0878E-01
8.8334E+00	4.8168E+05	-----------------------------+	2.0000E+00	2.4084E+05	9.1539E-01
8.8751E+00	4.6402E+05	----------------------------+	2.0000E+00	2.3201E+05	9.1702E-01
8.9167E+00	4.1372E+05	-------------------------+	2.0000E+00	2.0686E+05	9.1496E-01
8.9584E+00	3.6342E+05	----------------------+	2.0000E+00	1.8171E+05	8.9831E-01
9.0001E+00	3.8183E+05	-----------------------+	2.0000E+00	1.9091E+05	9.0610E-01
9.0417E+00	3.6172E+05	----------------------+	2.0000E+00	1.8086E+05	8.9752E-01
9.0834E+00	3.4161E+05	---------------------+	2.0000E+00	1.7081E+05	8.8820E-01
9.1251E+00	3.2157E+05	--------------------+	2.0000E+00	1.6078E+05	8.7870E-01
9.1667E+00	3.3881E+05	---------------------+	2.0000E+00	1.6940E+05	8.8690E-01
9.2084E+00	3.5604E+05	----------------------+	2.0000E+00	1.7802E+05	8.9488E-01
9.2501E+00	3.7336E+05	-----------------------+	2.0000E+00	1.8668E+05	9.0290E-01
9.2917E+00	4.3656E+05	---------------------------+	2.0000E+00	2.1828E+05	9.1957E-01
9.3334E+00	4.9975E+05	-------------------------------+	2.0000E+00	2.4988E+05	9.0858E-01
9.3751E+00	5.6284E+05	-----------------------------------+	3.0000E+00	1.8761E+05	9.0375E-01
9.4167E+00	5.6284E+05	-----------------------------------+	3.0000E+00	1.8761E+05	9.0375E-01
9.4584E+00	5.6284E+05	-----------------------------------+	3.0000E+00	1.8761E+05	9.0374E-01
9.5001E+00	5.6284E+05	-----------------------------------+	3.0000E+00	1.8761E+05	9.0374E-01
9.5417E+00	5.6572E+05	-----------------------------------+	3.0000E+00	1.8857E+05	9.0462E-01
9.5834E+00	5.6859E+05	-----------------------------------+	3.0000E+00	1.8953E+05	9.0530E-01
9.6251E+00	5.7151E+05	-----------------------------------+	3.0000E+00	1.9050E+05	9.0584E-01
9.6667E+00	6.0180E+05	-------------------------------------+	3.0000E+00	2.0060E+05	9.1144E-01
9.7084E+00	6.3170E+05	---------------------------------------+	3.0000E+00	2.1057E+05	9.1698E-01
9.7501E+00	6.2312E+05	--------------------------------------+	3.0000E+00	2.0771E+05	9.1539E-01
9.7917E+00	6.0302E+05	-------------------------------------+	3.0000E+00	2.0101E+05	9.1166E-01
9.8334E+00	5.8291E+05	------------------------------------+	3.0000E+00	1.9430E+05	9.0793E-01
9.8751E+00	5.6273E+05	-----------------------------------+	3.0000E+00	1.8758E+05	9.0365E-01
9.9167E+00	5.0527E+05	-------------------------------+	2.0000E+00	2.5264E+05	9.0612E-01
9.9584E+00	4.4782E+05	---------------------------+	2.0000E+00	2.2391E+05	9.1854E-01
1.0000E+01	4.2956E+05	--------------------------+	2.0000E+00	2.1478E+05	9.1930E-01
1.0042E+01	4.0624E+05	-------------------------+	2.0000E+00	2.0312E+05	9.1282E-01
1.0083E+01	3.8292E+05	-----------------------+	2.0000E+00	1.9146E+05	9.0634E-01
1.0125E+01	3.5969E+05	----------------------+	2.0000E+00	1.7984E+05	8.9647E-01
1.0167E+01	3.7968E+05	-----------------------+	2.0000E+00	1.8984E+05	9.0543E-01
1.0208E+01	3.9966E+05	------------------------+	2.0000E+00	1.9983E+05	9.1098E-01
1.0250E+01	4.1976E+05	--------------------------+	2.0000E+00	2.0988E+05	9.1655E-01
1.0292E+01	4.9305E+05	------------------------------+	2.0000E+00	2.4653E+05	9.1183E-01
1.0333E+01	5.6635E+05	-----------------------------------+	3.0000E+00	1.8878E+05	9.0472E-01
1.0375E+01	6.3949E+05	---------------------------------------+	3.0000E+00	2.1316E+05	9.1837E-01
1.0417E+01	6.3949E+05	---------------------------------------+	3.0000E+00	2.1316E+05	9.1836E-01
1.0458E+01	6.3949E+05	---------------------------------------+	3.0000E+00	2.1316E+05	9.1835E-01
1.0500E+01	6.3950E+05	---------------------------------------+	3.0000E+00	2.1317E+05	9.1835E-01
1.0542E+01	6.4283E+05	---------------------------------------+	3.0000E+00	2.1428E+05	9.1896E-01
1.0583E+01	6.4616E+05	--+	3.0000E+00	2.1539E+05	9.1957E-01

Minimum 0.0000E+00 — WATANA verses TIME — Maximum 8.0389E+05

TIME	WATANA	: :	N	GENKW	EFF
1.0625E+01	6.4956E+05	--+	3.0000E+00	2.1652E+05	9.1994E-01
1.0667E+01	6.8468E+05	--+	3.0000E+00	2.2823E+05	9.1777E-01
1.0708E+01	7.1935E+05	--+	3.0000E+00	2.3978E+05	9.1563E-01
1.0750E+01	7.0940E+05	---+	3.0000E+00	2.3647E+05	9.1625E-01
1.0792E+01	6.8608E+05	--+	3.0000E+00	2.2869E+05	9.1769E-01
1.0833E+01	6.6276E+05	--+	3.0000E+00	2.2092E+05	9.1913E-01
1.0875E+01	6.3935E+05	---------------------------------------+	3.0000E+00	2.1312E+05	9.1827E-01
1.0917E+01	5.7272E+05	-----------------------------------+	3.0000E+00	1.9091E+05	9.0594E-01
1.0958E+01	5.0609E+05	-------------------------------+	2.0000E+00	2.5305E+05	9.0597E-01
1.1000E+01	4.8959E+05	------------------------------+	2.0000E+00	2.4479E+05	9.1361E-01
1.1042E+01	4.6429E+05	----------------------------+	2.0000E+00	2.3215E+05	9.1706E-01
1.1083E+01	4.3900E+05	---------------------------+	2.0000E+00	2.1950E+05	9.1940E-01
1.1125E+01	4.1381E+05	-------------------------+	2.0000E+00	2.0690E+05	9.1480E-01
1.1167E+01	4.3549E+05	---------------------------+	2.0000E+00	2.1774E+05	9.1973E-01
1.1208E+01	4.5717E+05	----------------------------+	2.0000E+00	2.2858E+05	9.1773E-01
1.1250E+01	4.7897E+05	-----------------------------+	2.0000E+00	2.3949E+05	9.1571E-01
1.1292E+01	5.5847E+05	----------------------------------+	3.0000E+00	1.8616E+05	9.0212E-01
1.1333E+01	6.3796E+05	---------------------------------------+	3.0000E+00	2.1265E+05	9.1796E-01
1.1375E+01	7.1728E+05	--+	3.0000E+00	2.3909E+05	9.1579E-01
1.1417E+01	7.1728E+05	--+	3.0000E+00	2.3909E+05	9.1579E-01
1.1458E+01	7.1728E+05	--+	3.0000E+00	2.3909E+05	9.1580E-01
1.1500E+01	7.1729E+05	--+	3.0000E+00	2.3910E+05	9.1580E-01
1.1542E+01	7.2090E+05	--+	3.0000E+00	2.4030E+05	9.1558E-01
1.1583E+01	7.2451E+05	---+	3.0000E+00	2.4150E+05	9.1536E-01
1.1625E+01	7.2821E+05	---+	3.0000E+00	2.4274E+05	9.1513E-01
1.1667E+01	7.6630E+05	---+	3.0000E+00	2.5543E+05	9.0395E-01
1.1708E+01	8.0389E+05	---+	4.0000E+00	2.0097E+05	9.1143E-01
1.1750E+01	7.9310E+05	---+	4.0000E+00	1.9828E+05	9.0992E-01
1.1792E+01	7.6781E+05	---+	3.0000E+00	2.5594E+05	9.0353E-01
1.1833E+01	7.4252E+05	--+	3.0000E+00	2.4751E+05	9.1133E-01
1.1875E+01	7.1711E+05	--+	3.0000E+00	2.3904E+05	9.1583E-01
1.1917E+01	6.4485E+05	--+	3.0000E+00	2.1495E+05	9.1914E-01
1.1958E+01	5.7258E+05	-----------------------------------+	3.0000E+00	1.9086E+05	9.0578E-01

	Minimum	KWLOAD verses TIME	Maximum
	3.8821E+05		1.0839E+06

TIME	KWLOAD	THERML	SMHY	PEAKPL
0.0000E+00	7.0345E+05	2.0000E+05	8.0000E+04	0.0000E+00
4.1667E-02	6.8033E+05	2.0000E+05	8.0000E+04	0.0000E+00
8.3334E-02	6.5721E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.2500E-01	6.3410E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.6667E-01	6.5391E+05	2.0000E+05	8.0000E+04	0.0000E+00
2.0833E-01	6.7373E+05	2.0000E+05	8.0000E+04	0.0000E+00
2.5000E-01	6.9355E+05	2.0000E+05	8.0000E+04	0.0000E+00
2.9167E-01	7.6620E+05	2.0000E+05	8.0000E+04	0.0000E+00
3.3334E-01	8.3886E+05	2.0000E+05	8.0000E+04	0.0000E+00
3.7500E-01	9.1151E+05	2.0000E+05	8.0000E+04	0.0000E+00
4.1667E-01	9.1151E+05	2.0000E+05	8.0000E+04	0.0000E+00
4.5834E-01	9.1151E+05	2.0000E+05	8.0000E+04	0.0000E+00
5.0000E-01	9.1151E+05	2.0000E+05	8.0000E+04	0.0000E+00
5.4167E-01	9.1482E+05	2.0000E+05	8.0000E+04	0.0000E+00
5.8334E-01	9.1812E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.2501E-01	9.2143E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.6667E-01	9.5624E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.0834E-01	9.9070E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.5001E-01	9.8086E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.9167E-01	9.5775E+05	2.0000E+05	8.0000E+04	0.0000E+00
8.3334E-01	9.3463E+05	2.0000E+05	8.0000E+04	0.0000E+00
8.7501E-01	9.1150E+05	2.0000E+05	8.0000E+04	0.0000E+00
9.1667E-01	8.4545E+05	2.0000E+05	8.0000E+04	0.0000E+00
9.5834E-01	7.7940E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0000E+00	6.6496E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.0417E+00	6.4311E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.0833E+00	6.2126E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.1250E+00	5.9941E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.1667E+00	6.1814E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.2083E+00	6.3688E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.2500E+00	6.5562E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.2917E+00	7.2430E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.3333E+00	7.9299E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.3750E+00	8.6165E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.4167E+00	8.6165E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.4583E+00	8.6165E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.5000E+00	8.6165E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.5417E+00	8.6477E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.5833E+00	8.6789E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.6250E+00	8.7103E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.6667E+00	9.0394E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.7083E+00	9.3650E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.7500E+00	9.2720E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.7917E+00	9.0535E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.8333E+00	8.8350E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.8750E+00	8.6163E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.9167E+00	7.9919E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.9583E+00	7.3675E+05	1.5000E+05	8.0000E+04	0.0000E+00
2.0000E+00	6.0262E+05	1.5000E+05	8.0000E+04	0.0000E+00
2.0417E+00	5.8282E+05	1.5000E+05	8.0000E+04	0.0000E+00
2.0833E+00	5.6301E+05	1.5000E+05	8.0000E+04	0.0000E+00

```
                        Minimum            KWLOAD verses TIME            Maximum
                       3.8821E+05                                       1.0839E+06
 TIME        KWLOAD     :                                                  :      THERML      SMHY        PEAKPL
2.1250E+00  5.4322E+05  -----------+                                             1.5000E+05  8.0000E+04  0.0000E+00
2.1667E+00  5.6020E+05  ------------+                                            1.5000E+05  8.0000E+04  0.0000E+00
2.2084E+00  5.7717E+05  -------------+                                           1.5000E+05  8.0000E+04  0.0000E+00
2.2500E+00  5.9417E+05  --------------+                                          1.5000E+05  8.0000E+04  0.0000E+00
2.2917E+00  6.5641E+05  -------------------+                                     1.5000E+05  8.0000E+04  0.0000E+00
2.3334E+00  7.1865E+05  -----------------------+                                 1.5000E+05  8.0000E+04  0.0000E+00
2.3750E+00  7.8087E+05  ----------------------------+                            1.5000E+05  8.0000E+04  0.0000E+00
2.4167E+00  7.8087E+05  ----------------------------+                            1.5000E+05  8.0000E+04  0.0000E+00
2.4584E+00  7.8087E+05  ----------------------------+                            1.5000E+05  8.0000E+04  0.0000E+00
2.5000E+00  7.8087E+05  ----------------------------+                            1.5000E+05  8.0000E+04  0.0000E+00
2.5417E+00  7.8370E+05  ----------------------------+                            1.5000E+05  8.0000E+04  0.0000E+00
2.5834E+00  7.8653E+05  ----------------------------+                            1.5000E+05  8.0000E+04  0.0000E+00
2.6250E+00  7.8937E+05  ----------------------------+                            1.5000E+05  8.0000E+04  0.0000E+00
2.6667E+00  8.1920E+05  ------------------------------+                          1.5000E+05  8.0000E+04  0.0000E+00
2.7084E+00  8.4870E+05  ---------------------------------+                       1.5000E+05  8.0000E+04  0.0000E+00
2.7500E+00  8.4027E+05  --------------------------------+                        1.5000E+05  8.0000E+04  0.0000E+00
2.7917E+00  8.2047E+05  -------------------------------+                         1.5000E+05  8.0000E+04  0.0000E+00
2.8334E+00  8.0066E+05  -----------------------------+                           1.5000E+05  8.0000E+04  0.0000E+00
2.8750E+00  7.8084E+05  ----------------------------+                            1.5000E+05  8.0000E+04  0.0000E+00
2.9167E+00  7.2425E+05  ------------------------+                                1.5000E+05  8.0000E+04  0.0000E+00
2.9584E+00  6.6767E+05  --------------------+                                    1.5000E+05  8.0000E+04  0.0000E+00
3.0000E+00  5.3566E+05  ----------+                                              2.0000E+05  6.0000E+04  0.0000E+00
3.0417E+00  5.1805E+05  ---------+                                               2.0000E+05  6.0000E+04  0.0000E+00
3.0834E+00  5.0045E+05  --------+                                                2.0000E+05  6.0000E+04  0.0000E+00
3.1250E+00  4.8287E+05  ------+                                                  2.0000E+05  6.0000E+04  0.0000E+00
3.1667E+00  4.9796E+05  -------+                                                 2.0000E+05  6.0000E+04  0.0000E+00
3.2084E+00  5.1304E+05  --------+                                                2.0000E+05  6.0000E+04  0.0000E+00
3.2500E+00  5.2816E+05  ----------+                                              2.0000E+05  6.0000E+04  0.0000E+00
3.2917E+00  5.8349E+05  --------------+                                          2.0000E+05  6.0000E+04  0.0000E+00
3.3334E+00  6.3881E+05  ------------------+                                      2.0000E+05  6.0000E+04  0.0000E+00
3.3750E+00  6.9411E+05  ---------------------+                                   2.0000E+05  6.0000E+04  0.0000E+00
3.4167E+00  6.9411E+05  ---------------------+                                   2.0000E+05  6.0000E+04  0.0000E+00
3.4584E+00  6.9411E+05  ---------------------+                                   2.0000E+05  6.0000E+04  0.0000E+00
3.5000E+00  6.9411E+05  ---------------------+                                   2.0000E+05  6.0000E+04  0.0000E+00
3.5417E+00  6.9662E+05  ----------------------+                                  2.0000E+05  6.0000E+04  0.0000E+00
3.5834E+00  6.9914E+05  ----------------------+                                  2.0000E+05  6.0000E+04  0.0000E+00
3.6250E+00  7.0167E+05  ----------------------+                                  2.0000E+05  6.0000E+04  0.0000E+00
3.6667E+00  7.2818E+05  ------------------------+                                2.0000E+05  6.0000E+04  0.0000E+00
3.7084E+00  7.5440E+05  --------------------------+                              2.0000E+05  6.0000E+04  0.0000E+00
3.7500E+00  7.4691E+05  -------------------------+                               2.0000E+05  6.0000E+04  0.0000E+00
3.7917E+00  7.2930E+05  ------------------------+                                2.0000E+05  6.0000E+04  0.0000E+00
3.8334E+00  7.1170E+05  -----------------------+                                 2.0000E+05  6.0000E+04  0.0000E+00
3.8750E+00  6.9407E+05  ---------------------+                                   2.0000E+05  6.0000E+04  0.0000E+00
3.9167E+00  6.4377E+05  ------------------+                                      2.0000E+05  6.0000E+04  0.0000E+00
3.9584E+00  5.9347E+05  --------------+                                          2.0000E+05  6.0000E+04  0.0000E+00
4.0000E+00  4.8409E+05  ------+                                                  2.0000E+05  6.0000E+04  0.0000E+00
4.0417E+00  4.5874E+05  -----+                                                   2.0000E+05  6.0000E+04  0.0000E+00
4.0834E+00  4.3338E+05  ---+                                                     2.0000E+05  6.0000E+04  0.0000E+00
4.1250E+00  4.0804E+05  -+                                                       2.0000E+05  6.0000E+04  0.0000E+00
4.1667E+00  4.0804E+05  -+                                                       2.0000E+05  6.0000E+04  0.0000E+00
4.2084E+00  4.0804E+05  -+                                                       2.0000E+05  6.0000E+04  0.0000E+00
```

Minimum 3.8821E+05 — KWLOAD verses TIME — Maximum 1.0839E+06

TIME	KWLOAD	: … :	THERML	SMHY	PEAKPL
4.2500E+00	4.0811E+05	-+	2.0000E+05	6.0000E+04	0.0000E+00
4.2917E+00	4.9491E+05	-------+	2.0000E+05	6.0000E+04	0.0000E+00
4.3334E+00	5.8130E+05	-------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.3750E+00	6.2247E+05	----------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.4167E+00	6.6363E+05	-------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.4584E+00	6.7772E+05	--------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.5000E+00	6.9159E+05	---------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.5417E+00	6.8467E+05	---------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.5834E+00	6.7775E+05	--------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.6250E+00	6.7085E+05	--------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.6667E+00	6.7546E+05	--------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.7084E+00	6.8007E+05	--------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.7500E+00	6.8466E+05	---------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.7917E+00	6.6852E+05	--------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.8334E+00	6.5239E+05	------------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.8750E+00	6.3626E+05	-----------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.9167E+00	6.2934E+05	-----------------+	2.0000E+05	6.0000E+04	0.0000E+00
4.9584E+00	5.7745E+05	-------------+	2.0000E+05	6.0000E+04	0.0000E+00
5.0000E+00	4.7119E+05	-----+	2.0000E+05	8.0000E+04	0.0000E+00
5.0417E+00	4.4651E+05	----+	2.0000E+05	8.0000E+04	0.0000E+00
5.0834E+00	4.2182E+05	--+	2.0000E+05	8.0000E+04	0.0000E+00
5.1250E+00	3.9717E+05	+	2.0000E+05	8.0000E+04	1.1717E+05
5.1667E+00	3.9717E+05	+	2.0000E+05	8.0000E+04	1.1717E+05
5.2084E+00	3.9717E+05	+	2.0000E+05	8.0000E+04	1.1717E+05
5.2500E+00	3.9725E+05	+	2.0000E+05	8.0000E+04	1.1725E+05
5.2917E+00	4.8174E+05	------+	2.0000E+05	8.0000E+04	0.0000E+00
5.3334E+00	5.6582E+05	------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.3750E+00	6.0589E+05	---------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.4167E+00	6.4596E+05	------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.4584E+00	6.5966E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.5000E+00	6.7316E+05	--------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.5417E+00	6.6643E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.5834E+00	6.5969E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.6250E+00	6.5297E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.6667E+00	6.5746E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.7084E+00	6.6195E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.7500E+00	6.6641E+05	-------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.7917E+00	6.5071E+05	------------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.8334E+00	6.3500E+05	-----------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.8750E+00	6.1930E+05	----------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.9167E+00	6.1256E+05	----------------+	2.0000E+05	8.0000E+04	0.0000E+00
5.9584E+00	5.6205E+05	------------+	2.0000E+05	8.0000E+04	0.0000E+00
6.0000E+00	4.6056E+05	-----+	2.0000E+05	8.0000E+04	0.0000E+00
6.0417E+00	4.3644E+05	---+	2.0000E+05	8.0000E+04	0.0000E+00
6.0834E+00	4.1231E+05	-+	2.0000E+05	8.0000E+04	0.0000E+00
6.1250E+00	3.8821E+05	+	2.0000E+05	8.0000E+04	1.0821E+05
6.1667E+00	3.8821E+05	+	2.0000E+05	8.0000E+04	1.0821E+05
6.2084E+00	3.8821E+05	+	2.0000E+05	8.0000E+04	1.0821E+05
6.2501E+00	3.8831E+05	+	2.0000E+05	8.0000E+04	1.0831E+05
6.2917E+00	4.7089E+05	-----+	2.0000E+05	8.0000E+04	0.0000E+00
6.3334E+00	5.5307E+05	-----------+	2.0000E+05	8.0000E+04	0.0000E+00

SUSITNA PROJECT SIMULATION : 2000(MED.LOAD): WATANA 4-250

KWLOAD verses TIME

Minimum 3.8821E+05 — Maximum 1.0839E+06

TIME	KWLOAD	THERML	SMHY	PEAKPL
6.3751E+00	5.9224E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.4167E+00	6.3140E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.4584E+00	6.4479E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.5001E+00	6.5798E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.5417E+00	6.5140E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.5834E+00	6.4482E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.6251E+00	6.3825E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.6667E+00	6.4264E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.7084E+00	6.4703E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.7501E+00	6.5139E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.7917E+00	6.3603E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.8334E+00	6.2068E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.8751E+00	6.0534E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.9167E+00	5.9874E+05	2.0000E+05	8.0000E+04	0.0000E+00
6.9584E+00	5.4937E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.0001E+00	4.9015E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.0417E+00	4.6447E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.0834E+00	4.3880E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.1251E+00	4.1316E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.1667E+00	4.1316E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.2084E+00	4.1316E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.2501E+00	4.1328E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.2917E+00	5.0116E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.3334E+00	5.8861E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.3751E+00	6.3030E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.4167E+00	6.7198E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.4584E+00	6.8622E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.5001E+00	7.0025E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.5417E+00	6.9325E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.5834E+00	6.8625E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.6251E+00	6.7926E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.6667E+00	6.8393E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.7084E+00	6.8860E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.7501E+00	6.9324E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.7917E+00	6.7690E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.8334E+00	6.6056E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.8751E+00	6.4423E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.9167E+00	6.3720E+05	2.0000E+05	8.0000E+04	0.0000E+00
7.9584E+00	5.8466E+05	2.0000E+05	8.0000E+04	0.0000E+00
8.0001E+00	5.3564E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.0417E+00	5.1804E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.0834E+00	5.0043E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.1251E+00	4.8288E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.1667E+00	4.9797E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.2084E+00	5.1306E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.2501E+00	5.2821E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.2917E+00	5.8354E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.3334E+00	6.3887E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.3751E+00	6.9411E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.4167E+00	6.9411E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.4584E+00	6.9411E+05	1.5000E+05	8.0000E+04	0.0000E+00

Minimum KWLOAD verses TIME Maximum

3.8821E+05 1.0839E+06

TIME	KWLOAD	THERML	SMHY	PEAKPL
8.5001E+00	6.9411E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.5417E+00	6.9663E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.5834E+00	6.9914E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.6251E+00	7.0170E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.6667E+00	7.2821E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.7084E+00	7.5439E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.7501E+00	7.4689E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.7917E+00	7.2929E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.8334E+00	7.1168E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.8751E+00	6.9402E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.9167E+00	6.4372E+05	1.5000E+05	8.0000E+04	0.0000E+00
8.9584E+00	5.9342E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.0001E+00	6.1183E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.0417E+00	5.9172E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.0834E+00	5.7161E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.1251E+00	5.5157E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.1667E+00	5.6881E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.2084E+00	5.8604E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.2501E+00	6.0336E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.2917E+00	6.6656E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.3334E+00	7.2975E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.3751E+00	7.9284E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.4167E+00	7.9284E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.4584E+00	7.9284E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.5001E+00	7.9284E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.5417E+00	7.9572E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.5834E+00	7.9859E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.6251E+00	8.0151E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.6667E+00	8.3180E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.7084E+00	8.6170E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.7501E+00	8.5312E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.7917E+00	8.3302E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.8334E+00	8.1291E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.8751E+00	7.9273E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.9167E+00	7.3527E+05	1.5000E+05	8.0000E+04	0.0000E+00
9.9584E+00	6.7782E+05	1.5000E+05	8.0000E+04	0.0000E+00
1.0000E+01	7.0956E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0042E+01	6.8624E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0083E+01	6.6292E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0125E+01	6.3969E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0167E+01	6.5968E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0208E+01	6.7966E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0250E+01	6.9976E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0292E+01	7.7305E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0333E+01	8.4635E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0375E+01	9.1949E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0417E+01	9.1949E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0458E+01	9.1949E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0500E+01	9.1950E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0542E+01	9.2283E+05	2.0000E+05	8.0000E+04	0.0000E+00
1.0583E+01	9.2616E+05	2.0000E+05	8.0000E+04	0.0000E+00

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                          Minimum              KWLOAD verses TIME            Maximum
                         3.8821E+05                                        1.0839E+06
 TIME         KWLOAD        :                                                  :        THERML       SMHY         PEAKPL
1.0625E+01   9.2956E+05    --------------------------------------+                      2.0000E+05   8.0000E+04   0.0000E+00
1.0667E+01   9.6468E+05    ------------------------------------------+                  2.0000E+05   8.0000E+04   0.0000E+00
1.0708E+01   9.9935E+05    --------------------------------------------+                2.0000E+05   8.0000E+04   0.0000E+00
1.0750E+01   9.8940E+05    --------------------------------------------+                2.0000E+05   8.0000E+04   0.0000E+00
1.0792E+01   9.6608E+05    ------------------------------------------+                  2.0000E+05   8.0000E+04   0.0000E+00
1.0833E+01   9.4276E+05    ----------------------------------------+                    2.0000E+05   8.0000E+04   0.0000E+00
1.0875E+01   9.1935E+05    --------------------------------------+                      2.0000E+05   8.0000E+04   0.0000E+00
1.0917E+01   8.5272E+05    ---------------------------------+                           2.0000E+05   8.0000E+04   0.0000E+00
1.0958E+01   7.8609E+05    ----------------------------+                                2.0000E+05   8.0000E+04   0.0000E+00
1.1000E+01   7.6959E+05    ---------------------------+                                 2.0000E+05   8.0000E+04   0.0000E+00
1.1042E+01   7.4429E+05    -------------------------+                                   2.0000E+05   8.0000E+04   0.0000E+00
1.1083E+01   7.1900E+05    -----------------------+                                     2.0000E+05   8.0000E+04   0.0000E+00
1.1125E+01   6.9381E+05    ---------------------+                                       2.0000E+05   8.0000E+04   0.0000E+00
1.1167E+01   7.1549E+05    -----------------------+                                     2.0000E+05   8.0000E+04   0.0000E+00
1.1208E+01   7.3717E+05    -------------------------+                                   2.0000E+05   8.0000E+04   0.0000E+00
1.1250E+01   7.5897E+05    --------------------------+                                  2.0000E+05   8.0000E+04   0.0000E+00
1.1292E+01   8.3847E+05    --------------------------------+                            2.0000E+05   8.0000E+04   0.0000E+00
1.1333E+01   9.1796E+05    --------------------------------------+                      2.0000E+05   8.0000E+04   0.0000E+00
1.1375E+01   9.9728E+05    --------------------------------------------+                2.0000E+05   8.0000E+04   0.0000E+00
1.1417E+01   9.9728E+05    --------------------------------------------+                2.0000E+05   8.0000E+04   0.0000E+00
1.1458E+01   9.9728E+05    --------------------------------------------+                2.0000E+05   8.0000E+04   0.0000E+00
1.1500E+01   9.9729E+05    --------------------------------------------+                2.0000E+05   8.0000E+04   0.0000E+00
1.1542E+01   1.0009E+06    ---------------------------------------------+               2.0000E+05   8.0000E+04   0.0000E+00
1.1583E+01   1.0045E+06    ---------------------------------------------+               2.0000E+05   8.0000E+04   0.0000E+00
1.1625E+01   1.0082E+06    ---------------------------------------------+               2.0000E+05   8.0000E+04   0.0000E+00
1.1667E+01   1.0463E+06    ------------------------------------------------+            2.0000E+05   8.0000E+04   0.0000E+00
1.1708E+01   1.0839E+06    --------------------------------------------------+          2.0000E+05   8.0000E+04   0.0000E+00
1.1750E+01   1.0731E+06    --------------------------------------------------+          2.0000E+05   8.0000E+04   0.0000E+00
1.1792E+01   1.0478E+06    ------------------------------------------------+            2.0000E+05   8.0000E+04   0.0000E+00
1.1833E+01   1.0225E+06    ----------------------------------------------+              2.0000E+05   8.0000E+04   0.0000E+00
1.1875E+01   9.9711E+05    --------------------------------------------+                2.0000E+05   8.0000E+04   0.0000E+00
1.1917E+01   9.2485E+05    --------------------------------------+                      2.0000E+05   8.0000E+04   0.0000E+00
1.1958E+01   8.5258E+05    ---------------------------------+                           2.0000E+05   8.0000E+04   0.0000E+00
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RESERV verses TIME

Minimum 4.4711E+05 — Maximum 1.1428E+06

TIME	RESERV	: (Minimum 4.4711E+05) … (Maximum 1.1428E+06) :	INSTAL	KWLOAD	WATRES
0.0000E+00	8.2755E+05	---------------------------+	1.5310E+06	7.0345E+05	6.3079E+05
4.1667E-02	8.5067E+05	-----------------------------+	1.5310E+06	6.8033E+05	6.5387E+05
8.3334E-02	8.7379E+05	------------------------------+	1.5310E+06	6.5721E+05	6.7696E+05
1.2500E-01	8.9690E+05	--------------------------------+	1.5310E+06	6.3410E+05	7.0005E+05
1.6667E-01	8.7709E+05	------------------------------+	1.5310E+06	6.5391E+05	6.8020E+05
2.0833E-01	8.5727E+05	-----------------------------+	1.5310E+06	6.7373E+05	6.6036E+05
2.5000E-01	8.3745E+05	----------------------------+	1.5310E+06	6.9355E+05	6.4051E+05
2.9167E-01	7.6480E+05	----------------------+	1.5310E+06	7.6620E+05	5.6781E+05
3.3334E-01	6.9214E+05	-----------------+	1.5310E+06	8.3886E+05	4.9511E+05
3.7500E-01	6.1949E+05	------------+	1.5310E+06	9.1151E+05	4.2241E+05
4.1667E-01	6.1949E+05	------------+	1.5310E+06	9.1151E+05	4.2235E+05
4.5834E-01	6.1949E+05	------------+	1.5310E+06	9.1151E+05	4.2230E+05
5.0000E-01	6.1949E+05	------------+	1.5310E+06	9.1151E+05	4.2225E+05
5.4167E-01	6.1618E+05	------------+	1.5310E+06	9.1482E+05	4.1889E+05
5.8334E-01	6.1288E+05	-----------+	1.5310E+06	9.1812E+05	4.1554E+05
6.2501E-01	6.0957E+05	-----------+	1.5310E+06	9.2143E+05	4.1217E+05
6.6667E-01	5.7476E+05	---------+	1.5310E+06	9.5624E+05	3.7730E+05
7.0834E-01	5.4030E+05	------+	1.5310E+06	9.9070E+05	3.4279E+05
7.5001E-01	5.5014E+05	-------+	1.5310E+06	9.8086E+05	3.5256E+05
7.9167E-01	5.7325E+05	---------+	1.5310E+06	9.5775E+05	3.7562E+05
8.3334E-01	5.9637E+05	----------+	1.5310E+06	9.3463E+05	3.9868E+05
8.7501E-01	6.1950E+05	------------+	1.5310E+06	9.1150E+05	4.2175E+05
9.1667E-01	6.8555E+05	-----------------+	1.5310E+06	8.4545E+05	4.8775E+05
9.5834E-01	7.5160E+05	---------------------+	1.5310E+06	7.7940E+05	5.5376E+05
1.0000E+00	8.1604E+05	--------------------------+	1.5310E+06	6.6496E+05	6.1816E+05
1.0417E+00	8.3789E+05	----------------------------+	1.5310E+06	6.4311E+05	6.3997E+05
1.0833E+00	8.5974E+05	-----------------------------+	1.5310E+06	6.2126E+05	6.6180E+05
1.1250E+00	8.8159E+05	-------------------------------+	1.5310E+06	5.9941E+05	6.8361E+05
1.1667E+00	8.6286E+05	-----------------------------+	1.5310E+06	6.1814E+05	6.6485E+05
1.2083E+00	8.4412E+05	----------------------------+	1.5310E+06	6.3688E+05	6.4608E+05
1.2500E+00	8.2538E+05	---------------------------+	1.5310E+06	6.5562E+05	6.2730E+05
1.2917E+00	7.5670E+05	----------------------+	1.5310E+06	7.2430E+05	5.5858E+05
1.3333E+00	6.8801E+05	-----------------+	1.5310E+06	7.9299E+05	4.8985E+05
1.3750E+00	6.1935E+05	------------+	1.5310E+06	8.6165E+05	4.2114E+05
1.4167E+00	6.1935E+05	------------+	1.5310E+06	8.6165E+05	4.2108E+05
1.4583E+00	6.1935E+05	------------+	1.5310E+06	8.6165E+05	4.2103E+05
1.5000E+00	6.1935E+05	------------+	1.5310E+06	8.6165E+05	4.2098E+05
1.5417E+00	6.1623E+05	------------+	1.5310E+06	8.6477E+05	4.1780E+05
1.5833E+00	6.1311E+05	-----------+	1.5310E+06	8.6789E+05	4.1462E+05
1.6250E+00	6.0997E+05	-----------+	1.5310E+06	8.7103E+05	4.1144E+05
1.6667E+00	5.7706E+05	---------+	1.5310E+06	9.0394E+05	3.7847E+05
1.7083E+00	5.4450E+05	------+	1.5310E+06	9.3650E+05	3.4585E+05
1.7500E+00	5.5380E+05	-------+	1.5310E+06	9.2720E+05	3.5508E+05
1.7917E+00	5.7565E+05	---------+	1.5310E+06	9.0535E+05	3.7688E+05
1.8333E+00	5.9750E+05	----------+	1.5310E+06	8.8350E+05	3.9867E+05
1.8750E+00	6.1937E+05	------------+	1.5310E+06	8.6163E+05	4.2049E+05
1.9167E+00	6.8181E+05	----------------+	1.5310E+06	7.9919E+05	4.8287E+05
1.9583E+00	7.4425E+05	---------------------+	1.5310E+06	7.3675E+05	5.4527E+05
2.0000E+00	8.7838E+05	------------------------------+	1.5310E+06	6.0262E+05	6.7936E+05
2.0417E+00	8.9818E+05	--------------------------------+	1.5310E+06	5.8282E+05	6.9913E+05
2.0833E+00	9.1799E+05	---------------------------------+	1.5310E+06	5.6301E+05	7.1891E+05

Minimum 4.4711E+05 RESERV verses TIME Maximum 1.1428E+06

TIME	RESERV	INSTAL	KWLOAD	WATRES
2.1250E+00	9.3778E+05	1.5310E+06	5.4322E+05	7.3867E+05
2.1667E+00	9.2080E+05	1.5310E+06	5.6020E+05	7.2167E+05
2.2084E+00	9.0383E+05	1.5310E+06	5.7717E+05	7.0467E+05
2.2500E+00	8.8683E+05	1.5310E+06	5.9417E+05	6.8764E+05
2.2917E+00	8.2459E+05	1.5310E+06	6.5641E+05	6.2537E+05
2.3334E+00	7.6235E+05	1.5310E+06	7.1865E+05	5.6308E+05
2.3750E+00	7.0013E+05	1.5310E+06	7.8087E+05	5.0082E+05
2.4167E+00	7.0013E+05	1.5310E+06	7.8087E+05	5.0077E+05
2.4584E+00	7.0013E+05	1.5310E+06	7.8087E+05	5.0073E+05
2.5000E+00	7.0013E+05	1.5310E+06	7.8087E+05	5.0068E+05
2.5417E+00	6.9730E+05	1.5310E+06	7.8370E+05	4.9780E+05
2.5834E+00	6.9447E+05	1.5310E+06	7.8653E+05	4.9492E+05
2.6250E+00	6.9163E+05	1.5310E+06	7.8937E+05	4.9203E+05
2.6667E+00	6.6180E+05	1.5310E+06	8.1920E+05	4.6215E+05
2.7084E+00	6.3230E+05	1.5310E+06	8.4870E+05	4.3260E+05
2.7500E+00	6.4073E+05	1.5310E+06	8.4027E+05	4.4097E+05
2.7917E+00	6.6053E+05	1.5310E+06	8.2047E+05	4.6073E+05
2.8334E+00	6.8034E+05	1.5310E+06	8.0066E+05	4.8048E+05
2.8750E+00	7.0016E+05	1.5310E+06	7.8084E+05	5.0026E+05
2.9167E+00	7.5675E+05	1.5310E+06	7.2425E+05	5.5680E+05
2.9584E+00	8.1333E+05	1.5310E+06	6.6767E+05	6.1334E+05
3.0000E+00	9.7534E+05	1.5310E+06	5.3566E+05	7.7533E+05
3.0417E+00	9.9295E+05	1.5310E+06	5.1805E+05	7.9291E+05
3.0834E+00	1.0105E+06	1.5310E+06	5.0045E+05	8.1050E+05
3.1250E+00	1.0281E+06	1.5310E+06	4.8287E+05	8.2807E+05
3.1667E+00	1.0130E+06	1.5310E+06	4.9796E+05	8.1296E+05
3.2084E+00	9.9796E+05	1.5310E+06	5.1304E+05	7.9785E+05
3.2500E+00	9.8284E+05	1.5310E+06	5.2816E+05	7.8272E+05
3.2917E+00	9.2751E+05	1.5310E+06	5.8349E+05	7.2737E+05
3.3334E+00	8.7219E+05	1.5310E+06	6.3881E+05	6.7201E+05
3.3750E+00	8.1689E+05	1.5310E+06	6.9411E+05	6.1669E+05
3.4167E+00	8.1689E+05	1.5310E+06	6.9411E+05	6.1665E+05
3.4584E+00	8.1689E+05	1.5310E+06	6.9411E+05	6.1662E+05
3.5000E+00	8.1689E+05	1.5310E+06	6.9411E+05	6.1658E+05
3.5417E+00	8.1438E+05	1.5310E+06	6.9662E+05	6.1403E+05
3.5834E+00	8.1186E+05	1.5310E+06	6.9914E+05	6.1148E+05
3.6250E+00	8.0933E+05	1.5310E+06	7.0167E+05	6.0891E+05
3.6667E+00	7.8282E+05	1.5310E+06	7.2818E+05	5.8236E+05
3.7084E+00	7.5660E+05	1.5310E+06	7.5440E+05	5.5611E+05
3.7500E+00	7.6409E+05	1.5310E+06	7.4691E+05	5.6356E+05
3.7917E+00	7.8170E+05	1.5310E+06	7.2930E+05	5.8112E+05
3.8334E+00	7.9930E+05	1.5310E+06	7.1170E+05	5.9869E+05
3.8750E+00	8.1693E+05	1.5310E+06	6.9407E+05	6.1628E+05
3.9167E+00	8.6723E+05	1.5310E+06	6.4377E+05	6.6655E+05
3.9584E+00	9.1753E+05	1.5310E+06	5.9347E+05	7.1682E+05
4.0000E+00	1.0269E+06	1.5310E+06	4.8409E+05	8.2622E+05
4.0417E+00	1.0523E+06	1.5310E+06	4.5874E+05	8.5161E+05
4.0834E+00	1.0776E+06	1.5310E+06	4.3338E+05	8.7700E+05
4.1250E+00	1.1030E+06	1.5310E+06	4.0804E+05	9.0237E+05
4.1667E+00	1.1030E+06	1.5310E+06	4.0804E+05	9.0241E+05
4.2084E+00	1.1030E+06	1.5310E+06	4.0804E+05	9.0244E+05

Minimum 4.4711E+05 — RESERV verses TIME — Maximum 1.1428E+06

TIME	RESERV	INSTAL	KWLOAD	WATRES
4.2500E+00	1.1029E+06	1.5310E+06	4.0811E+05	9.0241E+05
4.2917E+00	1.0161E+06	1.5310E+06	4.9491E+05	8.1564E+05
4.3334E+00	9.2970E+05	1.5310E+06	5.8130E+05	7.2927E+05
4.3750E+00	8.8853E+05	1.5310E+06	6.2247E+05	6.8812E+05
4.4167E+00	8.4737E+05	1.5310E+06	6.6363E+05	6.4697E+05
4.4584E+00	8.3328E+05	1.5310E+06	6.7772E+05	6.3290E+05
4.5000E+00	8.1941E+05	1.5310E+06	6.9159E+05	6.1904E+05
4.5417E+00	8.2633E+05	1.5310E+06	6.8467E+05	6.2597E+05
4.5834E+00	8.3325E+05	1.5310E+06	6.7775E+05	6.3290E+05
4.6250E+00	8.4015E+05	1.5310E+06	6.7085E+05	6.3982E+05
4.6667E+00	8.3554E+05	1.5310E+06	6.7546E+05	6.3522E+05
4.7084E+00	8.3093E+05	1.5310E+06	6.8007E+05	6.3062E+05
4.7500E+00	8.2634E+05	1.5310E+06	6.8466E+05	6.2604E+05
4.7917E+00	8.4248E+05	1.5310E+06	6.6852E+05	6.4219E+05
4.8334E+00	8.5861E+05	1.5310E+06	6.5239E+05	6.5834E+05
4.8750E+00	8.7474E+05	1.5310E+06	6.3626E+05	6.7448E+05
4.9167E+00	8.8166E+05	1.5310E+06	6.2934E+05	6.8141E+05
4.9584E+00	9.3355E+05	1.5310E+06	5.7745E+05	7.3332E+05
5.0000E+00	7.9709E+05	1.5310E+06	4.7119E+05	5.9695E+05
5.0417E+00	8.2175E+05	1.5310E+06	4.4651E+05	6.2171E+05
5.0834E+00	8.4641E+05	1.5310E+06	4.2182E+05	6.4646E+05
5.1250E+00	8.7104E+05	1.5310E+06	3.9717E+05	7.8837E+05
5.1667E+00	8.7102E+05	1.5310E+06	3.9717E+05	7.8845E+05
5.2084E+00	8.7099E+05	1.5310E+06	3.9717E+05	7.8854E+05
5.2500E+00	8.7087E+05	1.5310E+06	3.9725E+05	7.8862E+05
5.2917E+00	7.8637E+05	1.5310E+06	4.8174E+05	5.8696E+05
5.3334E+00	7.0226E+05	1.5310E+06	5.6582E+05	5.0294E+05
5.3750E+00	6.6217E+05	1.5310E+06	6.0589E+05	4.6293E+05
5.4167E+00	6.2208E+05	1.5310E+06	6.4596E+05	4.2292E+05
5.4584E+00	6.0836E+05	1.5310E+06	6.5966E+05	4.0928E+05
5.5000E+00	5.9485E+05	1.5310E+06	6.7316E+05	3.9584E+05
5.5417E+00	6.0156E+05	1.5310E+06	6.6643E+05	4.0263E+05
5.5834E+00	6.0827E+05	1.5310E+06	6.5969E+05	4.0941E+05
5.6250E+00	6.1497E+05	1.5310E+06	6.5297E+05	4.1619E+05
5.6667E+00	6.1046E+05	1.5310E+06	6.5746E+05	4.1176E+05
5.7084E+00	6.0596E+05	1.5310E+06	6.6195E+05	4.0733E+05
5.7500E+00	6.0147E+05	1.5310E+06	6.6641E+05	4.0292E+05
5.7917E+00	6.1716E+05	1.5310E+06	6.5071E+05	4.1869E+05
5.8334E+00	6.3285E+05	1.5310E+06	6.3500E+05	4.3445E+05
5.8750E+00	6.4853E+05	1.5310E+06	6.1930E+05	4.5021E+05
5.9167E+00	6.5525E+05	1.5310E+06	6.1256E+05	4.5701E+05
5.9584E+00	7.0574E+05	1.5310E+06	5.6205E+05	5.0758E+05
6.0000E+00	1.0704E+06	1.5310E+06	4.6056E+05	8.7237E+05
6.0417E+00	1.0946E+06	1.5310E+06	4.3644E+05	8.9658E+05
6.0834E+00	1.1187E+06	1.5310E+06	4.1231E+05	9.2079E+05
6.1250E+00	1.1428E+06	1.5310E+06	3.8821E+05	1.0532E+06
6.1667E+00	1.1428E+06	1.5310E+06	3.8821E+05	1.0533E+06
6.2084E+00	1.1428E+06	1.5310E+06	3.8821E+05	1.0534E+06
6.2501E+00	1.1427E+06	1.5310E+06	3.8831E+05	1.0535E+06
6.2917E+00	1.0601E+06	1.5310E+06	4.7089E+05	8.6271E+05
6.3334E+00	9.7793E+05	1.5310E+06	5.5307E+05	7.8061E+05

Minimum 4.4711E+05 — RESERV verses TIME — Maximum 1.1428E+06

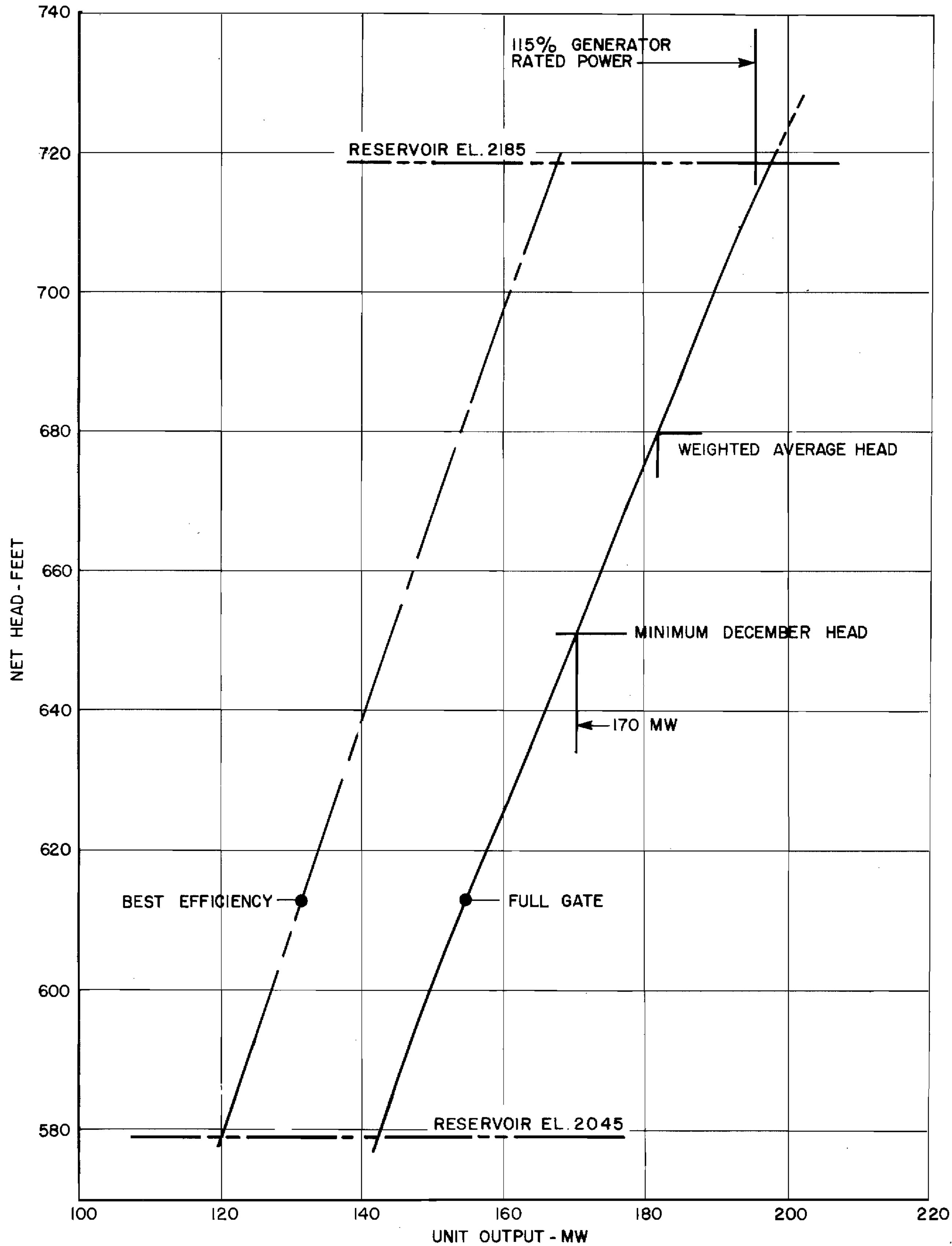
TIME	RESERV	INSTAL	KWLOAD	WATRES
6.3751E+00	9.3876E+05	1.5310E+06	5.9224E+05	7.4151E+05
6.4167E+00	8.9960E+05	1.5310E+06	6.3140E+05	7.0242E+05
6.4584E+00	8.8621E+05	1.5310E+06	6.4479E+05	6.8909E+05
6.5001E+00	8.7302E+05	1.5310E+06	6.5798E+05	6.7597E+05
6.5417E+00	8.7960E+05	1.5310E+06	6.5140E+05	6.8262E+05
6.5834E+00	8.8618E+05	1.5310E+06	6.4482E+05	6.8927E+05
6.6251E+00	8.9275E+05	1.5310E+06	6.3825E+05	6.9590E+05
6.6667E+00	8.8836E+05	1.5310E+06	6.4264E+05	6.9158E+05
6.7084E+00	8.8397E+05	1.5310E+06	6.4703E+05	6.8726E+05
6.7501E+00	8.7961E+05	1.5310E+06	6.5139E+05	6.8297E+05
6.7917E+00	8.9497E+05	1.5310E+06	6.3603E+05	6.9839E+05
6.8334E+00	9.1032E+05	1.5310E+06	6.2068E+05	7.1381E+05
6.8751E+00	9.2566E+05	1.5310E+06	6.0534E+05	7.2922E+05
6.9167E+00	9.3226E+05	1.5310E+06	5.9874E+05	7.3589E+05
6.9584E+00	9.8163E+05	1.5310E+06	5.4937E+05	7.8533E+05
7.0001E+00	1.0409E+06	1.5310E+06	4.9015E+05	8.4463E+05
7.0417E+00	1.0665E+06	1.5310E+06	4.6447E+05	8.7038E+05
7.0834E+00	1.0922E+06	1.5310E+06	4.3880E+05	8.9613E+05
7.1251E+00	1.1178E+06	1.5310E+06	4.1316E+05	9.2184E+05
7.1667E+00	1.1178E+06	1.5310E+06	4.1316E+05	9.2192E+05
7.2084E+00	1.1178E+06	1.5310E+06	4.1316E+05	9.2200E+05
7.2501E+00	1.1177E+06	1.5310E+06	4.1328E+05	9.2195E+05
7.2917E+00	1.0298E+06	1.5310E+06	5.0116E+05	8.3414E+05
7.3334E+00	9.4239E+05	1.5310E+06	5.8861E+05	7.4675E+05
7.3751E+00	9.0070E+05	1.5310E+06	6.3030E+05	7.0513E+05
7.4167E+00	8.5902E+05	1.5310E+06	6.7198E+05	6.6350E+05
7.4584E+00	8.4478E+05	1.5310E+06	6.8622E+05	6.4931E+05
7.5001E+00	8.3075E+05	1.5310E+06	7.0025E+05	6.3533E+05
7.5417E+00	8.3775E+05	1.5310E+06	6.9325E+05	6.4239E+05
7.5834E+00	8.4475E+05	1.5310E+06	6.8625E+05	6.4944E+05
7.6251E+00	8.5174E+05	1.5310E+06	6.7926E+05	6.5648E+05
7.6667E+00	8.4707E+05	1.5310E+06	6.8393E+05	6.5186E+05
7.7084E+00	8.4240E+05	1.5310E+06	6.8860E+05	6.4725E+05
7.7501E+00	8.3776E+05	1.5310E+06	6.9324E+05	6.4266E+05
7.7917E+00	8.5410E+05	1.5310E+06	6.7690E+05	6.5905E+05
7.8334E+00	8.7044E+05	1.5310E+06	6.6056E+05	6.7545E+05
7.8751E+00	8.8677E+05	1.5310E+06	6.4423E+05	6.9183E+05
7.9167E+00	8.9380E+05	1.5310E+06	6.3720E+05	6.9891E+05
7.9584E+00	9.4634E+05	1.5310E+06	5.8466E+05	7.5151E+05
8.0001E+00	9.4536E+05	1.5310E+06	5.3564E+05	7.5055E+05
8.0417E+00	9.6296E+05	1.5310E+06	5.1804E+05	7.6818E+05
8.0834E+00	9.8057E+05	1.5310E+06	5.0043E+05	7.8581E+05
8.1251E+00	9.9812E+05	1.5310E+06	4.8288E+05	8.0339E+05
8.1667E+00	9.8303E+05	1.5310E+06	4.9797E+05	7.8832E+05
8.2084E+00	9.6794E+05	1.5310E+06	5.1306E+05	7.7326E+05
8.2501E+00	9.5279E+05	1.5310E+06	5.2821E+05	7.5813E+05
8.2917E+00	8.9746E+05	1.5310E+06	5.8354E+05	7.0282E+05
8.3334E+00	8.4213E+05	1.5310E+06	6.3887E+05	6.4751E+05
8.3751E+00	7.8689E+05	1.5310E+06	6.9411E+05	5.9228E+05
8.4167E+00	7.8689E+05	1.5310E+06	6.9411E+05	5.9229E+05
8.4584E+00	7.8689E+05	1.5310E+06	6.9411E+05	5.9230E+05

Minimum 4.4711E+05 RESERV verses TIME Maximum 1.1428E+06

TIME	RESERV	INSTAL	KWLOAD	WATRES
8.5001E+00	7.8689E+05	1.5310E+06	6.9411E+05	5.9231E+05
8.5417E+00	7.8437E+05	1.5310E+06	6.9663E+05	5.8980E+05
8.5834E+00	7.8186E+05	1.5310E+06	6.9914E+05	5.8729E+05
8.6251E+00	7.7930E+05	1.5310E+06	7.0170E+05	5.8475E+05
8.6667E+00	7.5279E+05	1.5310E+06	7.2821E+05	5.5824E+05
8.7084E+00	7.2661E+05	1.5310E+06	7.5439E+05	5.3206E+05
8.7501E+00	7.3411E+05	1.5310E+06	7.4689E+05	5.3957E+05
8.7917E+00	7.5171E+05	1.5310E+06	7.2929E+05	5.5718E+05
8.8334E+00	7.6932E+05	1.5310E+06	7.1168E+05	5.7479E+05
8.8751E+00	7.8698E+05	1.5310E+06	6.9402E+05	5.9245E+05
8.9167E+00	8.3728E+05	1.5310E+06	6.4372E+05	6.4276E+05
8.9584E+00	8.8758E+05	1.5310E+06	5.9342E+05	6.9308E+05
9.0001E+00	8.6917E+05	1.5310E+06	6.1183E+05	6.7466E+05
9.0417E+00	8.8928E+05	1.5310E+06	5.9172E+05	6.9475E+05
9.0834E+00	9.0939E+05	1.5310E+06	5.7161E+05	7.1485E+05
9.1251E+00	9.2943E+05	1.5310E+06	5.5157E+05	7.3488E+05
9.1667E+00	9.1219E+05	1.5310E+06	5.6881E+05	7.1764E+05
9.2084E+00	8.9496E+05	1.5310E+06	5.8604E+05	7.0039E+05
9.2501E+00	8.7764E+05	1.5310E+06	6.0336E+05	6.8306E+05
9.2917E+00	8.1444E+05	1.5310E+06	6.6656E+05	6.1985E+05
9.3334E+00	7.5125E+05	1.5310E+06	7.2975E+05	5.5663E+05
9.3751E+00	6.8816E+05	1.5310E+06	7.9284E+05	4.9351E+05
9.4167E+00	6.8816E+05	1.5310E+06	7.9284E+05	4.9348E+05
9.4584E+00	6.8816E+05	1.5310E+06	7.9284E+05	4.9345E+05
9.5001E+00	6.8816E+05	1.5310E+06	7.9284E+05	4.9341E+05
9.5417E+00	6.8528E+05	1.5310E+06	7.9572E+05	4.9051E+05
9.5834E+00	6.8241E+05	1.5310E+06	7.9859E+05	4.8761E+05
9.6251E+00	6.7949E+05	1.5310E+06	8.0151E+05	4.8465E+05
9.6667E+00	6.4920E+05	1.5310E+06	8.3180E+05	4.5433E+05
9.7084E+00	6.1930E+05	1.5310E+06	8.6170E+05	4.2440E+05
9.7501E+00	6.2788E+05	1.5310E+06	8.5312E+05	4.3293E+05
9.7917E+00	6.4798E+05	1.5310E+06	8.3302E+05	4.5301E+05
9.8334E+00	6.6809E+05	1.5310E+06	8.1291E+05	4.7308E+05
9.8751E+00	6.8827E+05	1.5310E+06	7.9273E+05	4.9323E+05
9.9167E+00	7.4573E+05	1.5310E+06	7.3527E+05	5.5065E+05
9.9584E+00	8.0318E+05	1.5310E+06	6.7782E+05	6.0808E+05
1.0000E+01	8.2144E+05	1.5310E+06	7.0956E+05	6.2632E+05
1.0042E+01	8.4476E+05	1.5310E+06	6.8624E+05	6.4962E+05
1.0083E+01	8.6808E+05	1.5310E+06	6.6292E+05	6.7291E+05
1.0125E+01	8.9131E+05	1.5310E+06	6.3969E+05	6.9612E+05
1.0167E+01	8.7132E+05	1.5310E+06	6.5968E+05	6.7611E+05
1.0208E+01	8.5134E+05	1.5310E+06	6.7966E+05	6.5609E+05
1.0250E+01	8.3124E+05	1.5310E+06	6.9976E+05	6.3597E+05
1.0292E+01	7.5795E+05	1.5310E+06	7.7305E+05	5.6264E+05
1.0333E+01	6.8465E+05	1.5310E+06	8.4635E+05	4.8931E+05
1.0375E+01	6.1151E+05	1.5310E+06	9.1949E+05	4.1611E+05
1.0417E+01	6.1151E+05	1.5310E+06	9.1949E+05	4.1606E+05
1.0458E+01	6.1151E+05	1.5310E+06	9.1949E+05	4.1602E+05
1.0500E+01	6.1150E+05	1.5310E+06	9.1950E+05	4.1596E+05
1.0542E+01	6.0817E+05	1.5310E+06	9.2283E+05	4.1258E+05
1.0583E+01	6.0484E+05	1.5310E+06	9.2616E+05	4.0920E+05

Minimum 4.4711E+05 RESERV verses TIME Maximum 1.1420E+06

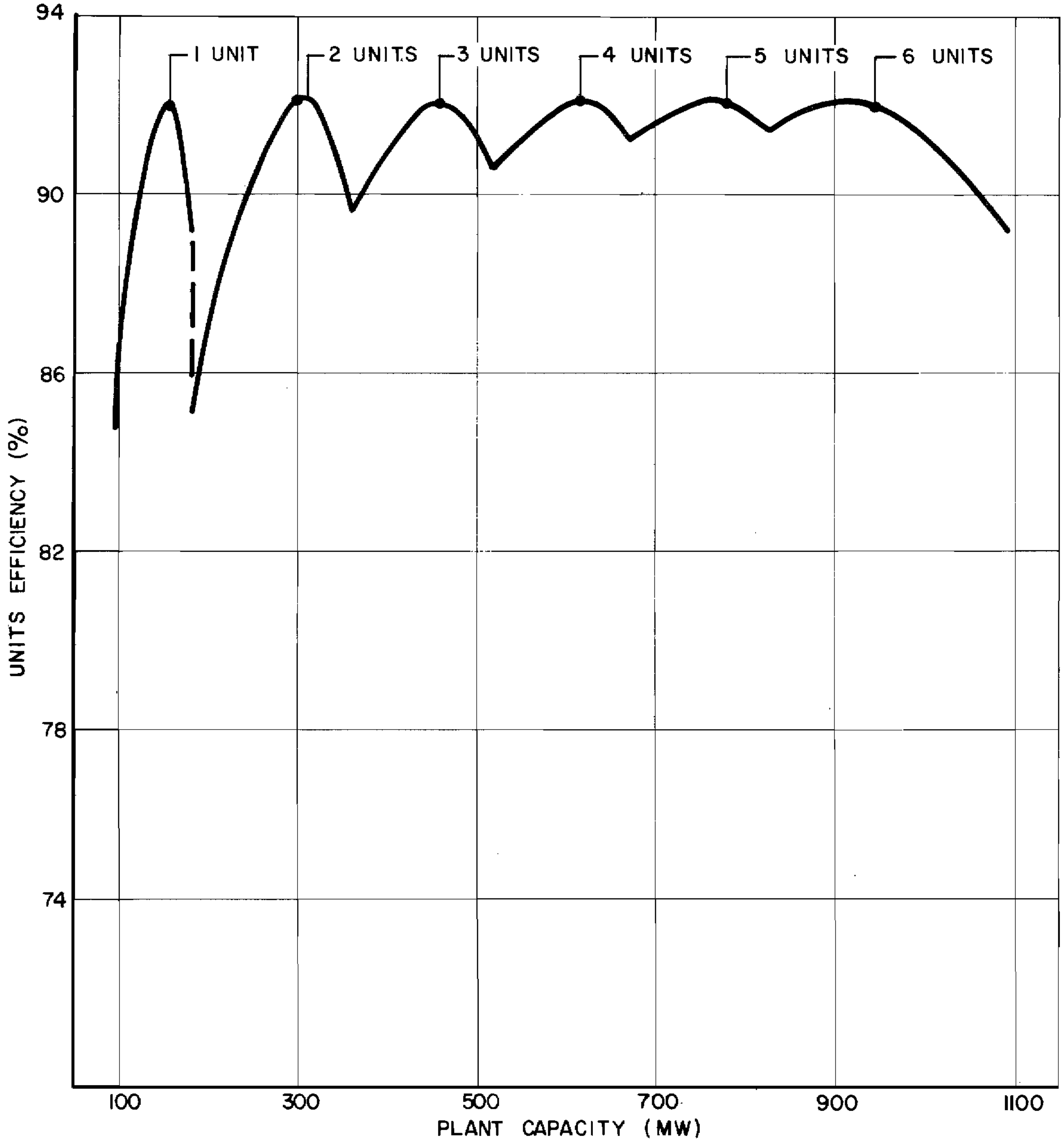
TIME	RESERV	: ... :	INSTAL	KWLOAD	WATRES
1.0625E+01	6.0144E+05	-----------+	1.5310E+06	9.2956E+05	4.0575E+05
1.0667E+01	5.6632E+05	--------+	1.5310E+06	9.6468E+05	3.7058E+05
1.0708E+01	5.3165E+05	------+	1.5310E+06	9.9935E+05	3.3585E+05
1.0750E+01	5.4160E+05	------+	1.5310E+06	9.8940E+05	3.4574E+05
1.0792E+01	5.6492E+05	--------+	1.5310E+06	9.6608E+05	3.6900E+05
1.0833E+01	5.8824E+05	----------+	1.5310E+06	9.4276E+05	3.9227E+05
1.0875E+01	6.1165E+05	-----------+	1.5310E+06	9.1935E+05	4.1563E+05
1.0917E+01	6.7828E+05	----------------+	1.5310E+06	8.5272E+05	4.8222E+05
1.0958E+01	7.4491E+05	---------------------+	1.5310E+06	7.8609E+05	5.4881E+05
1.1000E+01	7.6141E+05	----------------------+	1.5310E+06	7.6959E+05	5.6528E+05
1.1042E+01	7.8671E+05	------------------------+	1.5310E+06	7.4429E+05	5.9053E+05
1.1083E+01	8.1200E+05	--------------------------+	1.5310E+06	7.1900E+05	6.1579E+05
1.1125E+01	8.3719E+05	----------------------------+	1.5310E+06	6.9381E+05	6.4095E+05
1.1167E+01	8.1551E+05	--------------------------+	1.5310E+06	7.1549E+05	6.1924E+05
1.1208E+01	7.9383E+05	------------------------+	1.5310E+06	7.3717E+05	5.9752E+05
1.1250E+01	7.7203E+05	-----------------------+	1.5310E+06	7.5897E+05	5.7568E+05
1.1292E+01	6.9253E+05	-----------------+	1.5310E+06	8.3847E+05	4.9614E+05
1.1333E+01	6.1304E+05	-----------+	1.5310E+06	9.1796E+05	4.1660E+05
1.1375E+01	5.3372E+05	------+	1.5310E+06	9.9728E+05	3.3722E+05
1.1417E+01	5.3372E+05	------+	1.5310E+06	9.9728E+05	3.3716E+05
1.1458E+01	5.3372E+05	------+	1.5310E+06	9.9728E+05	3.3710E+05
1.1500E+01	5.3371E+05	------+	1.5310E+06	9.9729E+05	3.3703E+05
1.1542E+01	5.3010E+05	-----+	1.5310E+06	1.0009E+06	3.3336E+05
1.1583E+01	5.2649E+05	-----+	1.5310E+06	1.0045E+06	3.2969E+05
1.1625E+01	5.2279E+05	-----+	1.5310E+06	1.0082E+06	3.2594E+05
1.1667E+01	4.8470E+05	--+	1.5310E+06	1.0463E+06	2.8778E+05
1.1708E+01	4.4711E+05	+	1.5310E+06	1.0839E+06	2.5012E+05
1.1750E+01	4.5790E+05	+	1.5310E+06	1.0731E+06	2.6084E+05
1.1792E+01	4.8319E+05	--+	1.5310E+06	1.0478E+06	2.8607E+05
1.1833E+01	5.0848E+05	----+	1.5310E+06	1.0225E+06	3.1129E+05
1.1875E+01	5.3389E+05	------+	1.5310E+06	9.9711E+05	3.3663E+05
1.1917E+01	6.0615E+05	-----------+	1.5310E+06	9.2485E+05	4.0884E+05
1.1958E+01	6.7842E+05	----------------+	1.5310E+06	8.5258E+05	4.8106E+05



WATANA - UNIT OUTPUT

FIGURE B8.1

ACRES



WATANA - UNIT EFFICIENCY
(AT RATED HEAD)

FIGURE B8.2

ACRES