June 5, 1981

SUSITNA HYDROELECTRIC PROJECT

EXTERNAL REVIEW PANEL

REPORT NO. 2

INTRODUCTION

The Panel met with representatives of the Alaska Power Authority, Acres American, Terrestrial Environmental Specialists, Inc., and the Fish and Game Department in Anchorage on June 3-5, 1981 for discussions of on-going studies for the Susitna Hydroelectric Project. On June 3rd, representatives of Acres American, TES and ADF&G described the current status of these studies, after which separate group discussions were held on geotechnical, hydraulics and hydrology, and environmental subjects to review specific problem areas in more detail. A site inspection was made by Dr. Merritt on June 4th and 5th to review the field geotechnical exploration program. Dr. Rohan met with representatives of Battelle on June 2nd, Chugach Electric Association on June 4th and Union Oil on June 5th to discuss alternatives to the Susitna project. This report, which summarizes the Panel's opinions and recommendations, was prepared on June 4th and 5th and discussed with representatives of the Power Authority staff and Acres. Dr. Seed was not able to attend the meeting.

GEOTECHNICAL INVESTIGATIONS

Following Dr. Merritt's 1½ day visit to the Watana and Devil Canyon sites, discussions were held at High Lake concerning the on-going field program and preparation of information appropriate for the feasibility design. The following comments summarize these discussions and are offered to aid in the timely completion of the field program.

General - The preparation of finalized geologic maps and profiles is not keeping pace with the rapid accumulation of field information. This situation is compounded by the recent acquisition of a large quantity of field geologic data collected by previous Corp of Engineers work which was never reduced and presented in final form by the Corps. Moreover, the original Corps boring logs need to be reviewed (re-logged) to assure that all field information is presented in a consistent manner.

A schedule for completion of the various phases of work for the summer program has been prepared to assure that the necessary information is analyzed in time for the next phase of feasibility design. The External Review Panel will be prepared to review this work during our October meeting.

Watana Site

Field geologic mapping is underway, the results of which will be used to best locate the remaining exploratory borings. Present structure layouts indicate that the "Fins" shear zone should not intersect any tunnels or open cuts. Special attention is being given to the projection of the "Fingerbuster" shear zone concerning its possible intersection of the downstream portion of the tailrace tunnels. Present information suggests that this zone lies downstream of the proposed underground powerhouse; however, exploratory borings are planned to confirm this interpretation.

Additional seismic surveys will be done to better define the geometry of the buried channel on the right abutment and additional borings and pumping tests are planned for the next phase of exploration.

Devil Canyon Site

The geologic mapping is well advanced at this site and no new shear zones have been identified on the abutments. Boring BH-7 has confirmed the presence of a shear zone (previously recognized) beneath the topographic lineation on the left abutment. This feature wll be receiving careful attention during the upcoming Task 4 study.

Numerous open stress relief joints have been recognized in the upper portion of both abutments and are apparently more prevalent on the left side. The field geologists will be mapping these features in detail to assist in preliminary layouts of the required excavation for the arch dam.

Four borings remain to be drilled at Devil Canyon; 2 will pass beneath the river to explore for geologic structures and 2 more drilled into the abutments near the river to determine general rock quality. If the river hole in progress encounters favorable conditions, then the second hole may not be required for the feasibility design. Considering the excellent rock exposures, the two remaining borings may best be drilled at the upper elevations (on the left side) rather than close to the valley bottom as presently planned. These holes should be directed to cross the stress relief joints to determine their presence at depth. The drill advance can be carefully watched to determine the presence of open joints. A borehole camera would provide the most direct method of assessing the presence and magnitude of these features and is being considered by Acres' personnel.

SEISMIC STUDIES

Seismic studies have evaluated all known and detectable faults and lineaments in the project area. The 1981 field program calls for a study of thirteen features identified as signifcant in the 1980 investigations.

In order to firm up design for the major structures in the project, it is essential that conclusions regarding the significance and impact of each of these features be reached as soon as practicable. Delay in completing this

work and evaluating the parameters required for design will have an important effect on meeting the project schedule.

HYDRAULICS AND HYDROLOGY

The field program for surveys and collection of hydrologic data is considered to be adequate for the current feasibility study. Modifications to the original scope of work involve studies of navigation effects. However, after analyses of available existing data and data to be collected, it may be found necessary to collect some additional short-term information to firm up tentative conclusions in one or more areas. Specific comments on some areas of data collection are presented below.

Flood Flows

Stream flow data are being obtained at a sufficient number of existing, reactivated and newly installed gaging stations throughout the drainage area to enable a reliable determination of flood flows. Studies to date indicate that the Corps PMF is about 20,000 cfs too low. A report on flood discharges will be issued for review in a few weeks. Some 80 water level cross-sections have been taken in the Susitna River. HEC programs are being developed for free surface and ice covered water levels for various size floods. Reports will be issued on free surface water levels in July and ice covered conditions somewhat later. These studies should establish reliable bases for determining river tailwater levels at the dams and water surface profiles in downstream reaches of the Susitna River.

Sediment Data Collection

The river sediment measuring program has not been started. This program should be defined and started as soon as possible under the guidance of the USGS or a private river sediment expert. It is essential that bed load measurements be made during this runoff season to enable a reasonable assessment of the effects that depletion of sediment loads by construction of the dams would have on downstream river conditions. The Panel is concerned that the necessary sediment data may not be available in time for inclusion into the June 30, 1982 feasibility report.

Reservoir Capacity

Recent reservoir surveys have been completed from which more accurate capacity curves have been developed. At Watana, the revised curve indicates one to two percent less reservoir capacity between elevations 1700 and 2100, but the capacity is essentially the same as shown by the original curve at maximum pool elevation 2200. This small difference does not require revisions in the design development studies. However, the revised capacity curve should be used in final design.

At Devil Canyon, the revised reservoir capacity curve based on the latest survey indicates significantly greater capacity than the initial capacity curve, being approximately 30 percent greater at elevation 1500. Since

power operation would be near maximum pool nearly 100 percent of the time, the revised greater capacity would have little influence on design development studies. However, the greater capacity curve should be used in final design and reservoir filling and drawdown studies.

Energy Output

The firm energy output for the Watana/Devil Canyon system has been determined by routing actual stream flows which occurred for the 1969-79 period through the system. Since this was by far the period of lowest stream flow over 70 years of record, the Panel concurs that this is a satisfactory basis for establishing firm energy output.

DESIGN DEVELOPMENT

Acres described various alternative schemes for optimizing design of the main dams, coffer dams, saddle dams, spillways, power facilities and diversion tunnels for the two dams. The Panel was very impressed with the many specific alternatives which will be studied to arrive at the most functionally satisfactory and economical plan. We desire to emphasize, nowever, that full consideration should be given to the effects on ease of construction and construction schedules, as well as costs, for the various alternatives. Specific comments follow on some of the design features that will be considered in the optimization studies.

Multiple Level Outlets

There is some question whether multiple level outlets will be required in the power intakes, particularly at Watana Dam. Some experience in several Alaska lakes indicates that a marked thermal stratification may not occur in the two reservoirs and that the reservoir waters may never be free of turbidity, in which case multiple level outlets would not effectively enhance downstream water temperatures or quality. The Panel is of the opinion that sufficient studies should be made of other lakes to make a better assessment of what is most likely to occur in Watana and Devil Canyon reservoir. If the studies are inconclusive, then the Panel suggests that multiple level outlets be provided at both dams, since their costs would not be excessive and prototype experience may prove them to effectively enhance water temperatures and quality downstream of the dams. An exception to this statement, however, is that in the event Devil Canyon will be constructed earlier than anticipated due to greater power demand, then multiple level outlets may not be required at Watana Dam.

Low Level Outlet

Acres has given preliminary consideration to providing low level outlets at both dams for lowering the reservoirs in the event of an emergency. Based on general guidance information used by the Corps of Engineers, a low level outlet capacity of approximately 100,000 cfs would be required. This would require construction of an additional large gated tunnel at great cost. A

low level outlet was provided at Mica Creek Dam in British Columbia by providing a tunnel plug and gates in the diversion tunnel which would allow substantial lowering of the reservoir in a period of 8 months. The Panel believes that this type of low level outlet should be installed in the diversion tunnels at Watana and Devil Canyon. This low level outlet would provide for regulation of initial reservoir filling, minimum flow release when the powerhouse is not in operation and emergency lowering of the reservoir over a substantial period of time for repairs in the event that seepage problems should develop.

Service Spillway

One alternative scheme for Watana provides for a service spillway with a stilling basin designed for a 1 in 10,000 year flood and a fuse plug spillway to handle additional flows up to the PMF. While there may be some reduction in cost by reducing the size of the service spillway and increasing the size of the fuse plug spillway, the Panel is of the opinion that the service spillway should not be made smaller than required for a 1 in 10,000 year flood. However, some reduction in cost can be made by designing the stilling basin to function as a hydraulic jump basin for a smaller discharge, say 50 percent of the 1 in 10,000 year flow, and sweep out of the basin for larger discharges, if this would not endanger the stilling basin structure.

Spillway Outlets in Arch Dam

Although technically feasible, the Panel suggests that consideration be given to eliminating the spillway outlets through the arch dam at Devil Canyon and the concrete lined plunge pool near the toe of the dam by increasing the size of the service spillway. If there is not a substantial increase in cost, the Panel would prefer to eliminate the outlets through the arch dam.

Watana Dam

An embankment structure has been selected for feasibility studies at the Watana site. It appears that very little effort has been expended to study other types of dams for this site. A preliminary design has been prepared for an arch dam, but, to our knowledge, essentially no attempt has been made to compare the cost of these two structures, to evaluate construction time or difficulties, or to otherwise evaluate potential alternatives.

As a basis for proceeding with feasibility studies, we consider it important that economic comparisons be prepared for viable alternative dam types for the Watana site.

Devil Canyon Dam

An arch dam appears to be the most appropriate structure for the Devil Canyon site. This conclusion has been reached by essentially all investigators, and, we assume, is based on comparisons with other dam types for the site.

Acres has developed a satisfactory arch dam design for the Devil Canyon site. Stress levels appear to be acceptable for all normal loading conditions studies. A dynamic response spectrum analysis, assuming 0.5 gravity ground acceleration and a 5 percent damping rate, was conducted. The resulting stresses indicate that construction joints in the upper part of the dam would open intermittently. Some horizontal surface cracking may also occur on both faces.

We believe this loading to be extremely conservative. A damping rate of 10 percent is more appropriate for this situation, and a ground acceleration no greater than 0.4 gravity appears to be more realistic.

ENVIRONMENTAL CONSIDERATIONS

Substantial progress is being made in the study of various environmental considerations, such as the current status of fish and wildlife populations, cultural resources (archaeologic remains), vegetation types, and alternative location of access roads. Some crucial environmental issues, however, have not been adequately addressed. These will require extra attention in the 1981 field season. In this category are downstream effects of the dams on the river channel itself with potential secondary effects on fisheries and wildlife, effects of the dams on water turbidity, and possible effects of leaving standing timber in the impoundment areas.

Fisheries

Studies of fish population in the Susitna River Basin were late in starting in 1980, but considerable data were accrued through the fall and winter (1980-81). An accelerated program is underway in June 1981, which by 1982 should yield a preliminary picture of the existing situation.

The Susitna River above Devil Canyon apparently supports a substantial population of grayling, but few if any salmon are able to ascend the stream. Presumably, the grayling and probably lake trout will thrive in the impoundments. The question of whether they will constitute an important recreational fishery depends on the ultimate clarity or turbidity of the impounded waters. Even if the water is turbid, there will be some sport fishing at the mouths of clear streams entering the impoundments.

The lower Susitna River and its many tributaries and back waters carry substantial populations of salmon that support an important commercial fishery in Cook Inlet, as well as a sport fishery in the river channels and at the river mouth. There are additional populations of grayling and rainbow trout in many of the tributaries. On-going studies are intended to shed light on the relative importance of the various tributaries, backwaters and main channels in supporting fish life. Of particular significance in this regard is gaining an understanding of the possible effects of the impoundments on downstream hydrology. This can best be prognosticated by measuring the bed load of sediment now carried by the Susitna and its

various tributaries. When the silt load from the upper Susitna is cut off by the dams, what will be the changes in the conformation of the lower river and the chemistry and turbidity of the water? Data on bed load must be obtained before this important issue can be predicted.

Wildlife

The Alaska Department of Fish and Game is making commendable progress in studying populations of moose, caribou, black and grizzly bears, wolves and dall sheep. The moose will be directly affected by loss of winter range in the Watana impoundment. In time, there may be a compensatory development of new willow stands bordering the impoundment. Black bears will be all but eliminated from the Watana impounded area by flooding of denning areas and loss of protective timber. Caribou may be somewhat affected by disruption of seasonal migration to calving grounds. Dall sheep, grizzly bears, and wolves will probably be only peripherally affected by disturbance of their wilderness habitat.

The University of Alaska and the Alaska Cooperative Wildlife Research Unit are studying populations of furbearers, non-game mammals, and birds. As far as we know these studies are progressing satisfactorily.

Downstream Hydrology

Change in the amount of bed load carried by the Susitna River may affect fisheries and wildlife in a number of ways. There is some indication that the backwaters and billabongs of the lower Susitna may be important rearing areas for juvenile salmon. Summer flooding of these backwaters, sloughs, and ponds creates extensive waterfowl habitat. Peak floods cut into timber stands and deposit open bars which are colonized by willows that constitute winter forge for moose. Understanding the dynamics of the lower river is essential in predicting long-term effects of the Susitna project on wildlife.

The need for additional hydrologic studies - especially bed load studies - was discussed in the March meeting of the External Review Panel in San Francisco. But as of June 1981, no firm plan of action has been implemented. The Panel urges immediate action to assure that some useful data on bed load will be available for consideration in October, 1981. Without it, there will be no way that downstream effects can be evaluated.

Water Chemistry and Turbidity

The water quality program is being prepared for Acres American by R & M Consultants. No results have been made available to the Panel, nor even a list of specific questions being investigated. From the standpoint of fisheries it is important to know what may be the future turbidity of the reservoirs and the Susitna River below.

In summer, a substantial flow of turbid water will enter Watana Reservoir from the glacier above. Heavy materials will be deposited in the reservoir

head, and smaller particles will be carried on toward the dam. To what extent will the water clear as it approaches Watana dam? Will the water in Devil Canyon reservoir be clear or cloudy? And what of water passing Devil Canyon dam into the mainstream of the river below through summer and winter alike? Clouded water blocks the passage of light and reduces or precludes the growth of phytoplankton which form the base of the aquatic food chain. The productivity of these waters for fish will be an inverse function of turbidity. Are adequate studies underway to prognosticate post-project water conditions?

Timber in Impoundment Area

At the January, 1981 meeting of the Panel, the suggestion was made that consideration be given to stripping the timber from areas to be impounded, for the purpose of reducing the load of floating trash in the reservoirs. Has this idea been considered? Has the cost been estimated?

Nitrogen Supersaturation

To protect fish life in the Devil Canyon reservoir and in the river below, the design of both dams - including penstocks and overflow structures - must minimize or preclude the incorporation of nitrogen into solution if current studies by Mr. Milo Bell suggest this possibility.

Access Roads

Selection of the route or routes for constructing access roads should avoid, insofar as possible, disturbance of caribou or Dall sheep. These two species are expecially susceptible to environmental disturbance. The area south of the two reservoirs is of particular importance to sheep. The calving ground of caribou adjoins the upper reaches of Watana impoundment on the north.

ECONOMIC FEASIBILITY AND FINANCING

Battelle Pacific Northwest is responsible, under separate contract, to review and analyze alternatives to the Susitna project. Dr. Rohan met on June 2, 1981 at Battelle's office with Mr. Swift, the project manager and several of his staff to review Battelle's progress and to gain a better understanding of their approach. Battelle has addressed its initial effort at understanding the gas supply situation, and in improving the demand forecasting methodology. Copies of working draft reports on these subjects are being forwarded for review by the External Review Panel. Because the results of the Battelle study will be employed in Acre's final report due in April 1982, it is recommended that the Alaska Power Authority monitor the timeliness and work quality of Battelle.

From the initial Battelle meeting it was learned that Battelle's approach to comparing alternatives is not totally consistant with the work of Acres. In this respect, it clearly is advisable that Battelle and Acres meet in

the near future to arrive at a common basis to make economic comparisons of the various alternatives.

Because of the high level of uncertainty in estimating a) the future markets for electricity, b) the capital costs and construction time to build power plants, c) the availability and prices for fossil fuels and, d) future regulatory environments, it is recommended that all economic analysis incorporate this uncertainty. Techniques for making economic comparisons under uncertainty are well known and include sensitivity analysis, probabilistic assessments and decision analysis. Acres' current approach needs some improvement as it is narrowly focused. The External Review Panel would like to review in October, progress in developing a consistant approach to evaluating alternatives under uncertainty.

The issue of financing mechanisms for the Susitna project and the corresponding electric rates to the customers needs further analysis. Because of the financial risks, it is likely that the Susitna project cannot be financed without support in the form of equity participation, guarantees and the like by the State of Alaska. A determination of available and likely financing mechanisms needs to be further developed by Acres and available for review in October.

If the Susitna project is financed through direct state funding, and the corresponding rates for electricity are set less than the cost of gas or oil heating, there will be economic incentives to convert to electric heat. This would greatly accelerate the demand for electricity and have a major impact on Susitna and other power projects. The full impacts of this case need to be investigated.

From an economic viewpoint, it appears that gas is the competitive alternative to the Susitna project. Chugach Electric Association, which represents about half the power requirements for the Railbelt region, is favorably disposed to this gas alternative. The gas reserve situation and future prices for gas needs further investigation. Particular emphasis should be given to understanding potential long term contracting agreements for gas from the oil and gas companies.

The Panel would like to examine the criteria that FERC will employ in the market and economic area to be certain that Acre's report fully addresses these issues.

AGENDA FOR NEXT MEETING

The next meeting of the Panel is tentatively scheduled for the week of October 5, 1981 at the Acres Buffalo location. The Panel desires to make the following recommendations regarding this meeting:

1. A site visit should be made by Panel members who desire to do so before the October 5th before the full meeting.

2. Geotechnical problems should be resolved and discussed in more detail.

3. Results of design development studies for various alternatives schemes should be discussed in more detail.

4. Environmental study results should be presented and discussed more fully.

5. Battelle should present the results of their studies for Panel consideration.

6. Consideration should be given to having a FERC representative attend the meeting if this will be useful in speeding up their review process and earlier license approval.

CLOSING REMARKS

The Panel expresses its appreciation to the staff of the Alaska Power Authority and the staff of Acres American Incorporated for the many courtesies extended during the meeting.

Merlin D. Copen	Jacob H. Douma
A. Starker Leopold	Andrew H. Merritt
Dennis M. Rohan	H. Bolton Seed

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October 8, 1981

SUSITNA HYDROELECTRIC PROJECT
EXTERNAL REVIEW PANEL
REPORT NO. 3

INTRODUCTION

The third meeting of the External Review Panel for the Susitna hydroelectric Project was convened on October 6-8, 1981 at the Acres American office in Buffalo. In addition to Panel Members, representatives of the Alaska Power Authority and Acres American were present. Various members of the Acres American staff presented discussions regarding progress in geotechnical areas, seismicity, hydraulics, hydrology, and design. The discussions were well prepared and presented in such manner as to give a maximum amount of information in a reasonable time.

Prior to the meeting Panel Members received a document entitled "Susitna Hydroelectric Project, External Review Board, Meeting #3, Information Package, October 6-8, 1981". During the meeting other printed information was presented to the Panel as required.

The Panel appreciates the efforts of the Acres American Staff in planning and preparing for this very informative and successful meeting.

SEISMICITY AND SEISMIC GEOLOGY

Excellent progress has been made during the summer months in resolving most of the uncertainties regarding the possible presence of active faults in the vicinity of the dam sites, in developing an adequate model of the seismic geology of the region, and in assessing the maximum levels of earthquake shaking which could result from events occurring along the major seismic sources. These studies have led to the following preliminary conclusions:

WATANA DAM SITE

Four major lineaments were originally identified as being possible faults in the vicinity of the dam:

(1) The Talkeetna Thrust Fault
(2) The Fins Feature
(3) The Susitna Feature
(4) The Watana River Feature

Field geologic studies during the past several months have developed evidence indicating that:

(1) The Talkeetna Thrust Fault is not an active fault.
(2) The Watana River Feature is not a fault.
(3) The Susitna Feature is not a fault.
and (4) The Fins Feature may well be a fault but it is relatively short in length and, since there are apparently no other active faults in the area, it is very unlikely that it could be active. In any case its length would preclude the possibility of it being the source of a significant earthquake.

In consequence, there are apparently no active faults crossing the site and the major sources of earthquake shaking at the site may be attributed to earthquakes occurring on the Benioff Zone underlying the site at depth, the Denali fault, the Castle Mountain Fault, and smaller local earthquakes occurring with no apparent surface expression in the crust of the Talkeetna terrain. Considerations of fault distances and possible earthquake magnitudes leads to the conclusion that the approximate maximum levels of shaking from the different sources will be as follows:

Source	Closest Distance	Magnitude (Ms)	Peak Acc. (Mean)
Benioff Zone	≃ 63 km	≃ 8½	≃ 0.35g
Benioff Zone	≃ 48 km	≃ 7½	≃ 0.32g
Denali Fault	≃ 70 km	≃ 8+	≃ 0.22g
Local Event	*	*	*

* Information to be provided in Final WCC Report

Seismic geology considerations have led Woodward-Clyde Consultants to suggest that the maximum local earthquake which needs to be considered is a Magnitude 5½ to 6 event occurring at a distance of about 10 km from the site. Such an event would produce a peak acceleration (mean value) of about 0.35g and would therefore not be a controlling event. However, the Panel believes that in view of the past seismic history and other considerations it would probably be prudent to consider the possibility of a somewhat larger event at a slightly shorter distance. In this case the local earthquake would be responsible for the maximum accelerations likely to develop at the dam site. This does not mean however, that it will necessarily control the design.

For the Benioff Zone event, which seems to be controlling at this stage, the motions recommended by Woodward-Clyde Consultants for preliminary design evaluations appear to be entirely appropriate.

DEVIL CANYON SITE

At the end of 1980, nine lineaments were identified in the vicinity of the Devil Canyon site which could possibly be active faults. Field geologic studies during the past 6 months have led to the conclusion that only 3 of these

features are faults, that the three features recognized as faults are inactive, and that in any case they are so short in length that they could not generate earthquakes which would be controlling events with regard to earthquake motions at the dam site. Thus since there are no active faults in the vicinity of the dam site, the design earthquake motions will be determined by similar considerations to those applicable for the Watana site. The Panel agrees with these conclusions.

Consideration of the most significant seismic sources of ground shaking leads to the following:

Source	Closest Distance	Magnitude (Ms)	Peak Acc. (Mean)
Benioff Zone	≃ 90 km	≃ 8½	≃ 0.3g
Benioff Zone	≃ 58 km	≃ 7½	≃ 0.3g
Denali Fault	≃ 64 km	≃ 8+	≃ 0.24g
Local Event	*	*	*

As for the Watana site, there is a need to establish very soon the significant characteristics of the local earthquake (in the crust of the Talkeetna Terrain) in order to finalize the seismic criteria to be used for project design.

* To be provided in Final WCC Report

In light of the information presented at this meeting and on the basis of past experience, the Panel believes that through the use of appropriate design and construction procedures, dams with ample margins of seismic safety can be constructed at both sites. The Panel believes, however, that the question of seismic effects due to local crustal earthquakes should be resolved in the next few weeks so that more definitive design studies can be completed.

ROCK ENGINEERING CONSIDERATIONS

As a result of discussions during this meeting as well as observations made in the field by Panel member Merritt during the period of 23-25 September, we have the following comments regarding present designs.

WATANA

Every effort should be made to reduce the height of the cut slope at the inlet to the diversion tunnel. The structures can probably be moved closer to the river and perhaps shifted slightly in a downstream direction.

The surface excavation at the outlets of the tailrace tunnels and spillway structures is likewise very extensive. Further detailed examination is warranted to minimize possible slope stability problems.

* To be provided in Final WCC Report

Recent borings in the proposed underground powerhouse site encountered a zone of soft hydrothermally altered diorite. This is not acceptable material to have in a major underground excavation. Some shifting of these openings is required. Considering all borings made in the right abutment, the general quality of the diorite is quite high and we foresee that acceptable rock can be found for the proposed structures.

DEVIL CANYON

The graywacke and argillite at this site appear to be of acceptable quality for the proposed underground structures. No major shear zones have been recognized in these areas. The underground openings have been oriented with respect to the major known joint systems and bedding planes. The present layout is acceptable and it is recognized that some slight shift could result based upon the results of future exploration.

The axis of the proposed surface spillway on the right abutment will nearly parallel the strike of the bedding of the rock. The required cuts will daylight the bedding which dips at about 50 degrees into the excavation. Potential

major rock stability problems could result which might not be solved by simple rock bolting measures. This design likewise requires your review.

BURIED CHANNEL

The results of all geophysical surveys completed to date have defined a major channel beneath the plateau on the right abutment at the Watana site. The channel is approximately 15,000 ft wide when measured with respect to that portion of the bedrock channel below the proposed reservoir pool level. The deepest portion of the channel lies about 450 ft below pool level; however, perhaps as much as 60-70% of the channel lies 100 ft or less below maximum pool level.

The borings completed during the Corps of Engineers study indicated that the channel is filled with glacial till, outwash, and perhaps lacustrine deposits. The boring logs show that boulders (some as large as 12 ft) can be expected in these heterogeneous deposits, either as individual units or as thick layers. Contour maps made of the bedrock surface suggest a wide entrance channel or channels upstream of the damsite and a relatively narrow exit into Tsusena Creek downstream of the damsite.

The buried channel on the north slope of the reservoir at Watana Dam is much greater in extent than was anticipated a year ago and represents one of the greatest uncertainties associated with the Watana Dam project. Major problems posed by the presence and extent of this channel are

(1) The magnitude of possible seepage losses through the channel.
(2) The possibility of piping within the channel resulting from seepage from the reservoir towards Tsusena Creek.
(3) The possibility of seismic instability in the soils comprising the buried channel under strong earthquake shaking.

It appears that problems (1) and (2) above could be eliminated by construction of a cut-off wall and grout curtain through the soils filling the channel. However, the provision of such a cut-off would not solve any problems of seismic instability on the upstream side of the wall.

Since very little information is available concerning the nature of the soils forming the channel fill it is not possible to assess the magnitude of the seismic instability problem, if indeed it exists at all, or the need for an extensive cut-off wall, currently projected to be about 15,000 feet long and varying from a few feet to 450 feet in depth. However, it is clear that both the possibility of

seismic instability and the cost of a cut-off would be dramatically reduced if the reservoir level were about 100 feet lower than currently planned. Such a lowering could reduce the length of the cut-off to about 4,000 feet, facilitate its construction, and by lowering the water table in the soils, increase their seismic stability. In view of these advantages, together with the fact that economic advantages associated with the top 50 to 80 feet of Watana Dam do not appear to be very great, the Panel believes that careful consideration should be given to the potential benefits of reducing the height of Watana Dam by 50 to 100 feet. Such a reduced height might also facilitate layout problems for the dam.

The Panel cannot be sure that a reduction in dam height would be advantageous but believes that a careful study of the question is warranted in the next several months.

WATANA DAM EMBANKMENT

The Panel believes that the preliminary design section selected for Watana Dam is satisfactory and will produce a stable and economical structure. It is suggested however, that consideration be given to the following items:

(1) If the shells are constructed of densely compacted gravel or rockfill and the core of a much more compressible sandy-silty-clay, there is a danger of deleterious stress redistribution due to differential settlements. Consideration should be given to minimizing this possiblity by:

(a) inclining the core slightly upstream, providing this can be done without jeopardizing stability.

and/or (b) locating a relatively incompressible core material which is adequately impervious. Such a material appears to be available as a GC material in one of the borrow areas.

(2) Deformations of the upstream shell of the dam due to strong earthquake shaking can be minimized either by densifying the shell material to such extent that high pore pressures cannot develop or by using highly pervious rock-fill which will dissipate any pore pressures resulting from earthquake shaking almost as rapidly as they develop. Consideration should be given to using gravel-fill and rock-fill in the upstream shell in such a way as to optimize their use from a seismic design point of view.

(3) There is apparently ice in the rock joints in the abutments at Watana Dam site and this will have to be thawed before grouting. It would be desirable to determine whether construction costs have allowed for this.

(4) It appears that there may well be permafrost in the foundation soils for the saddle-dam. When this melts it could leave the soils in a very loose condition which may be adequate for static stability but inadequate for seismic stability. It would be desirable to explore this possibility further and examine the need for excavation of frozen foundation soils prior to saddle-dam or dike construction.

DEVIL CANYON DAM

Sufficient study has been completed to adequately support the present arch dam design for feasibility purposes. However, the linear feature through the pond areas where the wing dam will be located should be further explored in the near future. Similar considerations to those discussed for the Watana Site should be given to the foundation soils under the Devil Canyon wing dam.

WATANA DAM DIVERSION TUNNELS

Two diversion tunnels are proposed for diverting up to a 1 in 5-year flood during construction of Watana Dam. One tunnel would be located at a low level so that it would flow full at all times. The second tunnel, located at a higher level, would have free flow. After diversion the lower tunnel would be plugged. Two plugs would be constructed in the upper tunnel with gated outlets through them to permit release of low flows until Devil Canyon is completed and serve to lower the reservoir in case of an emergency. The Panel concurs in the general concept of the diversion tunnels and modification of the high level tunnel for use as a low-flow and emergency release outlet, subject to refinements discussed by Acres.

WATANA DAM SPILLWAYS

Spillway flows at Watana Dam would be handled by three separate flow release structures. Discharges corresponding up to a 1 in 100-year flood would be released through a low-level tunnel controlled by three or more Howell-Bunger or similar valves located at the downstream end of the tunnel. Discharges corresponding to floods in excess of 1 in 100-years and up to 1 in 10,000-years would flow through an open chute spillway with a flip bucket. Discharges in excess of the 1 in 10,000-year flood up to the PMF would pass through a bypass channel controlled by a fuse plug.

The Panel concurs in the proposed concept of handling spillway flows. Release of floods up to 1 in 100-years by low level valves would maintain the nitrogen supersaturation level to an acceptable limit. The Panel suggests that fixed cone valves as installed by the Corps of Engineers at New Melones Dam be used, since their greater rigidity makes them more suitable for high-head operation. The smaller chute spillway flows would reduce erosion in the downstream river channel. Hydraulic model tests will be required to determine the extent of material that should be pre-excavated in the plunge pool area. In view of the infrequency and short duration of spillway operation and the relatively high quality of rock in the steep river banks, the Panel is of the opinion that excessive erosion would not occur due to service spillway operation. With respect to the emergency spillway bypass channel, the Panel is concerned over the 45-ft height of the fuse plug. This high plug would need to be designed as a small earth dam to retain the power pool at maximum levels and also be capable of failure as a fuse plug when it is overtopped. It is suggested that the entrance to the bypass channel be widened, thereby requiring a smaller height of fuse plug. This would also reduce the amount of reservoir lowering in the event of fuse plug failure.

DEVIL CANYON DIVERSION TUNNEL

One diversion tunnel is proposed for Devil Canyon Dam to divert flows up to a 1 in 50-year flood during dam construction. The tunnel would be plugged after it is no longer needed for diversion. The Panel suggests that this tunnel could be used for spillway flow releases in an alternative spillway design discussed hereinafter.

DEVIL CANYON SPILLWAYS

As for Watana Dam, spillway flows at Devil Canyon would be handled by three separate flow release structures. Flows up to the 1 in 100-year flood would be released by four or five outlets through the base of the concrete arch dam controlled by Howell-Bunger or other type high pressure valves. Discharges in excess of 1 in 100-years and up to 1 in 10,000-years would flow through an open chute spillway with a high level flip bucket. Discharges in excess of the 1 in 10,000-year flood up to the PMF would pass through a bypass channel controlled by a fuse plug.

The Panel concurs in the concept of handling the spillway flows subject to the question raised below. Release of small flows through valves at the base of the dam will prevent excessive nitrogen supersaturation in the downstream river channel, as well as reduce discharges and flow frequency and duration in the chute/flip bucket spillway, thereby reducing plunge pool erosion. Based on a ground and

air inspection of the river channel at the Devil Canyon Site by Panel member Douma and Acres representatives on September 17, 1981, the Panel is of the opinion that the very high quality rock in the canyon walls should not experience excessive erosion due to spillway operation. In this case, pre-excavation of streambed material and weathered rock is probably not required. The Panel is concerned, however, over the deep sidehill rock cut required for construction of the spillway chute. It suggests that consideration be given to providing spillway tunnels, as required, instead of the chute spillway. In this alternate plan, the diversion tunnel and probably only one additional tunnel would be required. With respect to the emergency bypass channel spillway, the Panel is concerned over the 57-foot high fuse plug for the reasons stated for the Watana fuse plug. Consideration should be given to increasing the length and reducing the height of this fuse plug as described for Watana.

DEVIL CANYON POWERHOUSE TAILRACE

The Panel concurs in extending the tailrace for the Devil Canyon powerhouse about 1¼ mile to take advantage of the additional approximately 30 feet of head.

CLOSING REMARKS

The Panel requests that the topics raised in this report be thoroughly discussed in the next External Review Board Meeing tentatively scheduled for the week of January 11, 1982 in Anchorage.

The Panel greatly appreciates the many courtesies extended to it by the staff of the Alaska Power Authority and the staff of Acres American, Inc.

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