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SUSITNA HYDROELECTRIC PROJECT

EXTERNAL REVIEW BOARD
MEETING #3

[redacted]

REPORT

OCTOBER 6 - 8, 1981

Prepared by:

ACRES

ALASKA POWER AUTHORITY

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SUSITNA HYDROELECTRIC PROJECT

EXTERNAL REVIEW BOARD

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ALASKA POWER AUTHORITY

October 30, 1981
P5700.13

SUSITNA HYDROELECTRIC PROJECT
External Review Board Meeting No. #3

MINUTES OF MEETING HELD ON
October 6 - 8, 1981, AT OFFICES OF
ACRES AMERICAN INCORPORATED, BUFFALO, NEW YORK

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AGENDA

OCTOBER 6 - Moderator: D. Wozniak

08:30 - Introductory remarks - E. Yould

08:45 - Meeting objectives and study status - J. Lawrence

09:15 - Report on seismic studies - J. Lovegreen

10:15 - Coffee

10:30 - Discussion

11:30 - Report on geotechnical field program - J. Gill

12:00 - Lunch (brought in)

13:00 - Geotechnical interpretation: Watana - S. Thompson
(Geology, borrow area investigations, bed rock conditions, underground structures, relict channel investigations)

13:45 - Discussion

14:15 - Geotechnical interpretation: Devil Canyon - S. Thompson
(Geology, borrow area investigation, bedrock conditions, underground structures)

15:00 - Coffee

15:15 - Discussion

15:45 - Earthfill dams - D. W. Lamb
(Embankment/cofferdam designs, construction materials, foundation treatment, relict channel treatment)

16:45 - Discussion

17:15 - Adjourn

18:30 - Dinner - courtesy of Acres (M&T Plaza Suite, Jim Gill to organize "how to get there" from the Hilton)

AGENDA (Cont'd)

OCTOBER 7 - Moderator: J. Gill

08:30 - Introductory remarks - J. Lawrence

08:45 - Report on hydrologic field program - J. Hayden

09:15 - Report on hydraulic studies - J. Hayden
(Power/energy estimates, flood estimates)

10:00 - Coffee

10:15 - Report on hydraulic studies (cont'd) - J. Hayden
(Reservoir level optimization, sedimentation studies)

11:15 - Discussion

12:00 - Lunch (brought in)

13:00 - Watana spillway studies - J. Hayden

13:45 - Watana layout studies - J. Lawrence

14:30 - Discussion

15:00 - Coffee

15:15 - Watana/Devil Canyon diversion/low level outlets - R. Ibbotson

15:45 - Watana/Devil Canyon power developments - J. Hayden

16:15 - Discussion

17:15 - Adjourn

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AGENDA (Cont'd)

OCTOBER 8 - Moderator: D. Wozniak

08:30 - Introductory remarks - J. Lawrence

08:45 - Devil Canyon dam design - R. Ibbotson

09:30 - Discussion

10:00 - Coffee

10:15 - Devil Canyon spillway studies - J. Hayden

10:45 - Devil Canyon layout studies - J. Lawrence

11:30 - Discussion

12:00 - Lunch (as required)

Afternoon for panel to prepare report

16:30 - Closing statements: E. Yould/panel

LIST OF ATTENDEES

Alaska Power Authority

E. P. Yould - Executive Director
R. A. Mohn - Director of Engineering
D. D. Wozniak - Project Manager

APA External Review Panel

M. Copen
Dr. J. Douma
Dr. A. Merritt
Dr. H. Seed

Acres External Panel Members

Dr. A. Hendron
Dr. L. Sykes

Acres

E. Eichenbaum)
Dr. D. H. MacDonald) Internal Review Panel
J. G. S. Thomson)

J. D. Lawrence)
Dr. J. W. Hayden)
J. D. Gill)
S. N. Thompson) Participants
D. W. Lamb)
V. Singh)
R. K. Ibbotson)

M. F. Dumont/D. Peck - Recorders

D. C. Willett)
M. R. Vanderburgh)
G. Krishnan) Observers
K. Young)

Woodward-Clyde Consultants

J. Lovegreen

ALASKA POWER AUTHORITY

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SUSITNA HYDROELECTRIC PROJECT
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MINUTES OF MEETING HELD ON
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REPORT OF MEETING

October 6, 1981

General

Dr. Seed and Dr. Hendron were delayed. J. Lawrence proposed that the Agenda be adjusted accordingly; Geotechnical Field Program and Geotechnical Interpretation brought forward, and Seismic Studies Report postponed until later this morning.

1. Introductory Remarks (E. Yould; Executive Director, APA)

   - Would be primarily a technical session.
   - APA board has been reconstituted.
   - Other studies are in hand to assess the viable alternatives to Susitna:

     (i) Tidal power at Cook Inlet - studies by Acres.

     (ii) Chakachamna - studies by Bechtel.

     (iii) Battelle/Ebasco - energy requirements and demand growth studies in the Railbelt area.

     (iv) Long-term planning of potential industrial expansion in the state.

   - All results of the studies will be available to the legislature by April 1982 for a final decision on FERC application.

   - $5 billion commitment for state development has already been approved under the "Energy Program for Alaska" legislation.

   - At the federal level, negotiation is underway to accelerate the FERC licensing procedure for the Susitna application.

2. Meeting Objectives and Study Status (J. D. Lawrence)

   - five major objectives:
     (i) Status report
     (ii) Review field studies
     (iii) Review proposed layouts
     (iv) Address previous Board comments
     (v) Study completion requirements

   2.1 Status of Study

   - Power Studies: Acres study is complete; results of Battelle forecasts will be incorporated in the Feasibility Report.

   - Camp/access: Survey and report completed. Meeting with APA later this month to consider the recommended access route.

- Environmental	Studies continue - to be discussed with APA on Friday, October 9.
- Transmission	Corridor Selection Report has been issued.
- Cost Estimates	To be issued to Ebasco for independent assessment.
- Licensing	Will be filed in accordance with new Regulations.
- Marketing/Finance/ Risk	This work has been on hold. To be discussed with APA next week (12-16 October).
- Public Participation	PPO work continues, monthly news letters.

2.2 <u>Field Studies</u> — To be detailed at this meeting.

2.3 <u>Proposed Layouts</u> — To be detailed at this meeting.

2.4 <u>Previous Board Comments:</u>

- 10 comments were listed. These will be dealt with during the course of this meeting.

2.5 <u>Completion Requirements</u>

- Cost estimates will be given to Battelle by end October 1981.
- Preliminary costs for preferred developments will be available to Ebasco by end of October (Devil Canyon), November (Watana).
- Geotechnical Report (1981 Studies) by February 1982.
- Feasibility Report — First Draft by 15 February 1982. Final Draft by 15 March 1982.
- License Documents — By May 1982.

3. <u>Geotechnical Field Work</u> (J. Gill)

3.1 <u>Watana</u>

- Previous investigations were summarized, (USBR & Corps of Engineers, 1950-1978,); a total of 28 boreholes, 18 auger holes and 27 test pits, plus extensive seismic refraction survey (in excess of 70,000 linear feet).
- Acres 1980 investigations: 3 boreholes and 21 auger holes. Seismic survey extended in the dam abutments and the relict channel area. Also in the river alluvium to assess its depth (60 to 70 feet near the dam axis).

- Acres 1981 investigations: 4 boreholes and 18 auger holes, plus 21 test pits to assess the material available from the borrow areas. Two of the boreholes (BH3 and BH4) were drilled at the powerhouse location on the north abutment. Seismic refraction survey extended farther (38,200 feet).

- Relatively deep permafrost in the south abutment (170 feet in BH8). Also in the low-lying area to the south.

3.2 Devil Canyon

- Previous investigations were summarized: 22 boreholes, 19 trenches and test pits, 1,300 linear feet seismic lines.

- Acres 1980 and 1981 investigations: 7 boreholes, 8 auger holes, 6 test pits, 1,600 linear feet seismic refraction lines.

- 1980 - BH1 and BH2 on the north abutment, and BH4 drilled across the pond areas to locate the suspected shear zone; not found.

- 1981 - BH7 did locate the pond shear feature; BH3 drilled through open shear features; two further holes at the river and the north abutment.

4. Geotechnical Interpretation (S. Thompson)

4.1 Watana

- Fins structure is not a single feature, but a series of ribbed shear zones. The diversion portal should be downstream from the Fins.

- Major dam foundation is a granodiorite, overlain by andesite. The contact has been mapped.

- Downstream Fingerbuster structure is more complex, not a single direction but multidirectional; mainly N-S and at 300°.

- Hydrothermally altered zone of weak rock also exists, running NE-SW.

- Some weathering of the contact between the andesite and the diorite (1-2 feet); no deep zones. Fracturing goes through both rocks, but the hydrothermal alteration is in the diorite only. The contact zone is well healed, conformable, and extrusive.

- Many slide blocks in the Fingerbuster area.

- Some felsic dykes, but these are not a significant problem.

- Boreholes BH3 and BH4 were drilled into the present powerhouse location; an altered zone was detected, which may require minor adjustment of the powerhouse position. The altered zone cannot be identified with any surface feature.

- Rock quality is generally good; RQD values increase with depth.

Borrow Areas

- A: quarry in andesite for rockfill.
- D: impervious fill.
- E: filter material and concrete aggregates.
- H: alternative to D, farther downstream.

- general discussion on materials; core material from area D has low plasticity; core material from area H would be preferable despite the longer haul distance.

Relict Channel

- 1981 survey limited to seismic refraction survey to assess the extent of the problem. Becker drill rig not used because of budget limitations.

- Now known to extend to a maximum of 450 feet in depth, with an overall length approaching 15,000 linear feet at present full reservoir level (2,215).

- Only information on material at depth is from Corps of Engineers' boreholes, which indicate wide diversity of alluvial deposits, ranging from cobbles and boulders through to gravels, sands, and lacustrine clays. No data on permeability are available.

- Serious problem for potential seepage loss and possible piping failure unless preventive measures are adopted. Acres has allowed for the construction of a continuous cut-off trench in the feasibility design.

- Further field investigations are planned for the next phase (1983/1984).

- No advantage in moving the damsite upstream.

- E. Yould (APA) expressed concern at the possible serious impact on licensing, despite the assurance that feasibility would not be affected.

4.2 Devil Canyon

- Predominant rock is an argillite; the strike of the bedding plane is parallel to the river.

- Felsic dykes run N-S, interspersed with other shear zones.

- USBR drill logs were correlated with the 13 series holes to assess a potential linear shear zone along the river on the north abutment.

- COE holes were relogged also - "gouge" confirmed the linear shear zone in the river which is not as significant as the known shear zone through the ponds area. Thought to be an extension of the N-S shears across the river. May require local treatment during construction.

- The Argillite at the site is a good quality rock; RQD values good to excellent from 100 feet down.

- Tension relief fractures are evident on the south abutment; cost will be allowed for these during construction, but feasibility will not be affected.

- Any evidence of a buried channel on the northside? Nothing found to indicate this, although there is deep alluvium on the ponds shear feature.

5. Report on Seismic Studies (J. Lovegreen, WCC)

- A brief summary of Task 4 objectives was given.

- Known major earthquake sources in the area are the active crustal faults to the north and south, and the Benioff zone beneath the surface.

- Total of 200 known faults and lineaments were studied and assessed for potential seismic activity; a screening model reduced these to 13 features requiring further study - 4 at Watana, 9 at Devil Canyon.

- Summary of methodology for assessing seismic geology was given, together with the methods used - these included:

  geology
  field mapping
  magnetic and seismic refraction surveys
  discussions with other research groups
  remote sensing imagery
  aerial and low-sun-angle photography

- Approach: What is likelihood of a fault?
  Age and distribution of quaternary units.
  Identify most fault-like scarp.
  Trench the scarp.
  Any detectable earthquake within 100,000 YBP?
  Judgment and experience with other active faults.
  What is the likelihood it is an active fault?

- Quaternary dates were confirmed by C_{14} dating, oxidation, and weathering depth.

5.1 Watana

Talkeetna Thrust Fault

- To the north, a 5-foot tertiary displacement was located in coal deposits, dated at 20 million YBP, close to the Denali fault.

- At Watana Creek some evidence of no activity in 10-20 million YBP, based on folding.

- In the Susitna River, iron-stain deposits show no tectonic movement across the fault, only small-scale slumping.

- The most significant feature was trenched 15 km from the river; fluvial gravels (20,000-40,000 years old), with no evidence of fault movement. Resolution down to 1 cm.

- Talkeetna Hill; the fault is vertical. No evidence of a fault scarp or movement expressed in the morphology.

- In summary, the fault is considered to be inactive.

- (Dr. Seed) If the fault were active, what magnitude of earthquake would be anticipated? J. Lovegreen would not comment on this question, since it was judged not to be an active fault.

Susitna Feature

- Evidence for the fault: to the north, Turner & Smith's work on age dating of fault material and differential cooling rates; middle area, some mapping by Turner; seismic activity in the lower area (magnitude 5-5.2).

- Rock outcrop mapping does not agree with the "fault" alignment.

- Magnetic tracelines give no evidence of a fault.

- No evidence of tectonic movement along the fault in Tsusena Creek.

- Trench excavation across the most likely surface feature, determined by low-sun-angle photography, showed glacial origin. No evidence of fault movement.

- Joint orientation studies? No hard evidence.

- Seismicity? Strike-slip and crust faulting suggested by Gadney & Schapiro at a peak distance of 80 km. Benioff zone is only 50 km--this evidence appears to be incorrect.

- Conclusion: no surficial evidence for activity of the Susitna feature within the last 10,000 years.

River Feature (KD37)

- No evidence of morphology of a structural feature, either upstream or downstream.

Fins Feature

- This is a fault, but not considered an active fault, in view of its length (about 2 km).

5.2 Devil Canyon

- Of the 13 features considered, only 3 are faults: KC55, KD5'2, and KD5'43; the rest are lineaments.

- There is no evidence of fault activity within the last 40,000 years; dyke feature shows a complete outcrop across the fault line; also confirmed by terrace deposits.

5.3 Seismic Geology

- Magnitude of anticipated maximum earthquakes:

Castle Mountain	7.5
Denali	8 to 8+
Benioff	8+
Talkeetna Terrain	5.75+

5.4 Seismology

- A new model has been developed for the Benioff zone activity; this indicates maximum intensities up to 8.5 on the interplate zone, and up to 7.5 on the intraplate zone, with a transition between.

- Could the 1943 earthquake (7.3) have originated on an extension to the Talkeetna Thrust Fault? This is outside the area of the present WCC study. Thought that this earthquake originated in the Denali or Castle Mountain faults, but an extended study program would be required to consider this. Did the Review Board consider that a further study would be necessary?

- Floating Terrain earthquake? WCC considers an earthquake magnitude 5.5-6.0 would give noticeable surficial expression within 10 km. This is based on Alaskan and worldwide data source.

- What magnitude earthquake could occur just below the damsite? 5.5-6.0, with a focal depth of about 10 km.

- All 5.0-5.5 considered had active faults associated with them.

- General discussion on the anticipated magnitude of the floating terrain earthquake followed. Ground acceleration corresponding to 5.5-6.0 would be 0.35g. Dr. Seed considered that the magnitude selected would not affect feasibility, only the extent of dam material compaction and, hence, costs.

- General consensus was more than 5.75, say 6.25-6.50. Decision on magnitude would be made outside the present meeting after further studies and consultation.

- Reservoir induced seismicity: from a worldwide study all reported instances were related to active faults; hence, RIS impacts are expected to be minimal.

6. Earthfill Dams (D. W. Lamb)

6.1 Materials

- Core	(D, H)	factor of 10 on required volume
- Fillers	(E)	factor of 8-10
- Rockfill	(A)	factor of 5 (within 11 miles)

- Grading curves for material D were shown: 20-30 percent passing 200.

- Optimum moisture content 6-7 percent. Permeability 10^{-5} cm/s.

- Material is on the wetter side of optimum and drainage will be necessary.

- Higher compaction will reduce OMC and accentuate the problem.

- Area E material will be separated into two materials for fine and coarse filters; many cobbles must be removed.

- Area H is a core alternative source, with good grading and higher plasticity.

- General: ice content may be a construction problem for handling and compaction.

- (Dr. Seed) Core material selection: should avoid differential compressibility in the core, which causes arching action between the shells.

- Devil Canyon: a problem with the Saddle dam. No core material is available. It must either be transported from Watana or material available at site will be treated with bentonite.

6.2 Relict Channel Treatment

- Hydraulic gradient is 1 in 10 along the shortest route (6,200 feet).

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6.2 Relict Channel Treatment

- Hydraulic gradient is 1 in 10 along the shortest route (6,200 feet).

- Saddle dam is required, 2,300 feet long and up to 40 feet deep.

- Material in the channel is a diverse mixture of sands, gravels, boulders, and lacustrine clays with unknown permeabilities.

- An assessment of seepage loss using an average value of 10^{-2} cm/s gave an annual energy loss of 23 GWh, worth about $23 million capitalized. There is also the danger of piping at the downstream exit.

- Alternative solutions were considered: upstream blanket treatment would cost $100 million, but these are notorious for not being effective: downstream filter would control the seepage loss but not prevent it: continuous grout/slurry cutoff trench would prevent seepage loss at an estimated cost of $50 million.

- Length of cutoff trench about 15,000 feet, depth up to 450 feet.

- All available data is based on Corps of Engineers' boreholes, drilled to rock: no material samples were taken.

- Do-nothing option is not acceptable; Acres considers continuous cutoff trench to be best solution at feasibility stage.

- More investigations along cutoff wall possible during feasibility study? Would cost $500,000 - $700,000 for a Becker drill rig to provide large bulk samples. Schedule? If decision November 1, February 1, 1982, onsite, offsite in 2 months.

- It was suggested that both cutoff wall and downstream filter should be included for FERC license application.

6.3 Dam Design

- Shell is currently assumed to be river gravel, not rockfill, using material properties from Oroville dam. Preliminary results indicate up to 100 percent p.w.p. buildup. Upstream drainage will be provided to dissipate excessive p.w.p. Gravel properties not known in detail but control of placing will govern permeability.

- Rockfill may be used if it proves to be safer, or a combination of the two.

- Slopes being analyzed are 2.25:1 upstream, 2.0:1 downstream.

- Layouts are being based on 2.4:1 upstream.

- Core width is 50 percent of head; filters 60-80 feet at base of dam.

- 10 feet excavation in rock everywhere, increasing to 40-50 feet under the core.

- Allowance is being made for static and seismic settlements.

- Devil Canyon Saddle dam: assumed same design and slopes as Watana.

- (Panel Comments) core material from area D has SM gradings: possibility of piping, since it is not plastic. Design totally reliant on the filters to prevent piping. Material from area H is a better option and would have fewer problems in placing.

October 7, 1981

1. Introductory Remarks (J. D. Lawrence)

   - Dr. Sykes and Dr. Hendron will not be attending the final day (10/8/81) and will be reporting to Acres separately.

   - (Panel Comment) Are permafrost and ice lenses found in the abutments at Watana? Yes, mainly in the left abutment. How does this affect the foundation treatment? Ice would be thawed prior to grouting and foundation treatment. Have costs been allowed for? Yes. Will river alluvium be removed? Yes.

2. Hydrologic Field Program (J. Hayden)

   2.1 Data Sources

   - Basin data up to Talkeetna.

   - Gold Creek has 30 years of records, other stations have usually a minimum of 10 years.

   - Work carried out under two main headings:

     (i) Regional Flood Studies - R&M.
     (ii) Long-term, average monthly flows and daily flows for energy predictions - Acres.

   - A fill-in program was used to formulate stochastic 30-year flows at other stations of interest; e.g., Vee Canyon where only 10 years of records were available.

   - Long-term flows at Watana and Devil Canyon were then derived, based primarily on area--secondary effects were precipitation, snow melt, and topography.

   2.2 Flood Studies

   - R&M flood studies were based on other basins in Alaska with similar characteristics. The results were incorporated with the Gold Creek results for 30 years of records to derive flood flows at Devil Canyon and Watana for various return periods.

- There are two flood peaks per year; a snowmelt flood in June, and a less severe glacial melt/precipitation flood in August. Control structures needed for the summer flood only.

- Watana floods were presented: the PMF is now 315,000 cfs, compared with Corps value of 230,000 cfs. The increase is caused by a revised PMP from the NWS, sharper temperature rise, etc. Work was done by Acres and will be incorporated in the Feasibility Report.

- Devil Canyon floods were also presented (based on Watana being constructed).

2.3 Water Quality

- Recording stations were summarized.

- Will there be degradation of the downstream channel? No, it is already sufficiently armored.

- Temperature and river-level modeling studies continue.

- Sediment entrapment is about 100 percent.

- Bedload is less than 5 percent of the suspended sediment load; the total annual load figure is similar to the Corps value. Load duration curves shown for the major rivers; Chulitna and Susitna about the same, Talkeetna much less.

2.4 Ongoing Work

- Site flows continue to be recorded; these are used to confirm the "fill-in" program (v.s.).

- HEC program has been calibrated for use in predicting river levels.

- River morphology report is now available.

- Ice modeling is completed.

- Temperature modeling has been revised to allow for surficial heat loss, but still indicates extensive open water downstream from Devil Canyon.

- Fisheries now want extensive water releases in summer, up to 18,000 cfs. For power releases only, the releases are in excess of 9,000 cfs for 17 out of 30 years. Some compromise will be possible after negotiation with the Fisheries Mitigation Task Force. Reservoir operation may also need to be modified.

- Water temperature? A multi-level intake is being designed at Watana to maintain water temperature as close to normal regime as possible. Releases from Devil Canyon will be sensibly at a constant temperature of 39°F.

3. Energy Simulation (J. Hayden)

- Energy output from the model is assumed to match the shape of the demand curves. Peak load is in December; peak flows are in summer; seasonal storage is used to maximize firm energy.

- Watana reservoir provides almost total regulation.

- Critical dry periods? For a single dry year, the return period is about 1 in 100 years; for 2 consecutive dry years, the return period is about 1 in 400 years.

- Constraint is externally applied that the reservoir should be full at the end of the 30 years of hydrological record.

- With both Watana and Devil Canyon constructed, the total energy demand can be met with no thermal backup from 2,000 to 2,003 (medium load growth forecast.)

- Further extension of the tailrace tunnel at Devil Canyon has been found to be cost-effective. The net head is increased by about 30 feet and annual firm energy is increased by about 100 GWh.

- Post-project flows from Devil Canyon vary from 6,000 to 10,000 cfs because it is operated as a base load station; peaking only at Watana.

- (Panel comment) What are temperature and flow impacts on the salmon? Temperature effects concern the incubation of the eggs, predation, and thermal shock. Flow impacts concern the possible isolation of spawning salmon in minor tributaries, owing to low power releases in critical months.

4. Reservoir Level Optimization (J. Hayden)

- Firm energy can be increased by two methods:

  (a) increased dam height; and
  (b) increased drawdown.

- (a) Firm energy variation with dam height: the flow is 98 percent regulated; hence, a linear variation of firm energy with dam height. Dam height was optimized using incremental costs compared with incremental system costs from OGP5 runs. The curve is very flat, and any level between 2,175 to 2,215 would be acceptable. Upper limit of about 2,240 determined by flooding limitation upstream at Fog Creek.

- Results will be checked later using the Batelle load growth forecast, escalation rates, coal values and so on.

- Devil Canyon reservoir level is fixed at Watana tailwater level, 1,455, to fully utilize the available head.

- (b) Firm energy increases with drawdown up to 190 feet. Above this level there is little or no improvement because of low head energy loss in the dry years. The maximum drawdown (190 feet) is cost-effective; i.e., the capitalized extra firm energy value exceeds the increased cost of intake works and approach channel.

5. System Model Studies (John Hayden)

- Economic parameters have been used (0 percent inflation, 3 percent discount rate.) The OGP5 model incorporates all existing and planned power developments in the Railbelt Area, and allows for annual costs of fuel, operation and maintenance, and financing charges.

- Watana is assumed to come on-line in the fall of 1993; Devil Canyon on-line in the year 2000. The Intertie is allowed for by increasing the system load factor from 0.52 (present) to 0.62.

- Sensitivity analysis has been carried out on discount rates, fuel costs, rate of load growth, etc.

- "Devil Canyon first" option was also considered, with suitable adjustment of costs (access road, extra cost of spillway facilities). Slightly in favor of "Watana first" but not a lot.

- (APA comment) Could Devil Canyon be brought on line earlier, if required, for a major industrial expansion program? This would be addressed in the Feasibility Report. Could be justified only by a significant increase in demand; would have significant impact on manpower and other key resources in Alaska.

- Reservoir levels: the June flood is absorbed, but the August flood causes some spilling.

- Filling: time taken is dependent on inflows and compensation flow downstream. Freeboard will be maintained sufficiently to absorb the 1-in-500-year flood during filling.

- (Panel comment) Regarding the optimum dam height, can the cost of the dyke/saddle dam be justified? A 25-foot dyke constructed on 25 feet permafrost could suffer slumping failure under earthquake shaking. Design of the dyke should be carefully considered, particularly the cutoff wall below the dyke. Earthquake and permafrost conditions are the major design concerns for foundations in Alaska.

6. Installed Capacity (J. Hayden)

- Assessed by estimating the peak load on Susitna, knowing the peak demand, and the available system energy from alternative sources. Susitna used at peak (Watana) or base (Devil Canyon).

- Using the medium load forecast, the peak load on Watana increases from 567 MW (1993) to 626 MW (2000).

- Peak load on (Watana + Devil Canyon) increases from 1,029 MW (2000) to 1,119 MW (2010), again using the medium load forecast.

- By extension of the method beyond 2010, the Susitna demand would increase to about 1,600 MW by the year 2040.

- From these studies the following capacities have been selected for overall development:

Watana	900 MW	(6 x 150 MW)
Devil Canyon	600 MW	(4 x 150 MW)

- Surface powerhouse or underground? Costs favor the underground powerhouse, basically because of increased cost of penstocks with a surface powerhouse.

- Number of units installed? Minimum requirement at Watana is 4 units; 6 units give greater flexibility of operation, i.e., higher efficiency at part load conditions. Extra cost, about $30 million, can be justified by value of extra energy generated. Present layouts are based on 6 units of 150 MW.

- At Devil Canyon, 450 MW is required to generate all available energy at 100 percent load factor. Final design requires 600 MW. Hence, 4 units of 150 MW were selected.

7. <u>Dykes on Permafrost</u> (M. Vanderburgh)

- In view of Panel concern over the dyke at Watana, details were given of design of dykes constructed on 40 feet permafrost in north Manitoba; 30 feet high, constructed on varved clays/silts. Sand drains were used to facilitate settlement resulting from permafrost thawing. Up to 6 feet settlement has been measured over 20 years.

8. <u>Spillway Design</u> (J. Hayden)

- Summary was given of flood flows under 4 main headings:

(i)	Diversion flood	1 in 50 years.
(ii)	Environmental	1 in 100 years (nitrogen problem).
(iii)	Design flood	1 in 10,000 years.
(iv)	PMF	--

Structures have to be designed to handle these flows.

- Watana: design requirement is to avoid nitrogen supersaturation problems for floods up to the 1-in-100-year event. This can be achieved either by a cascade spillway on the left bank or by a tunnel spillway on the right bank with Howell Bunger valves. Cascade spillway is more expensive, and quality of the rock is very doubtful; hence, high maintenance costs are anticipated. Also, the spillway is pushed downstream by the known shear zones which again increases cost.

- Powerhouse flow is included for flood routing up to the 1-in-100-year event; above this flood the powerhouse flow is not included.

- Flows up to 10,000-year floods are taken partly by surcharging the reservoir (up to 4 feet); then the main spillway gates are opened and excess flow is discharged to the river by chute and flip bucket.

- For floods in excess of the 1-in-10,000-year event, reservoir surcharge is increased (7 feet) and excess flow is taken by the main spillway and an emergency spillway; a fuse plug dam in the emergency spillway retains water to the 10,000-year flood. Emergency spillway discharges into Tsusena Creek.

- (Panel comment) Design of fuse plug dam to fail at a critical level is difficult; may be better to have positive control, e.g., gated structure, but at higher cost. Also, depth of fuse plug is excessive and could lose valuable water when plug fails.

- Operating characteristics shown for two floods:

  (a) 1 in 100 years - Howell Bunger valves opened for about 14 days.

  (b) 1 in 10,000 years - Main spillway operates full bore for 3 days (reservoir initially empty) or 5 days from 2,215 level.

- In the event of seismic or other emergency, reservoir could be drawn down 200 feet by service (tunnel) spillway and powerhouse, then low-level outlet would be opened.

9. Watana Layout Studies (J. D. Lawrence)

- Original layouts showed 2 diversion tunnels, crest level 2,225; 2.75:1 upstream slope, 2.0:1 downstream.

- Points of design concern were tabulated for Watana and Devil Canyon. Major design variations concern the types of spillway.

- Copies of the current design criteria were issued to the Panel Members.

- Basic methodology for scheme selection was described:

  (i) From DSR--8 layouts.
  (ii) Screened to give 4 best options.
  (iii) Further developed to select 2 best options, of which the chute/flip bucket spillway is the current preferred option.

- Selection procedure and layout variations were described in detail, together with broad conclusions drawn from each layout.

9.1 Preliminary Layouts (8 alternatives)

- Dam centerline should be as far upstream as possible.
- Minimize upstream dam slope.
- Diversion, 2 tunnels on right bank with low-level outlet.
- Powerhouse underground.
- Single spillway unacceptable; use separate emergency spillway.
- Chute/flip spillway preferred.
- Cascade spillway to be investigated further.

9.2 Preferred Layouts (4 alternatives)

- Considered from the following aspects:

  technical feasibility
  construction methods
  component size
  cost
  environmental impact
  operation
  schedule

- Four layouts were described in detail, the main differences being associated with the spillway location and type and the powerhouse location.

- Cost comparisons were shown, favoring the chute/flip spillway option.

- Conclusions drawn:

  (i) Lower upstream cofferdam to reduce general site congestion.
  (ii) Major structures on the right bank.
  (iii) Keep left-bank spillway as an option.

- Dam design is now being carried out, and upstream slope has been reduced to 2.4 to ease congestion and reduce diversion costs.

9.3 Arch Dam Alternative

- Layout shown, geometry plus main structures.

- Cost estimates show the rockfill dam to be cheaper, with a concrete unit rate of $150 per cubic yard. (Compared with $210 for Devil Canyon.) This is likely to be low; hence, rockfill alternative was selected.

10. Low-Level Outlets (R.K. Ibbotson)

10.1 Watana

- Flows: diversion--the routed 1-in-50-year flood, 76,000 cfs.
  reservoir filling--up to 10,000 cfs.
  operation--up to 30,000 cfs for emergency drawdown.

- Current layout was described in detail. The upstream diversion portal will be kept downstream from the Fins feature.

- Two options were initially considered:

  (a) 2 pressure tunnels
  (b) 2 free-flow tunnels

- Optimum diameters were 30 feet (a) and 35 feet (b), with maximum design velocities of 50 feet/second.

- Plugs and gates will be constructed in one tunnel in the winter while the diversion flow passes through the other.

- Selected scheme has one pressure and one free-flow tunnel with suitable energy dissipating devices for emergency releases. The right diversion tunnel is also used as an outlet for one of the two tailrace tunnels, to ease site congestion downstream.

- Operating curves shown for emergency drawdown condition. Four months would be required to level 2,000; about 30 months to 1,800 level. The reservoir can be held at 1,800 level if necessary.

- Gates would be needed on the pressure tunnel to construct the concrete plugs; these could be designed for emergency use to give extra drawdown capacity.

- Summary of recommended layout:

  50-year flood, (83,000 cfs) routed flow 76,000 cfs. Optimum cofferdam height reduced 40 feet to ease site congestion; 2 x 35 feet diameter tunnels (1 pressure, 1 free-flow).

- (Panel comment) The maximum cut on the upstream portal is about 300 feet. It would be worth reducing this by any possible means, e.g., separate cofferdam across portal entrance.

10.2 Devil Canyon

- Single 35-foot pressure tunnel - no bypass flows required, these will be provided by Howell Bunger valves in the dam. Design flow is 52,000 cfs (routed through Watana).

- Portals will almost certainly be moved from the positions shown, from topography considerations.

11. Power Development (J. Hayden)

- If Watana dam height were to be lowered 100 feet because of problems with the relict channel, $\$5.2 \times 10^9$ could be spent on the Susitna development; actual cost would be $\$5.0 \times 10^9$; hence, the project would still be viable, although annual firm energy would be reduced from

6,100 to 5,400 GWh. This represents a capitalized value of $700 million in reduced energy from Susitna.

- Summary of power developments at present envisaged.

Watana - 6-unit powerhouse, underground, fed from multi-level intake.

Devil Canyon - 4-unit powerhouse, underground, from single-level intake; one machine discharging at the dam, three machines discharging over 1 mile downstream to gain extra head.

12. Tidal Power (C. Debelius)

- Part of an overall study of energy alternatives, broken down as follows:

(i) Site reconnaissance and selection.

(ii) Evaluation, based on medium and high load forecasts.

(iii) Tides - top of inlet 20 to 25 feet, maximum 40 feet. Cascade alternatives, using time phase difference.

(iv) Computer model developed to assess energy output for a given configuration.

(v) Mils/kwh not sensitive to total energy generated over a wide range from optimum.

(vi) Caisson Construction - floated in and sunk on prepared sand bed.

(vii) Power available is large compared with the system requirements. Hence, storage will be required to use the available pulses:

(a) compressed air energy storage;
(b) hydroelectric storage; or
(c) industrial usage on same pattern as available pulses.

(viii) General environmental considerations.

(ix) Risk analysis.

(x) FERC licensing - similar to Susitna.

(xi) Costs? Same order mils/KWh as coal-fired thermal.

(xii) Further work? Sedimentation should not be a problem within the first 50 years.

October 8, 1981

1. Introductory Remarks (J. D. Lawrence)

   - Panel would be writing their report after the morning session; lunch would be brought in.

2. Devil Canyon Dam Design (R. K. Ibbotson)

   - Arch dam is to be constructed at the upstream end of the canyon in an asymmetrical valley.

   - Tension cracks and general instability at the upper left abutment increase excavation by about 100 feet in the area of the thrust block.

   - Geometry presented in graphical form.

   - Properties of materials assumed were presented.

   - Allowable tensile stresses: - 250 psi (normal)
     - 750 psi (dynamic)

   - Rock modulus (2 x 10^6 psi) not altered, but work on other dams indicates about 10 percent change in stresses for a change in modulus of a factor of 2.

   - Details of assumed temperature variation and combined load conditions were presented.

   - Normal loading results:

Load case UL1	- 27 psi tension +1100 psi
Load case UL3	-393 psi at left centilever +1180 psi

   - Dynamic analysis: mean response spectrum was shown. Dr. Seed queried the term "mean"; the normal acceleration used would be 0.84 percentile (say 1.35 x 0.35g = 0.47g). Also, design earthquake may increase as a result of discussions with WCC (v.s., October 6th Report).

   - Extreme loading results:

EL1(i)	- 729 psi upstream crown centilever +3600 psi.
EL1(ii)	- 577 psi crown centilever -2000 psi in arches.
EL2	-1392 psi in crown of upper arch.

   (EL1 assumes 0.5g acceleration and 5 percent damping factor; EL2 assumes 0.4g acceleration and 10 percent damping factor.) 10 percent damping factor is applicable for this type of arch dam, based on previous experience.

- Pseudo-static analysis was then carried out assuming vertical cracks and construction joints open up to 50% of the dam height: USBR program on reduced cantilevers gave maximum tensile stresses of -322 psi in the arch; with reduction in hydrodynamic loading to 60 percent because of the constricted approach and the valley shape, the maximum tensile stress reduces to -251 psi (EL2).

- (Panel Comment) M. Copen confirmed that Acres design approach was very conservative.

3. <u>Devil Canyon Spillway Studies</u> (John Hayden)

- Synthetic flood flows, routed through Watana.

- Diversion flow, taken through a single-gated pressure tunnel, eventually plugged.

- Flood-handling philosophy is similar to Watana:

  (i) Up to 1-in-100-year event - 5 Howell-Bunger valves set in the dam.
  (ii) Above 1-in-100-year event - chute/flip bucket on main right bank spillway; alternative stilling basin has been rejected on cost grounds, as well as lack of precedent for this head.
  (iii) Above 10,000-year event - fuse plug dam in an emergency spillway channel is designed to fail: passes flow up to the PMF.

- (Panel comments) Main spillway on the right bank will require excessive rock bolting and support work. Had consideration been given to a tunnel spillway, possibly using part of the diversion tunnel? This would be difficult to fit into the available space, and intakes would be a problem. However, it would be given further attention.

  - Concrete spillway structure on the left bank? Not advisable because of the depth of alluvium.

  - Fuse plug dam: same comments as for Watana. Height is excessive and would result in extensive energy losses; better to be lower and wider, with a flared approach.

  - Erosion of river channel caused by chute and flip bucket would tend to raise the tailwater level, but with the proposed extension of the tailrace tunnel 6,000 feet downstream the station output would not be affected.

4. <u>Devil Canyon Layout Studies</u> (J. D. Lawrence)

- Position was summarized after the Development Selection Report (June 1981), with the Design Criteria being used at that time.

- Major design considerations and concerns were summarized.

4.1 Dam Selection: (a) concrete thin arch dam (preferred option).
(b) fill dam alternative.

- For the fill dam alternative, a brief block estimate was carried out based on steep upstream slope and assuming that all necessary materials would be available. The cost was about the same as the thin arch dam, but likely to rise significantly because of lack of data on materials (subsequently proved to be true). Hence, the fill dam alternative was not considered further.

- (Panel comment) Was a concrete faced rockfill dam considered? Yes, but rejected on technical grounds: settlement problems under earthquake motions and thermal movements and rotations of the abutment concrete slabs in the extreme temperature range encountered in Alaska.

- (Panel comment) Dr. Merritt and Dr. Seed did not agree that concrete faced rockfill dams were unsuitable in seismic areas, and considered seismic settlements were overestimated; only about 0.25 percent settlement had been observed in a 400-foot dumped rockfill dam subjected to 0.36g earthquake. The settlement for rolled rockfill would be even lower, about 12 inches, not 1-1/2 percent height; this is very conservative. Concrete-faced rockfill dams are inherently very stable; with upstream slopes of 1.3 to 1.8 because of no pore-water pressure problems.

- Would only be worth changing if economically advantageous, in view of present advanced stage of the work.

4.2 Layout Studies

- Three alternative layouts were described in detail and a tabular presentation of costs was shown. The original orifice spillway through the dam was removed to simplify the arch dam design, and replaced by 5 Howell Bunger valves through the base of the dam. These handle floods up to the 1-in-100-year event.

- Three alternative layouts are different in the location and type of the main spillway, which handles floods in excess of the 100-year event:

  (i) chute/flip on right abutment
  (ii) chute/flip on left abutment
  (iii) stilling basin on the right abutment

- Right bank chute/flip is the preferred option, based on cost grounds. Further study will be carried out on the tunnel spillway alternative mentioned this morning.

- Environmental flow, Devil Canyon to Portage Creek. In view of the extension of the tailrace tunnel, compensation flow will be required to maintain flow downstream from the dam. One small turbine will be installed to pass an acceptable flow (1,000 cfs?).

5. <u>General</u>

- Dr. Seed was given figures on cost for rockfill and gravel fill at Watana (to determine relative suitability for design purposes). In response to a query on the practice of alternate layering of rockfill and gravel fill, Dr. Seed considered this unacceptable; possibly a rationale of what actually occurs when constructing dams, i.e., fines trapped on top of layers of rockfill, giving low, vertical permeability.

- General presentations by Acres staff and discussion of matters arising terminated at 11:30.

- Panel Report was presented at 15:15, in draft form.

6. <u>Closing Statement</u> (D. D. Wozniak, Project Manager, APA).

- Preliminary date for the fourth and final External Review Board Meeting was scheduled for January 11, 1982, in Anchorage. This date will be confirmed by end of October 1981.

- Dr. Sykes and WCC are to discuss and confirm the anticipated intensity of the Floating Terrain Earthquake.

- Panel Report on Meeting No. 3 will be typed by Acres American in draft, and returned to APA for issue.

Reported by:

M. F. Dumont

M. F. Dumont

MFD/jgk

ALASKA POWER AUTHORITY P5700.13

SUSITNA HYDROELECTRIC PROJECT
External Review Board Meeting No. #3

MINUTES OF MEETING HELD ON
October 6 - 8, 1981, BUFFALO, NEW YORK

APPENDIX A Supporting Documentation

Copies of viewgraphs, etc., presented at the meetings and additional to that provided in the advance Information Package.

ALASKA POWER AUTHORITY P5700.13

SUSITNA HYDROELECTRIC PROJECT
External Review Board Meeting No. #3

MINUTES OF MEETING HELD ON
October 6 - 8, 1981, BUFFALO, NEW YORK

Presentation on: Geotechnical Field Program - J. Gill

WATANA

EXPLORATIONS SUMMARY

USBR	1950-1953	RECONNAISSANCE
COE	1975	RECONNAISSANCE
		22500 LF SEISMIC REFRACTION LINE
COE	1978	28 BOREHOLES (30-600 FT DEEP)
		18 AUGER HOLES
		27 TEST PITS
		47665 L.F. SEISMIC LINES
		10 PIEZOMETERS, 13 TEMP. PROBES
ACRES	1980-1981	7 BOREHOLES (300-955 FT DEEP)
		39 AUGER HOLES
		41 TEST PITS (APPROX)
		63000 L.F. SEISMIC LINES
		4 PIEZOMETERS
		3 THERMISTER STRINGS

MATERIALS TESTING

COE	ROCK TYPE PETROGRAPHIC ANALYSIS
	FILTER AND CORE MATERIALS GRADATIONS
	CORE MATERIALS STRENGTH, CONSOL.
	ROCK STRENGTH
ACRES (IN PROGRESS)	ROCK STRENGTH, PROPERTIES
	FILTER AND CORE GRADATIONS
	SAMPLE MOISTURE ANALYSIS
	CORE MATERIALS PLASTICITY, PIPING POTENTIAL, STRENGTH
	FILTER MATERIAL ANALYSIS

DEVIL CANYON
EXPLORATIONS SUMMARY

USBR	1957-1960	22 BOREHOLES	(20-150 FT DEEP)
		19 TEST PITS	
COE	1978	1300 L.F. SEISMIC REFRACTION LINE	
ACRES	1980-1981	7 BOREHOLES	(150-750 FT DEEP)
		8 AUGER HOLES	
		6 TEST PITS	
		1600 L.F. SEISMIC LINE	

MATERIALS TESTING

USBR	AGGREGATE SUITABILITY TESTS
	AGGREGATE GRADATIONS
	ROCK STRENGTH, PROPERTIES
	ROCK TYPE PETROGRAPHIC ANALYSIS
ACRES (IN PROGRESS)	AGGREGATE SUITABILITY
	AGGREGATE GRADATIONS
	ROCK STRENGTH, PROPERTIES
	ROCKFILL SUITABILITY (FOR SADDLE DAM)

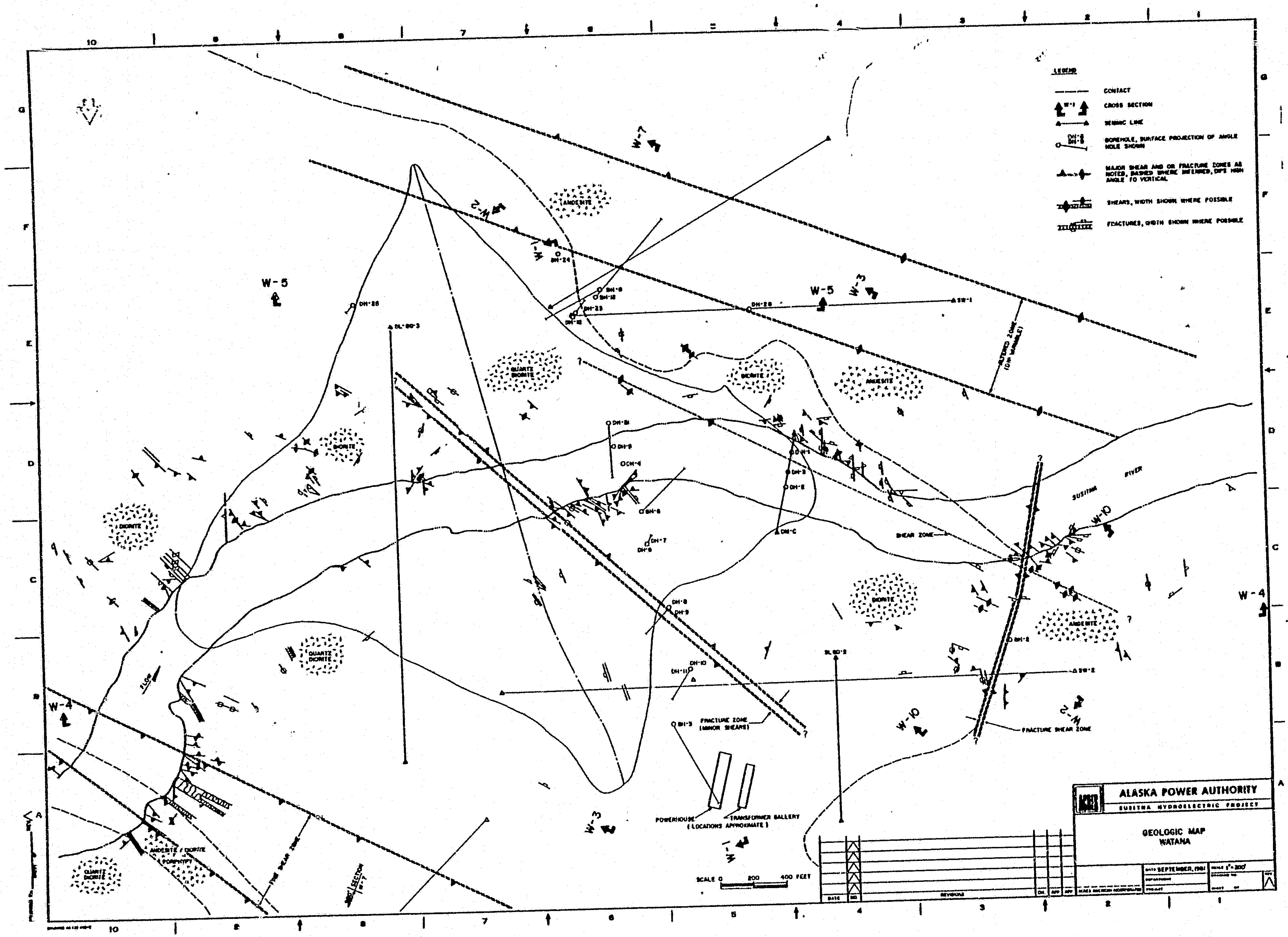
ALASKA POWER AUTHORITY P5700.13

SUSITNA HYDROELECTRIC PROJECT
External Review Board Meeting No. #3

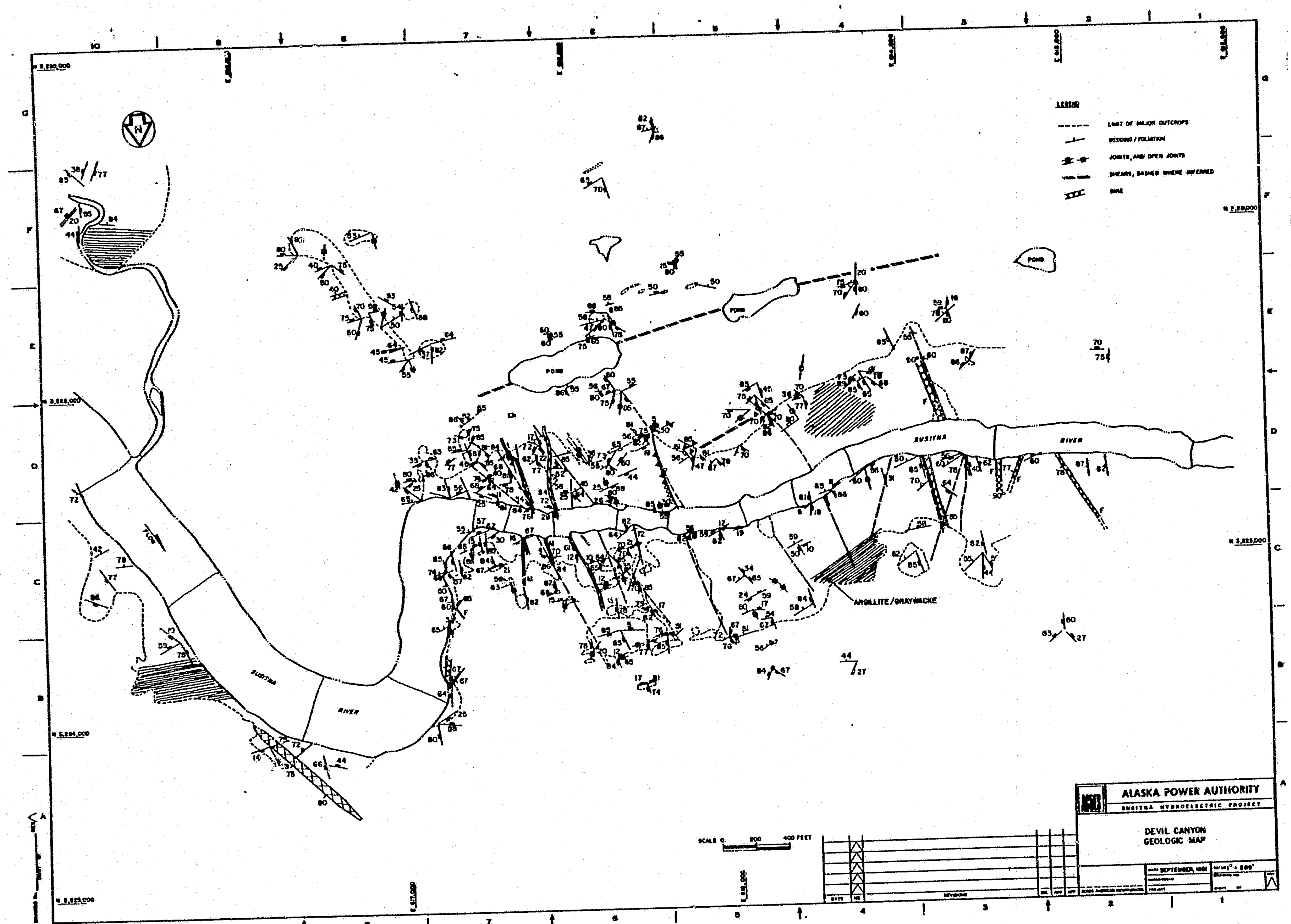
MINUTES OF MEETING HELD ON
October 6 - 8, 1981, BUFFALO, NEW YORK

Presentation on: Geotechnical Interpretation - S. Thompson

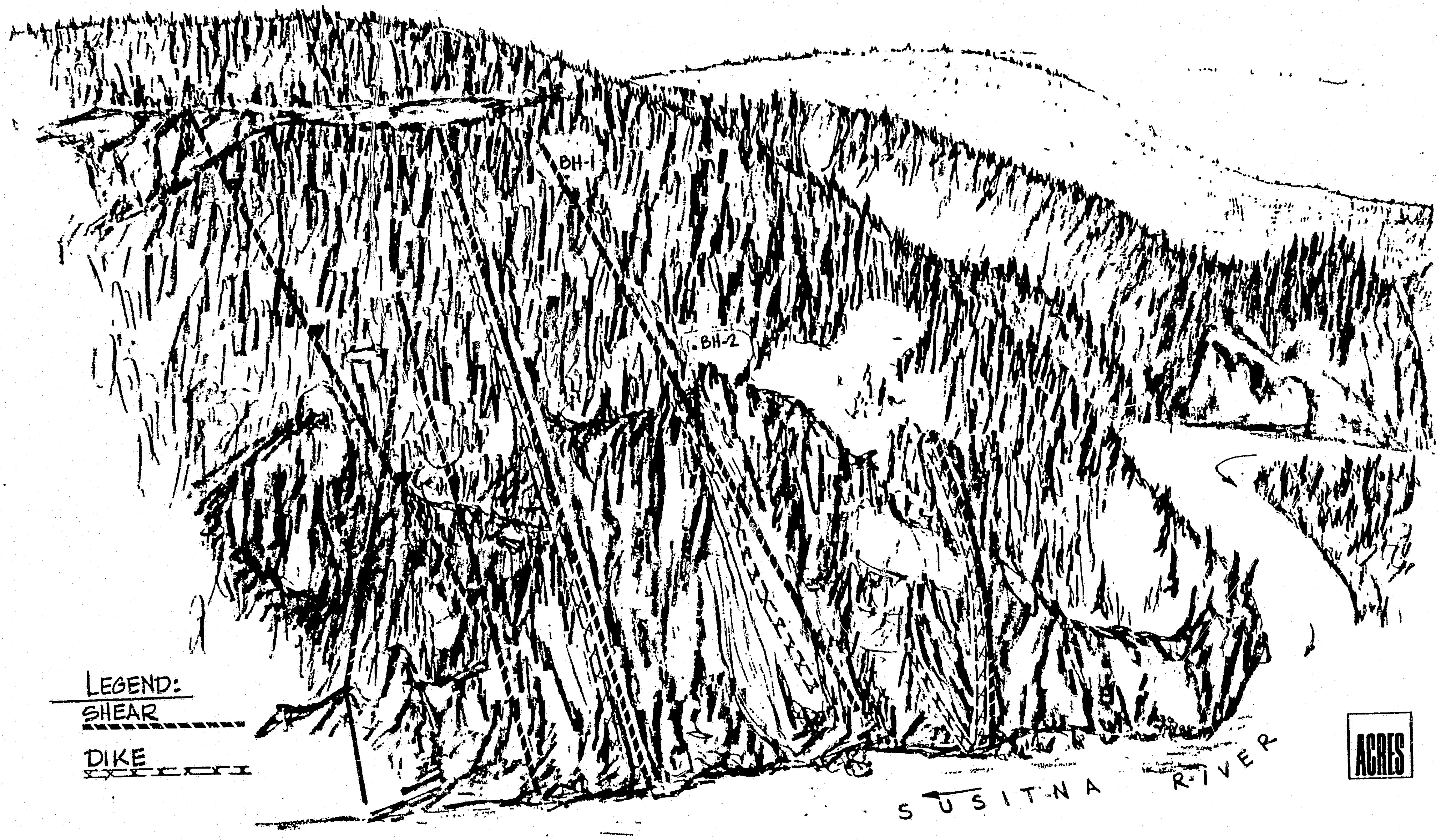
1) WATANA DAMSITE GEOLOGY


LEGEND
CONTACT
CROSS SECTION
SEISMIC LINE
BOREHOLE, SURFACE PROJECTION OF ANGLE HOLE SHOWN
MAJOR SHEAR AND OR FRACTURE ZONES AS NOTED, DASHED WHERE INFERRED, DIPS HIGH ANGLE TO VERTICAL
SHEARS, WIDTH SHOWN WHERE POSSIBLE
FRACTURES, WIDTH SHOWN WHERE POSSIBLE
ANDESITE
QUARTZ DIORITE
DIORITE
ANDESITE / DIORITE PORPHYRY
SUSITNA RIVER
SHEAR ZONE
FRACTURE SHEAR ZONE
FRACTURE ZONE (MINOR SHEARS)
ALTERED ZONE
FLOW
FINS SHEAR ZONE
POWERHOUSE
TRANSFORMER GALLERY (LOCATIONS APPROXIMATE)
W-1
W-2
W-3
W-4
W-5
W-7
W-10
DH-8
DH-12
DH-21
DH-23
DH-24
DH-25
DH-26
DH-28
DL-80-3
SW-1
SW-2
SCALE 0 200 400 FEET
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
GEOLOGIC MAP
WATANA
DATE SEPTEMBER, 1981
SCALE 1" = 200'
DATE
NO
REVISIONS
CH.
APP
APP
ACRES AMERICAN INCORPORATED

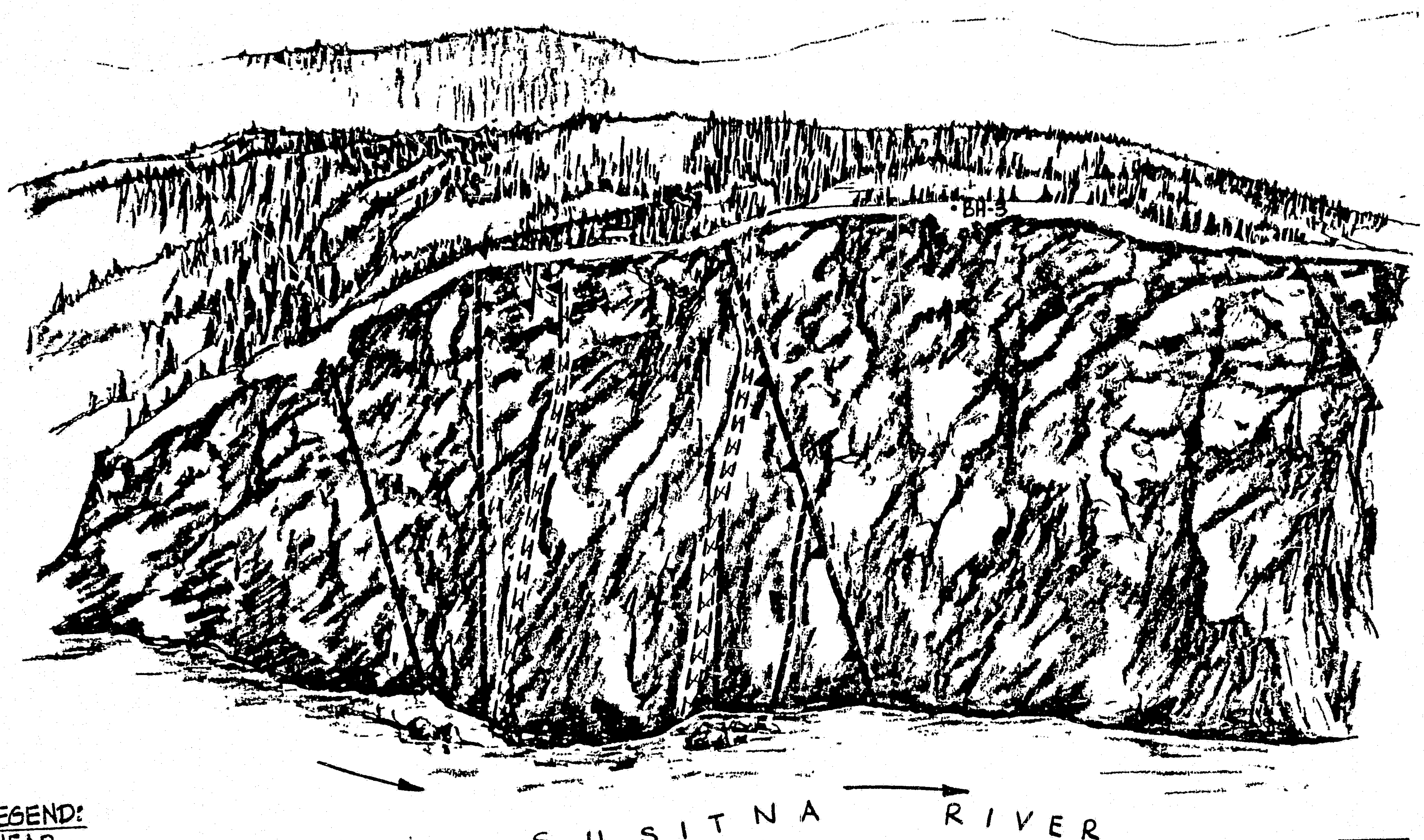
2) DEVIL CANYON DAMSITE GEOLOGY



LEGEND
LIMIT OF MAJOR OUTCROPS
BEDDING / FOLIATION
JOINTS, AND OPEN JOINTS
SHEARS, DASHED WHERE INFERRED
DIKE
POND
SUSITNA RIVER
ARGILLITE / GRAYWACKE
SCALE 0 200 400 FEET
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
DEVIL CANYON
GEOLOGIC MAP
SEPTEMBER, 1981
REVISIONS


BH-1
BH-2
LEGEND:
SHEAR
DIKE
SUSITNA RIVER
ACRES

00236



LEGEND:
SHEAR
DIKE

ACRES

ALASKA POWER AUTHORITY

P5700.13

SUSITNA HYDROELECTRIC PROJECT
External Review Board Meeting No. #3

MINUTES OF MEETING HELD ON
October 6 - 8, 1981, BUFFALO, NEW YORK

Presentation on: Earthfill Dams - D. W. Lamb

WATANA

CORE MATERIAL

PRELIMINARY DESIGN VALUES

OPTIMUM MOISTURE (95% STD. PROCTOR)	6 %	(4 IN. MOLD)
	7.5%	(6 IN. MOLD)
OPTIMUM DENSITY	129-133 PCF	
BULK SPECIFIC DENSITY	2.67	
PERMEABILITY (MINUS 1 INCH)	10^{-5} CM/SEC (4.4 IN DIA.)	

TRIAXIAL TEST DATA:

TYPE Q - UNSATURATED, UNCONSOLIDATED, UNDRAINED TEST

(ANGLE OF FRICTION PHI, COHESION)	35^{0}	0.14 TSF
	(OPTIMUM WATER -4%)	
	33^{0}	0.66 TSF
	(OPTIMUM WATER CONTENT)	
	2^{0}	0.44 TSF
	(OPTIMUM PLUS 4%)	

TYPE R - CONSOLIDATED, UNDRAINED WITH BACK-PRESSURE

EFFECTIVE STRESS RESULTANT ANGLE	37^{0}	
	12^{0}	1.1 TSF
	(OPTIMUM WATER CONTENT)	
	13^{0}	0.52 TSF
	(OPTIMUM MINUS 4%)	

CONSOLIDATION TESTS: (4.4 INCH MOLD, 3/4 INCH MINUS MATERIAL)

REMOLDED, DRAINED, 95% STANDARD COMPACTION

PERCENT STRAIN	OPT-4%	OPTIMUM	OPT+4%
1 TSF	0.85%	0.76%	2.12%
10	2.38	2.46	4.49
32	4.82	4.83	6.86

REVISED 10/06/81

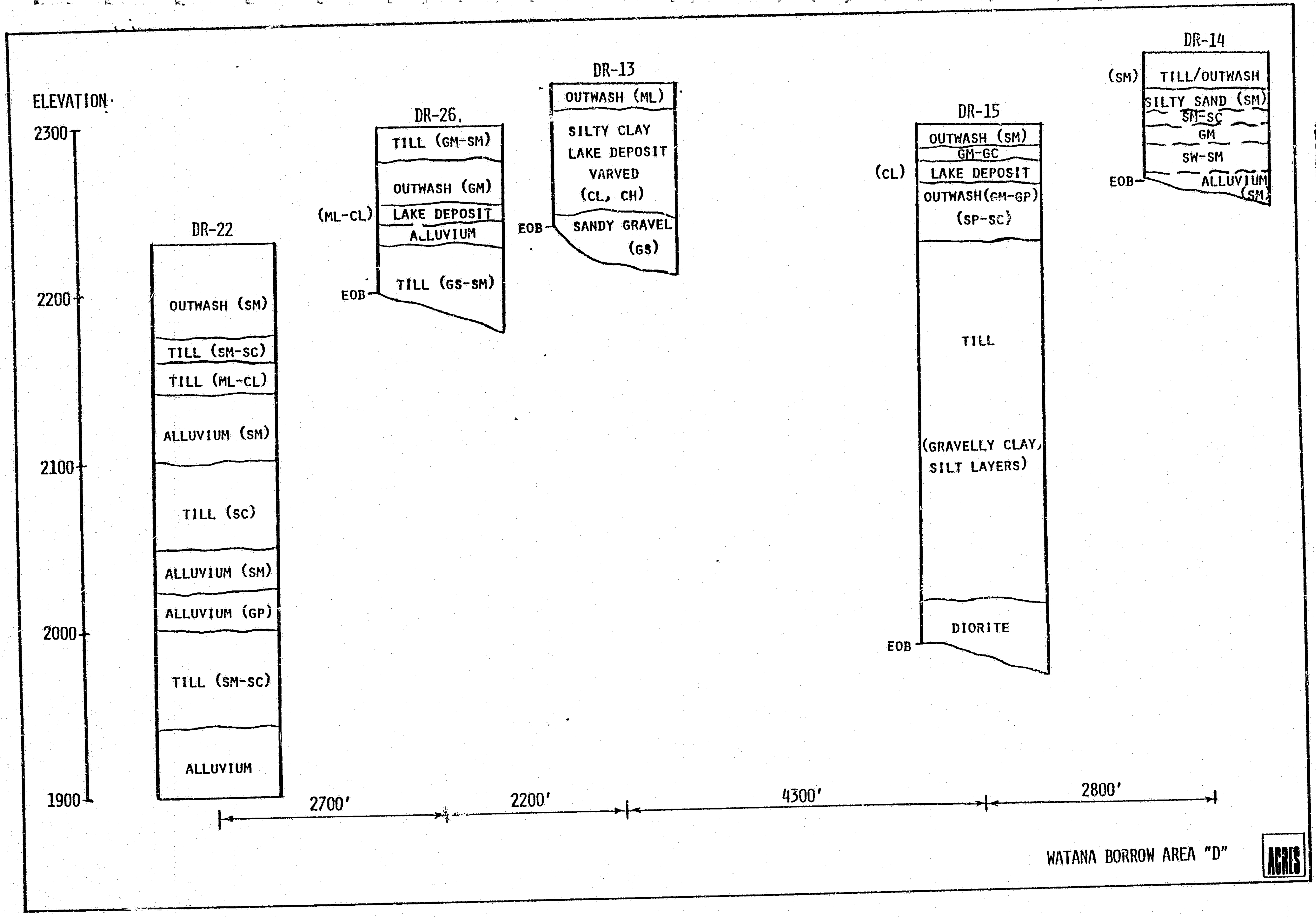
WATANA DAM

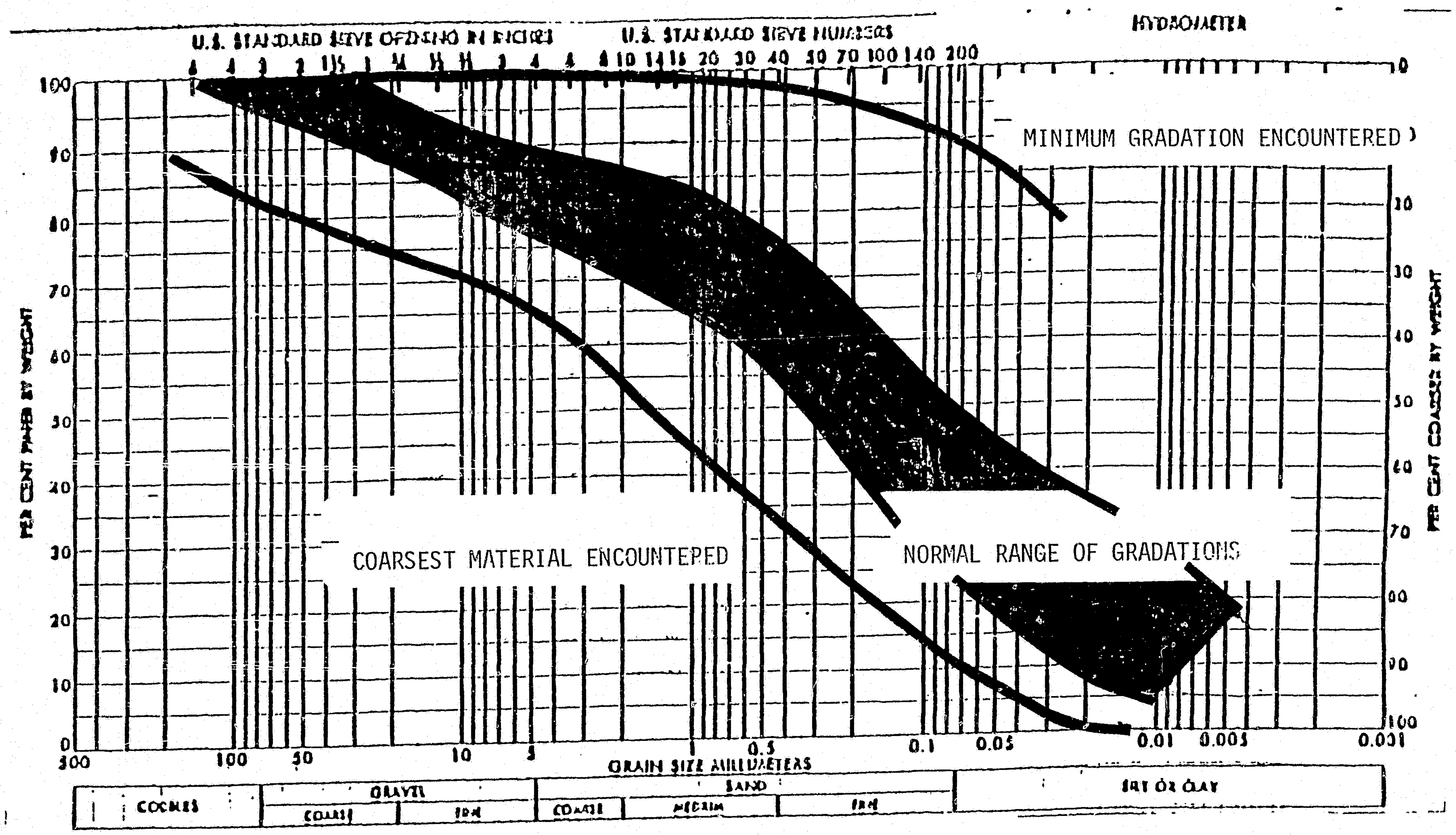
EMBANKMENT QUANTITIES

($\times 10^6$ CY)

TYPE OF MATERIAL	AMOUNT REQ.	EST. AVAIL.	SOURCE
IMPERVIOUS	9-10	50-75+	AREA D
		15-40	AREA H
FINE FILTERS	3-4	12.5	AREA E
COARSE FILTERS	3-4	16	AREA E
		40+	RIVER
ROCKFILL	50-55 COMBINED	100+	QUARRY A
GRAVEL FILL		47-100	RIVER-WITHIN 6 MI.
		160+	-WITHIN 11 MI.
CONCRETE AGGREGATE	< 1	10+ (SAME MATERIAL AS AREA E FILTERS)	
TOTAL	65-75		

REVISED 10/06/81


ELEVATION
2300
2200
2100
2000
1900
DR-22
OUTWASH (SM)
TILL (SM-SC)
TILL (ML-CL)
ALLUVIUM (SM)
TILL (SC)
ALLUVIUM (SM)
ALLUVIUM (GP)
TILL (SM-SC)
ALLUVIUM
DR-26
TILL (GM-SM)
OUTWASH (GM)
(ML-CL)
LAKE DEPOSIT
ALLUVIUM
TILL (GS-SM)
EOB
DR-13
OUTWASH (ML)
SILTY CLAY
LAKE DEPOSIT
VARVED
(CL, CH)
SANDY GRAVEL
(GS)
EOB
DR-15
OUTWASH (SM)
GM-GC
(CL)
LAKE DEPOSIT
OUTWASH(GM-GP)
(SP-SC)
TILL
(GRAVELLY CLAY,
SILT LAYERS)
DIORITE
EOB
DR-14
(SM)
TILL/OUTWASH
SILTY SAND (SM)
SM-SC
GM
SW-SM
ALLUVIUM
(SM)
EOB
2700′
2200′
4300′
2800′
WATANA BORROW AREA "D"
ACRES

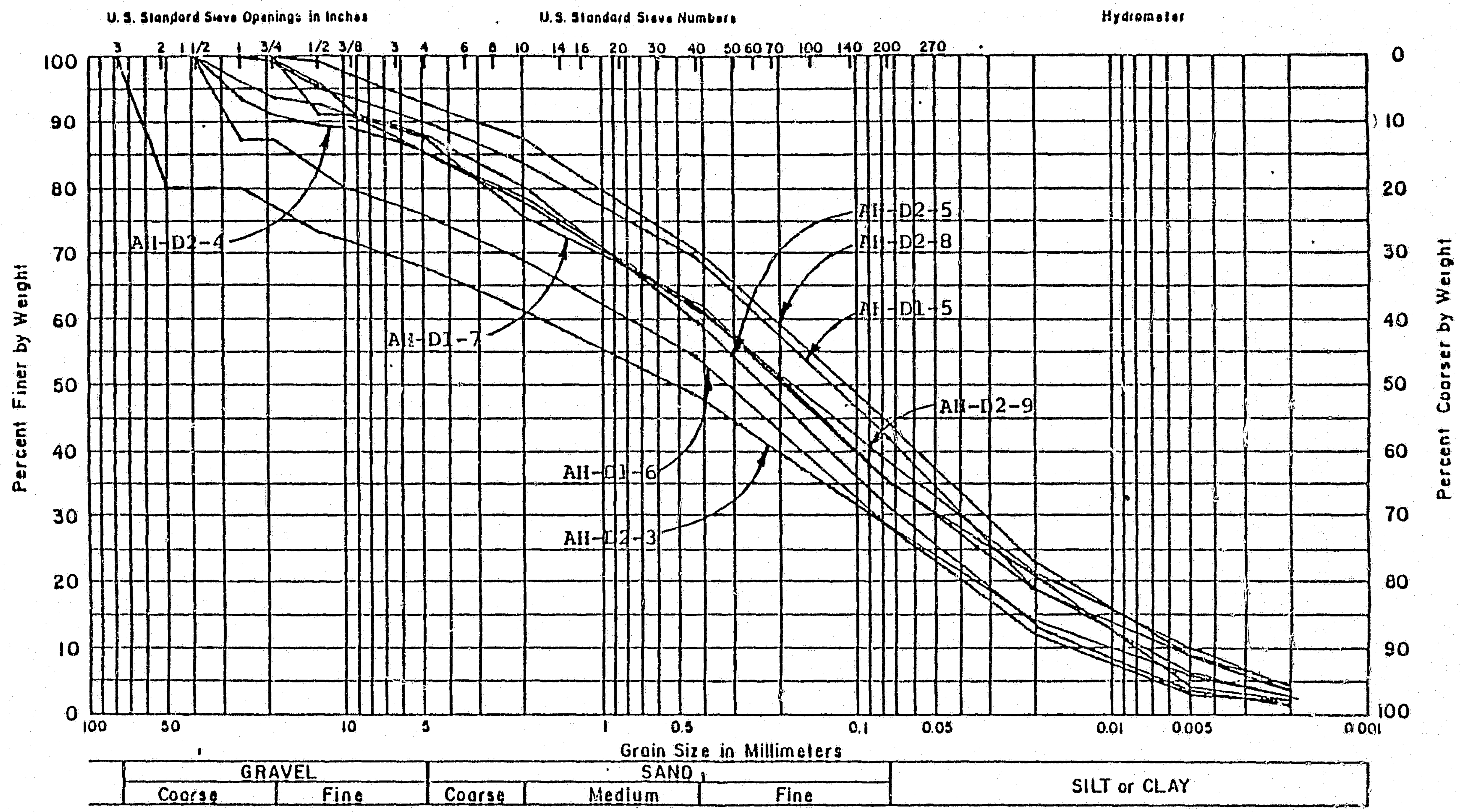


WATANA BORROW AREA D

ENVELOPE OF IMPERVIOUS MATERIAL GRADATION CURVES

(MAJORITY OF SAMPLES LIE IN DARK BAND SHOWN ABOVE)

REVISED 10/6/81



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION
AH-D1-5					SM
AH-D1-6					SM
AH-D1-7					SM
AH-D2-3					SM
AH-D2-4					SM
AH-D2-5					SM
AH-D2-8					SM
AH-D2-9					SM

TYPICAL CORE MATERIAL GRADATIONS - WATANA AREA D

APPARENT VARIATION WITH DEPTH: WATER CONTENT DECREASES
GRADATION BECOMES COARSER
NUMBER OF FINES DECREASES

(SAMPLES FROM 0-21 FEET)

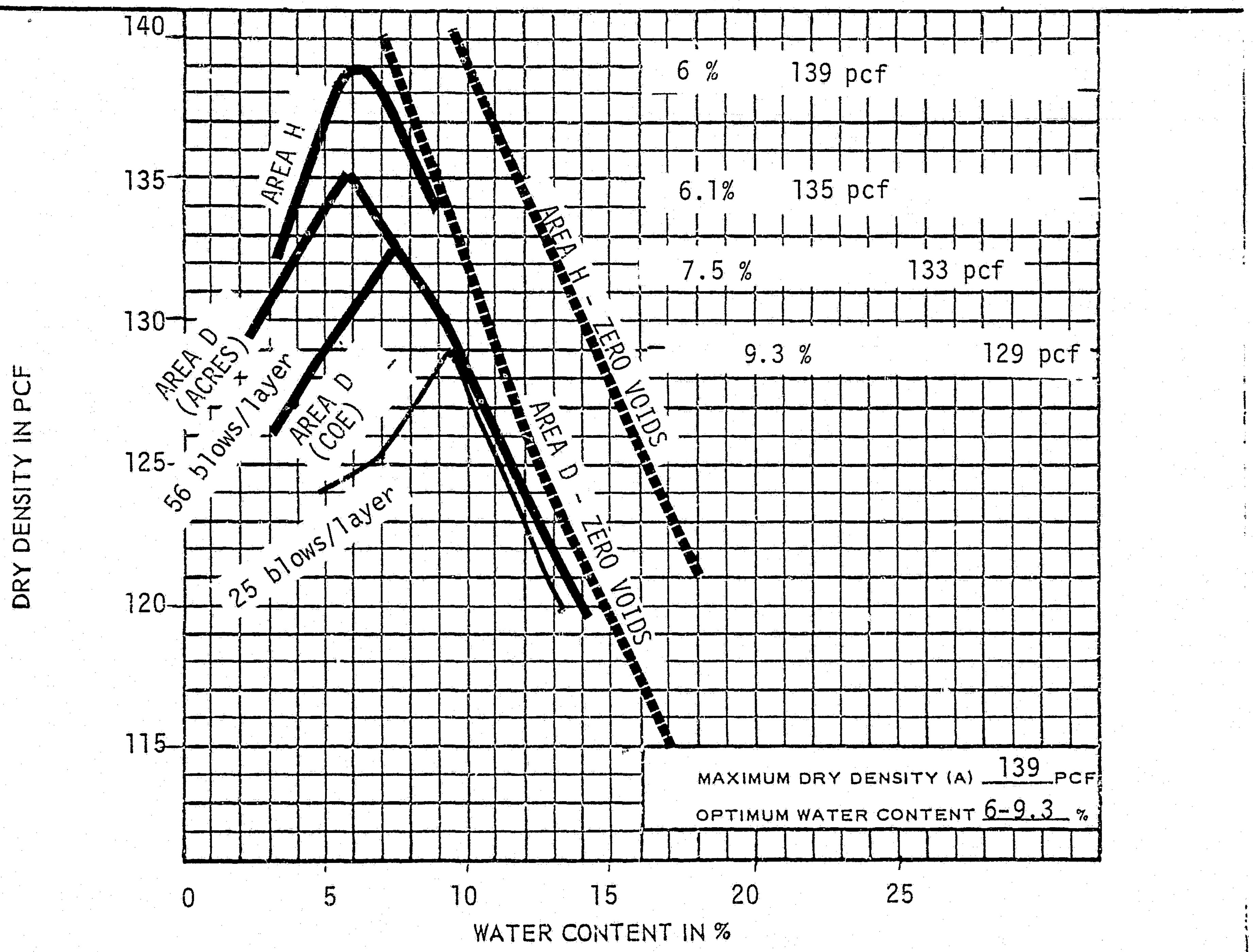
R & M CONSULTANTS, INC.

BORROW AREA D

SUMMARY OF GRAIN SIZE DISTRIBUTIONS

DRAWN BY DL
APPROVED BY
DATE DEC. 1980
PROJECT NO. [illegible]

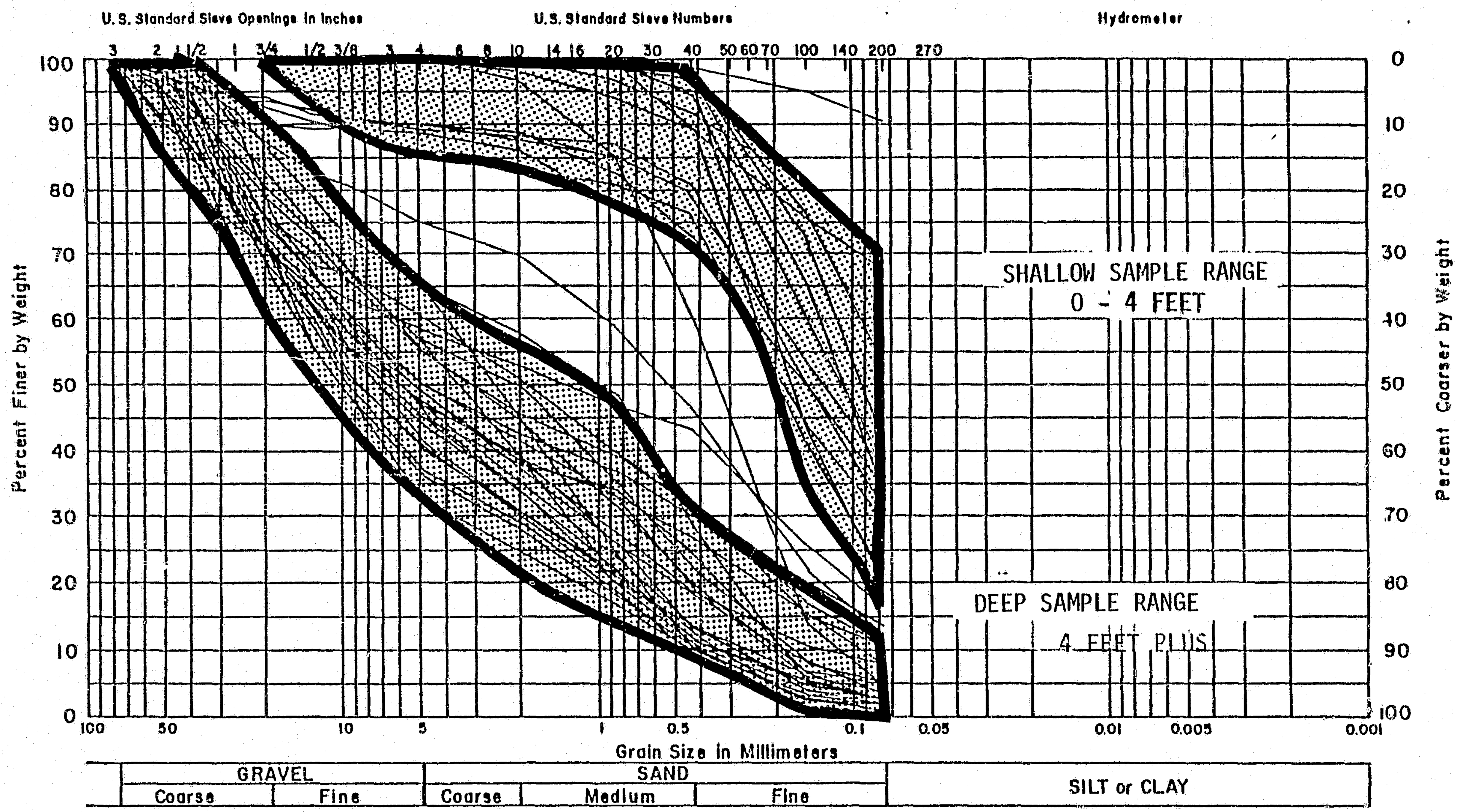
OPTIMUM DENSITY & MOISTURE



WATANA IMPERVIOUS MATERIAL

PROCTOR COMPACTIONS

SIEVE ANALYSES:	% PASSING 2"	#4	#10	#200
COE - AREA D	100	87	unknown	
ACRES - AREA D	100	80	76	27
- AREA H	100	71	64	38



RANGE OF GRADATIONS ENCOUNTERED

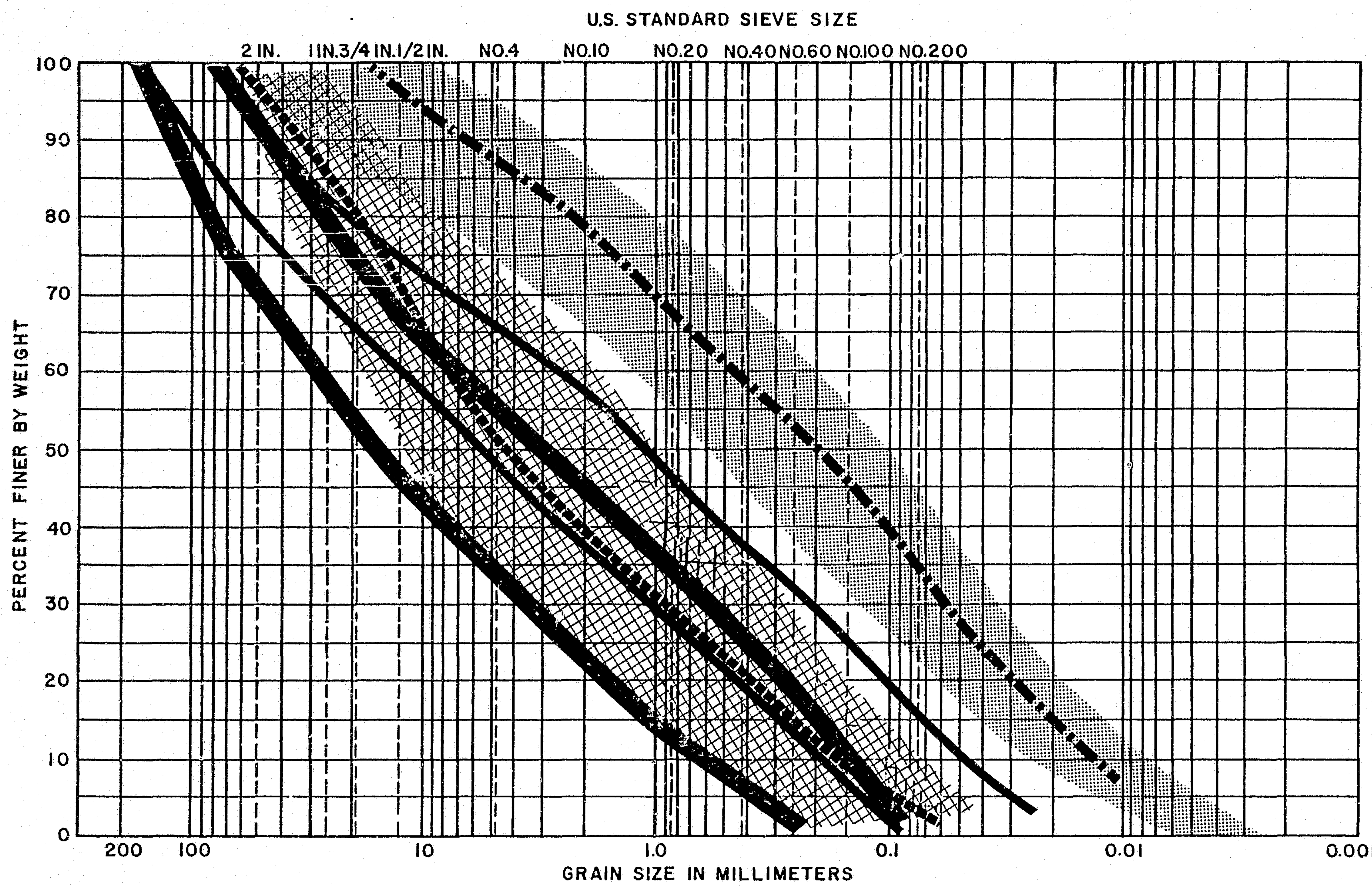
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION

R&M Engineering & Geological Consultants
ANCHORAGE FAIRBANKS ALASKA JUNEAU

COMPOSITE GRADATION CURVES FOR BORROW AREA E
SUSITNA HYDROELECTRIC PROJECT
FILTER & AGGREGATE SOURCE AREA

DRAWN BY
APPROVED BY
DATE 8/21/81
PROJECT NO. 052506

REVISED 10/06/81



COBBLES	GRAVEL		SAND			SILT OR CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	COARSE	FINE	COARSE	MEDIUM	FINE		

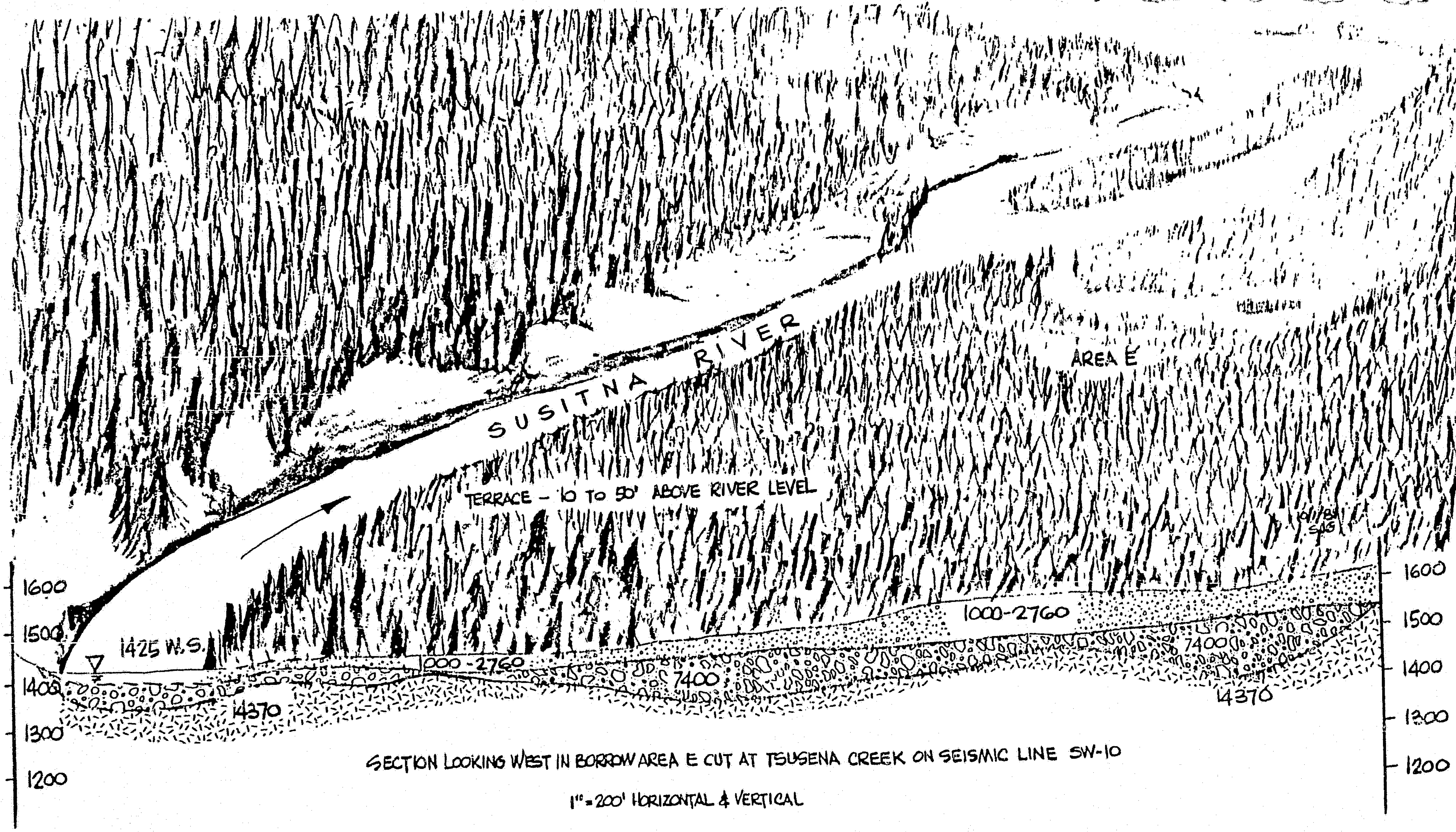
LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION

GRADATION ANALYSIS CURVES

ACRES AMERICAN INCORPORATED
BUFFALO, NEW YORK

WATANA FINE FILTER DESIGN CRITERIA
COE, TERZAGHI USBR

FILE: P5700 DATE: 9/30/81 FIG.



SECTION LOOKING WEST IN BORROW AREA E CUT AT TSUSENA CREEK ON SEISMIC LINE SW-10

1" = 200' HORIZONTAL & VERTICAL

INFERRED MATERIALS

1000-2760 FPS	SANDS, GRAVELS AS PER TEST PIT RESULTS POSSIBLE SATURATED GRAVELS
7400 FPS	(APPROXIMATE WATER TABLE) TAKEN TO BE TILL UNTIL PROVEN OTHERWISE.
14370 FPS	BEDROCK (DIORITE AND/OR LAVA FLOWS)

WATANA - RIVER ALLUVIUM

ACRES

WATANA DAMSITE

RELICT CHANNEL

CHANNEL SPECIFICS:

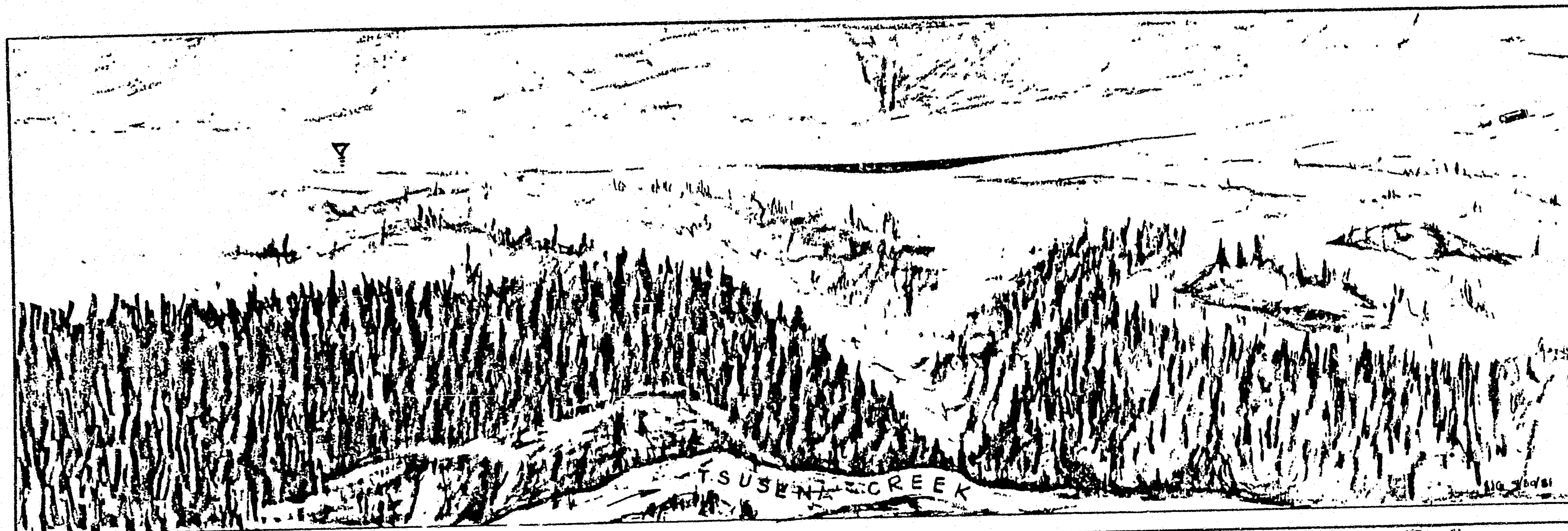
MAXIMUM OBSERVED DEPTH	454	FEET
AVERAGE DEPTH	200	
MINIMUM OBSERVED WIDTH	14075	
SHORTEST FLOW PATH (FROM RESERVOIR)	6200	
HEAD LOSS - MAX. OPER. POOL	590	
AVERAGE GRADIENT	1 IN 10	

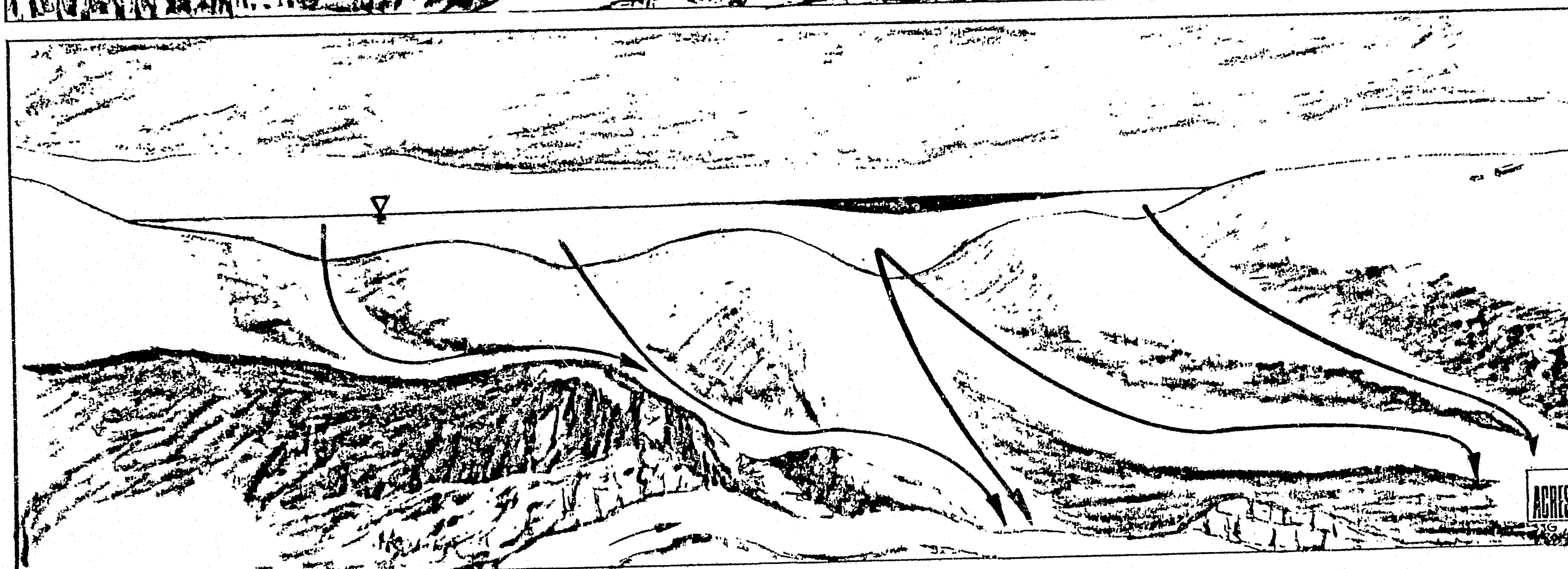
CUTOFF SCHEME SPECIFICS:

TOTAL LENGTH OF CUTOFF	14075	FEET
MAXIMUM DEPTH	400	
AVERAGE DEPTH	200	

SADDLE DAM:

TOTAL LENGTH	2300	FEET
MAXIMUM HEIGHT	40	
AVERAGE HEIGHT	20	
OVERBURDEN DEPTH - MAXIMUM	300	
- AVERAGE	165	
RIPRAP SHORE PROTECTION REQUIRED	3000	


TSUSENA CREEK


ACRES

ALASKA POWER AUTHORITY P5700.13

SUSITNA HYDROELECTRIC PROJECT
External Review Board Meeting No. #3

MINUTES OF MEETING HELD ON
October 6 - 8, 1981, BUFFALO, NEW YORK

Presentation on: Hydraulic Studies - J. Hayden

DATA COLLECTION PROGRAMS AT MAJOR STATIONS IN THE SUSITNA RIVER BASIN

STATION	Streamflow Gaging[1]	Crest Stage Gage	Staff Gage	Water Quality (1)	Water Temperature	Sediment Discharge	Climate (1)	In-cloud icing	Freezing Rain	Snow Creep	Period of Historical Stream Flow Records (USGS)
Susitna River near Denali	X				X	X	X	X	X		1957-1966, 1968-Present
Susitna River at Vee Canyon	X			X	X	X					1961-1972, 1980-Present
Susitna River near Watana Damsite	X	X		X[2]	X		X	X	X	X	(1980-Present R&M)
Susitna River near Devils Canyon		X	X[3]				X			X	--
Susitna River at Gold Creek	X			X	X	X					1949-Present
Chulitna River near Talkeetna	X				X	X					1958-1972, 1980-Present
Talkeetna River near Talkeetna	X			X	X	X					1964-Present
Susitna River near Sunshine[4]	X				X	X					1969-1971 Part., (1976-'80 NWS)
Skwentna River near Skwentna	X			X	X	X	X				1959-Present
Yentna River near Susitna Station	X				X	X					1980-Present
Susitna River at Susitna Station	X			X	X	X					1974-Present

NOTES:

(1) Parameters Measured listed in Appendix F
(2) Continuous water quality monitor installed
(3) Proposed
(4) Proposed - data collection to begin 1981

SUMMARY OF PRE-PROJECT FLOW CONTRIBUTIONS BY MONTH AT TALKEETNA

	Flow Contribution by: *			Total Flow D/S
	Chulitna	Talkeetna	Susitna	Talkeetna
October	4859	2537	5580	12976
November	1994	1187	2435	5616
December	1457	838	1748	4043
January	1276	671	1438	3385
February	1095	565	1213	2873
March	976	492	1085	2553
April	1158	557	1339	3054
May	8511	4176	13400	26087
June	22540	11910	28150	62600
July	26330	10390	23990	60710
August	22190	9749	21950	53889
September	11740	5853	13770	31363
Annual	8748	4086	9707	22429

* Discharge data from U.S.G.S. records

AVERAGE MONTHLY FLOWS (FT^3/s)

MONTH	WATANA POST PROJECT	DEVIL CANYON POST PROJECT	GOLD CREEK PRE PROJECT	GOLD CREEK POST PROJECT	SUNSHINE PRE PROJECT	SUNSHINE POST PROJECT
OCT	7095	7898	5639	8343	13,690	16,394
NOV	8746	9070	2467	9250	5,829	12,613
DEC	9346	9596	1773	9735	4,199	12,161
JAN	8676	8872	1454	8982	3,498	11,026
FEB	9238	9408	1236	9503	2,952	11,219
MAR	7540	7683	1114	7764	2,631	9,280
APR	6919	7090	1367	7184	3,177	8,994
MAY	5470	7341	13317	8381	27,717	22,781
JUN	4765	7871	27928	9598	64,198	45,868
JUL	6002	8259	23853	9513	63,178	48,839
AUG	10920	13168	21478	14424	55,900	48,845
SEP	9555	11208	13171	12121	32,304	31,253

AVERAGE RESERVOIR LEVELS

MONTH	WATANA LEVEL (FT)	WATANA VOLUME TO FILL (MILLION A.C. FT)	DEVIL CANYON LEVEL (FT)
JAN	2168	1.834	1455
FEB	2154	2.332	1455
MAR	2142	2.734	1455
APR	2131	3.084	1455
MAY	2140	2,787	1455
JUN	2172	1,681	1455
JUL	2196	0.816	1455
AUG	2206	0.390	1455
SEP	2208	0.327	1455
OCT	2204	0.490	1455
NOV	2193	0.899	1455
DEC	2180	1.379	1455

PEAK FLOOD FLOWS

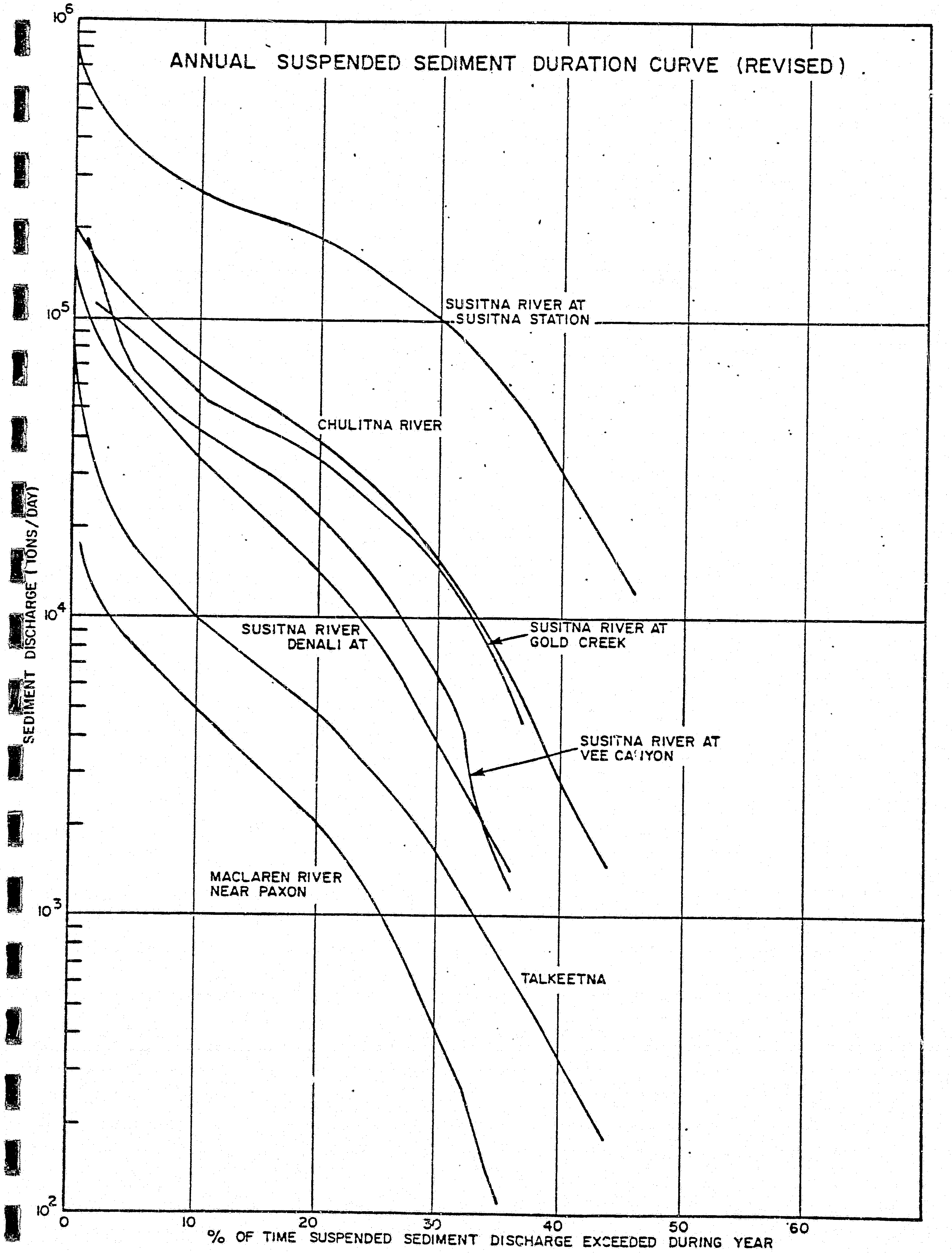
RETURN PERIOD	WATANA FLOW FT³/S	WATANA VOLUME OF FLOOD M ACRE FT	WATANA DISCHARGE FT³/S	DEVIL CANYON ROUTED IN FLOW	DEVIL CANYON DISCHARGE
1:50 YEAR ANNUAL	84,000	1.56	68,000	52,000	52,000
1:100 YEAR ANNUAL	92,000	1.74	45,000	54,000	54,000
SUMMER	70,000		45,000	54,000	54,000
1:10,000 YEAR ANNUAL	156,000	3.67	120,000	140,000	140,000
PMF	315,000	9.24	270,000	325,000	300,000
AVERAGE ANNUAL	7,860			8,960 (1)	

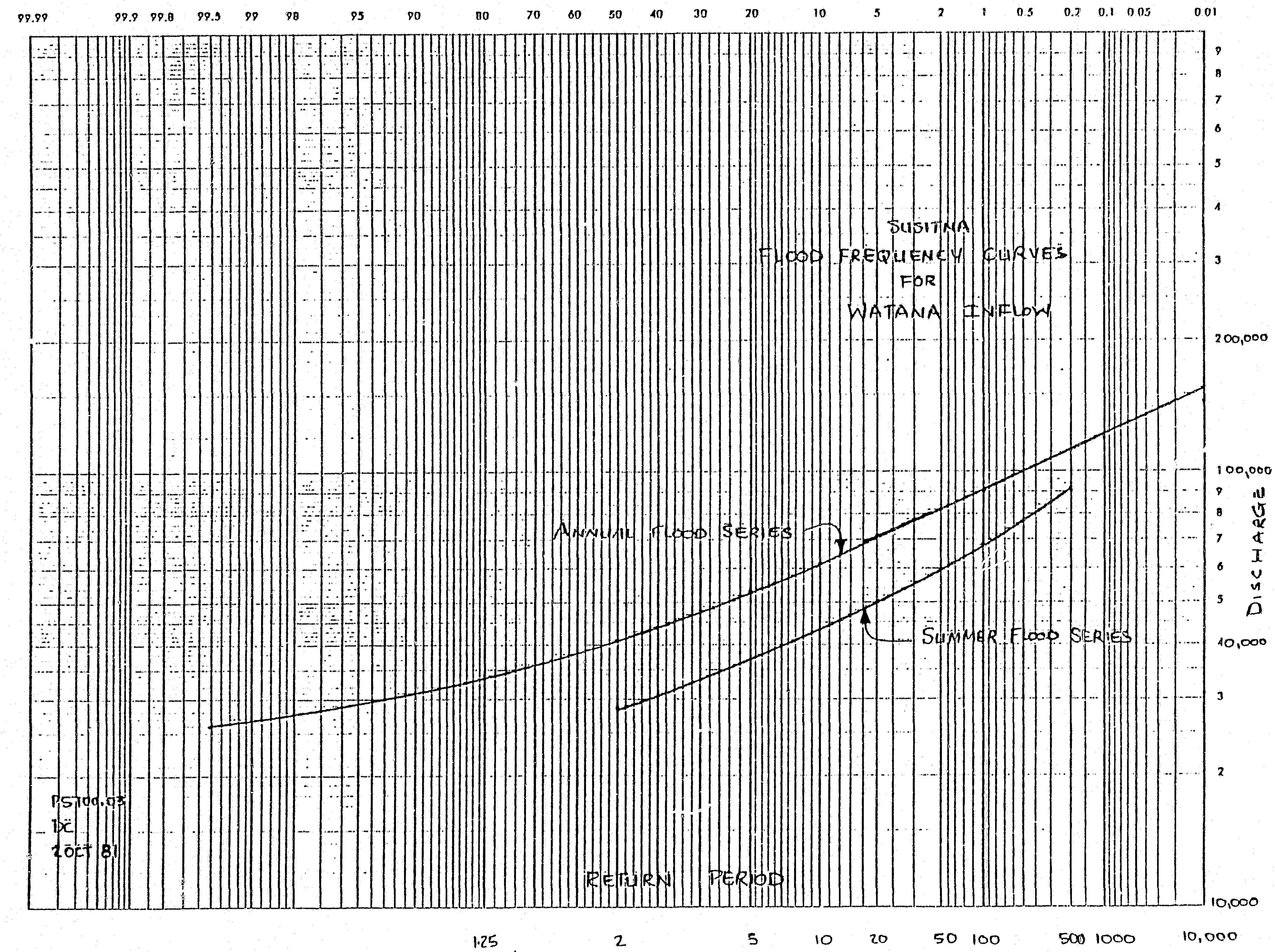
(1) NATURAL INFLOW

WATER QUALITY - PREPROJECT

SUSITNA RIVER AT GOLD CREEK

MONTH	AVG. FLOW FT^3/S	TEMPERATURE$^{\circ}$ F	AVG. SUSPENDED SEDIMENT LOAD TONS/DAY
OCT	5,639	35.2	1,600
NOV	2,467	33.6	230
DEC	1,773	32.0	100
JAN	1,454	32.0	70
FEB	1,236	32.0	45
MAR	1,114	32.0	40
APR	1,367	37.0	60
MAY	13,317	41.9	12,200
JUNE	27,928	45.5	69,900
JUL	23,853	50.9	48,200
AUG	21,479	49.6	37,700
SEP	13,171	42.3	11,900

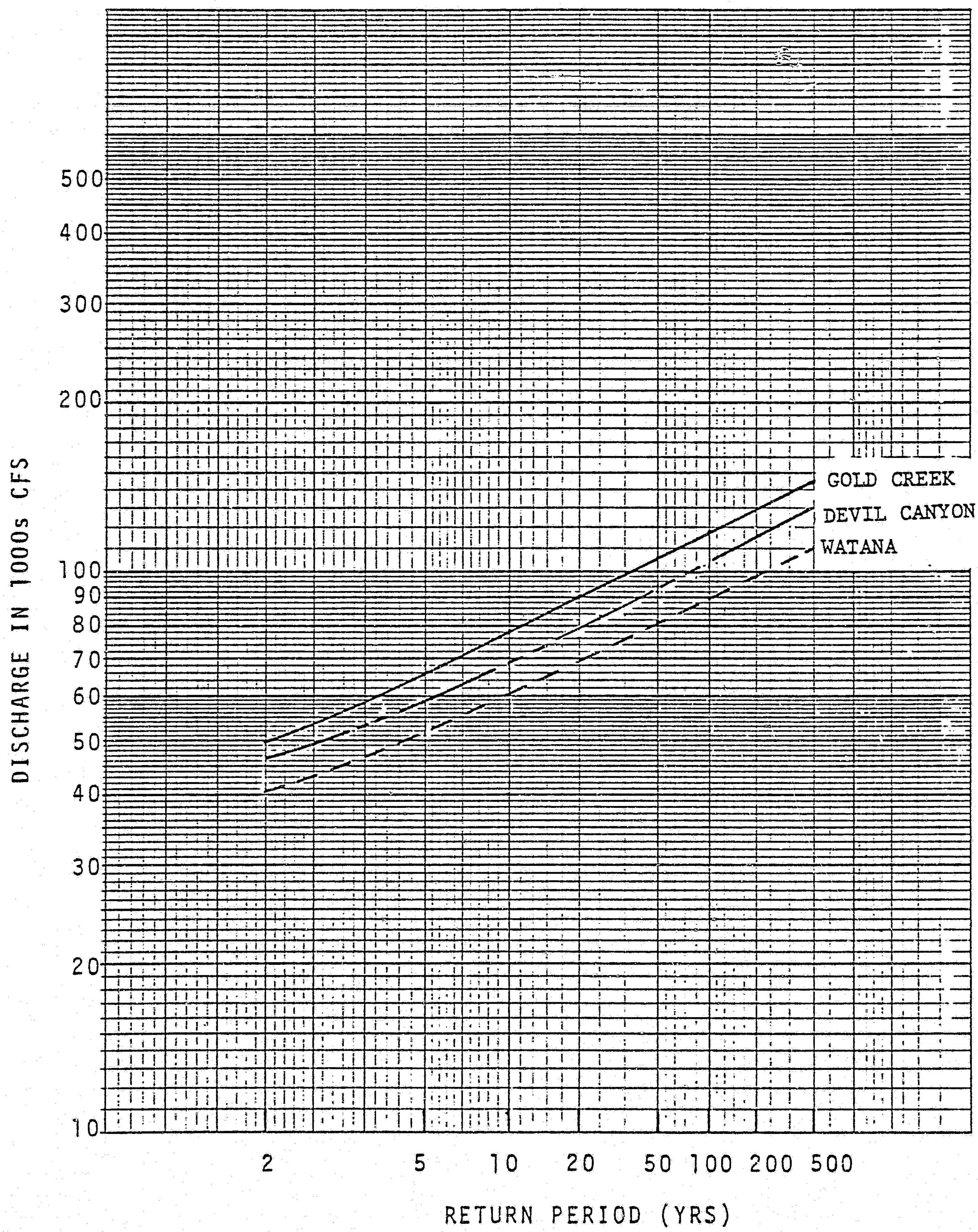

ANNUAL SUSPENDED SEDIMENT DURATION CURVE (REVISED)
SUSITNA RIVER AT SUSITNA STATION
CHULITNA RIVER
SUSITNA RIVER DENALI AT
SUSITNA RIVER AT GOLD CREEK
SUSITNA RIVER AT VEE CANYON
MACLAREN RIVER NEAR PAXON
TALKEETNA
SEDIMENT DISCHARGE (TONS/DAY)
10^6
10^5
10^4
10^3
10^2
0
10
20
30
40
50
60
% OF TIME SUSPENDED SEDIMENT DISCHARGE EXCEEDED DURING YEAR

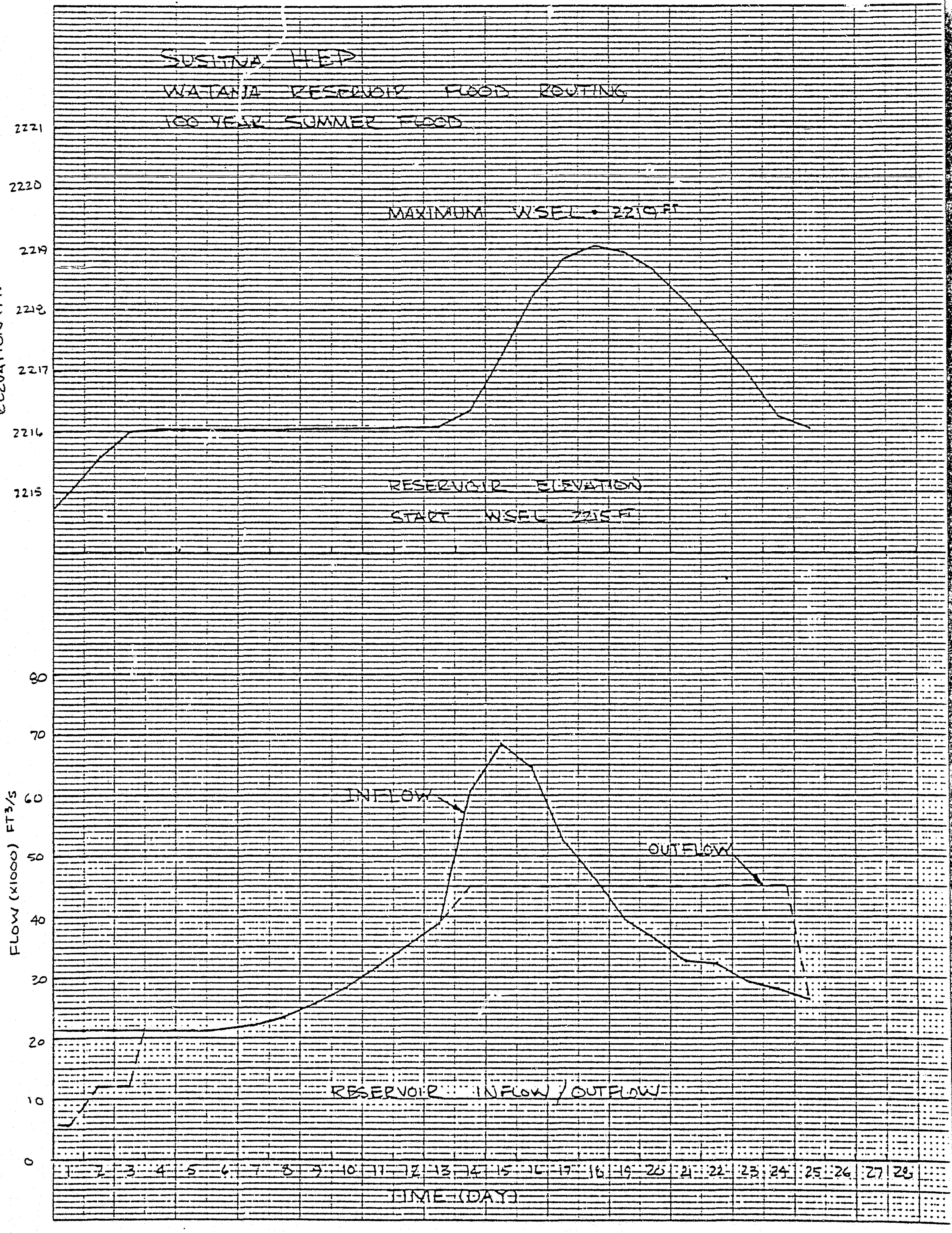


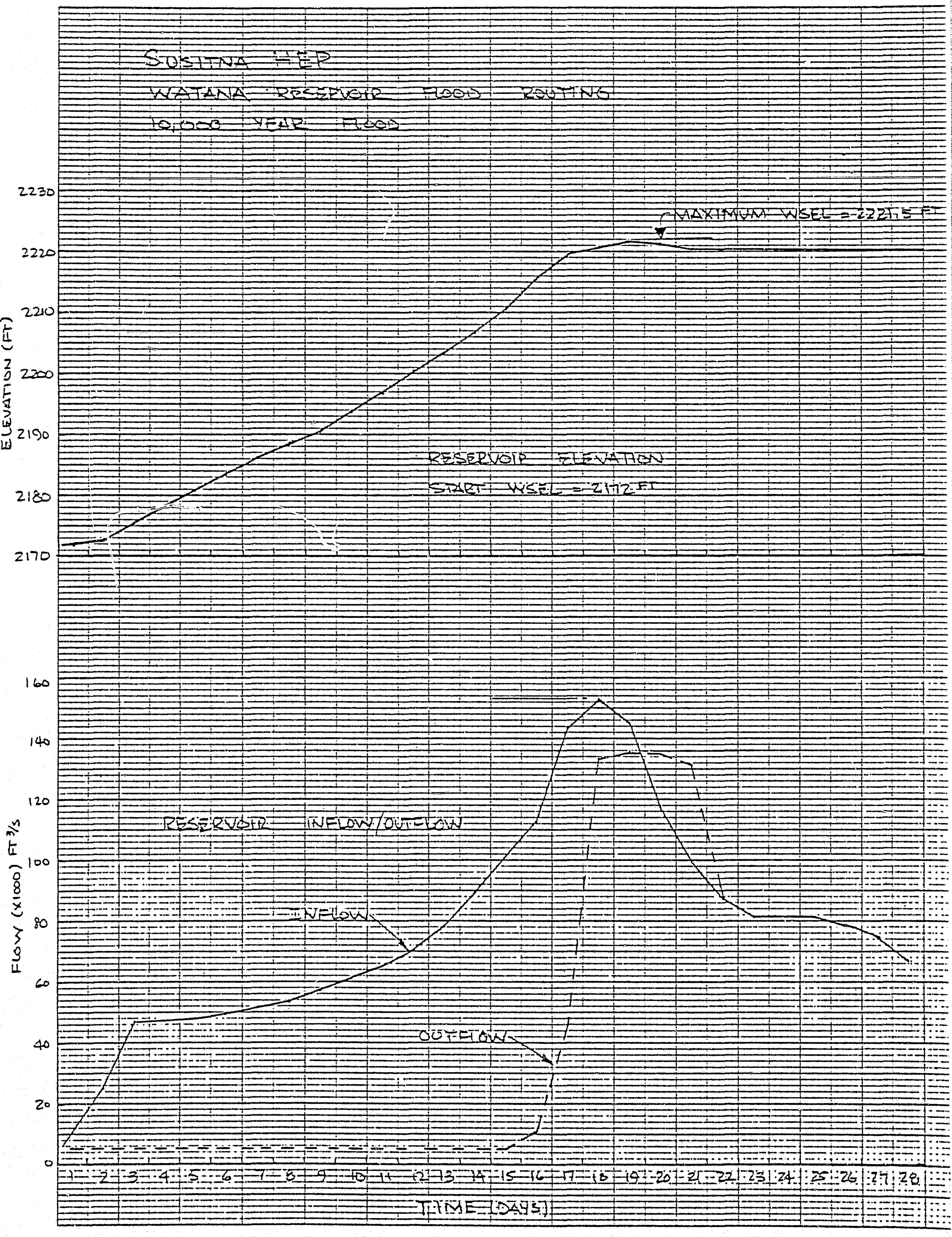
99.99
99.9
99.8
99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01
SUSITNA
FLOOD FREQUENCY CURVES
FOR
WATANA INFLOW
200,000
100,000
40,000
10,000
DISCHARGE
ANNUAL FLOOD SERIES
SUMMER FLOOD SERIES
PS100.03
DC
2 OCT 81
RETURN PERIOD
1.25
2
5
10
20
50
100
500
1000
10,000

FLOOD FREQUENCY CURVES

PRE-PROJECT




SUSITNA HEP
WATANA RESERVOIR FLOOD ROUTING
100 YEAR SUMMER FLOOD
MAXIMUM WSEL • 2219 FT
RESERVOIR ELEVATION
START WSEL 2215 FT
ELEVATION (FT)
2221
2220
2219
2218
2217
2216
2215
INFLOW
OUTFLOW
RESERVOIR INFLOW / OUTFLOW
FLOW (X1000) FT3/S
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
TIME (DAY)



SUSITNA HEP
WATANA RESERVOIR FLOOD ROUTING
10,000 YEAR FLOOD
ELEVATION (FT)
2230
2220
2210
2200
2190
2180
2170
MAXIMUM WSEL = 2221.5 FT
RESERVOIR ELEVATION
START WSEL = 2172 FT
FLOW (X1000) FT3/S
160
140
120
100
80
60
40
20
0
RESERVOIR INFLOW/OUTFLOW
INFLOW
OUTFLOW
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
TIME (DAYS)

WATANA SPILLWAYS

FACILITY	FLOOD FLOWS (FT^3/S) RETURN PERIOD 1:100	1:10,000	PMF	COST MILLION $
CASCADE	ALL (1)	120,000	120,000	264
HB	ALL (1)	30,000	30,000	50
FLIP		90,000	90,000	130
EMERGENCY	-	-	150,000	47

ENVIRONMENTAL CONSIDERATIONS

DESIGN CONSIDERATIONS

(1) EXCEPT FOR FLOW THROUGH POWERHOUSE

DEVIL CANYON SPILLWAYS

FACILITY	FLOOD FLOW (FT^3/S) RETURN PERIOD 1:100	1:10,000	PMF	COST MILLION $
STILLING BASIN	0	90,000	90,000	85
FLIP	0	90,000	90,000	47
HB	ALL (1)	50,000	50,000	COMMON
EMERGENCY	_	_	160,000	25

ENVIRONMENTAL CONSIDERATIONS

DESIGN CONSIDERATIONS

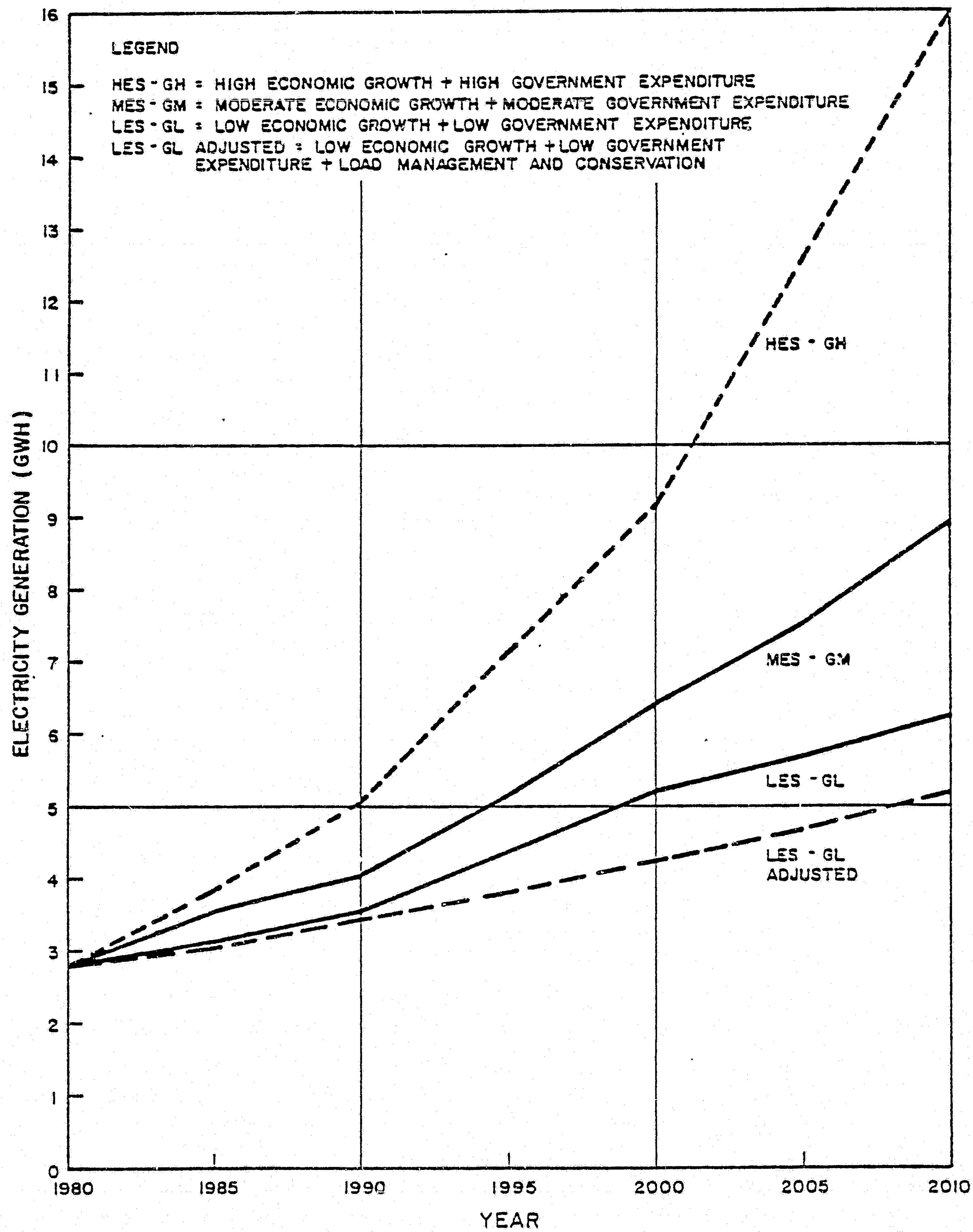
(1) EXCEPT FOR FLOW THROUGH POWERHOUSE

ALASKA POWER AUTHORITY P5700.13

SUSITNA HYDROELECTRIC PROJECT
External Review Board Meeting No. #3

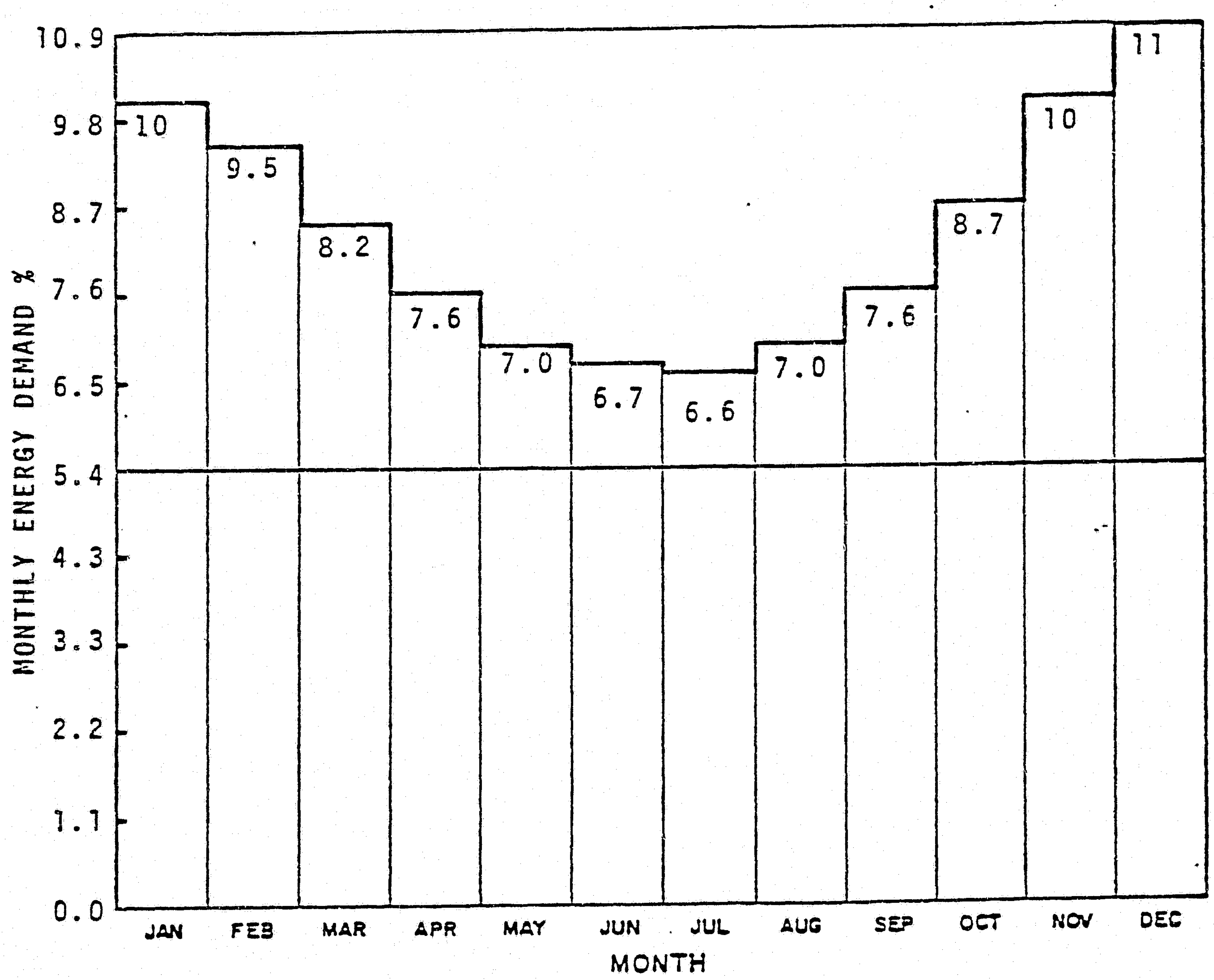
MINUTES OF MEETING HELD ON
October 6 - 8, 1981, BUFFALO, NEW YORK

Presentation on: Power Developments - J. Hayden



ENERGY FORECASTS USED FOR GENERATION PLANNING STUDIES

ACRES



FORECAST MONTHLY ENERGY DEMAND

REF: WOODWARD CLYDE CONSULTANTS,
"FORECASTING PEAK ELECTRIC
DEMAND FOR ALASKA'S RAILBELT"

ACRES

ENERGY DEMAND (GWH)

MEDIUM FORECAST

	DEMAND (YEAR)			POTENTIAL GENERATION (AVERAGE)	
	1993	2000	2020	WATANA & D.C. W/O TUNNEL	WATANA & D.C. WITH TUNNEL
JAN	484	655	911	607	612
FEB	422	564	784	577	609
MAR	420	571	793	516	521
APR	362	490	685	455	468
MAY	335	460	638	425	430
JUN	310	428	599	407	420
JUL	309	422	592	478	483
AUG	326	447	623	727	729
SEP	343	467	655	682	695
OCT	410	558	777	528	533
NOV	466	633	881	607	621
DEC	526	714	998	662	665

POWER REQUIREMENT (MW)
DECEMBER

YEAR	PEAK DEMAND	SMALL HYDRO	THERMAL[3]	SUSITNA
1993	860	144	149	567
2000	1,173	144	403/0[4]	626/1029[4]
2010	1,635	144	372	1,119
2040 (EST)	4,443	144	2,676	1,623
2010[1]	2,901	144	1,422	1,335
2010[2]	1,855	144	372	1,339

(1) HIGH LOAD FORECAST

(2) LOAD FACTOR OF 55%

(3) BASE LOADED

(4) WITH DEVIL CANYON ON-LINE

EXAMPLE CALCULATION

DECEMBER 2010

DEMAND	MID RANGE FORECAST	HIGH RANGE FORECAST
ENERGY (GWH)	998	1,779
PEAK POWER (MW)	1,635	2,901
ENERGY SUPPLY (GWH)		
SMALL HYDRO	59	59
THERMAL	277	1,058
SUSITNA	662	662
POWER SUPPLY (MW)		
SMALL HYDRO	144	144
THERMAL (1)	372	1,422
SUSITNA (2)	1,119	1,335
WATANA	750	900
DEVIL CANYON	450	450

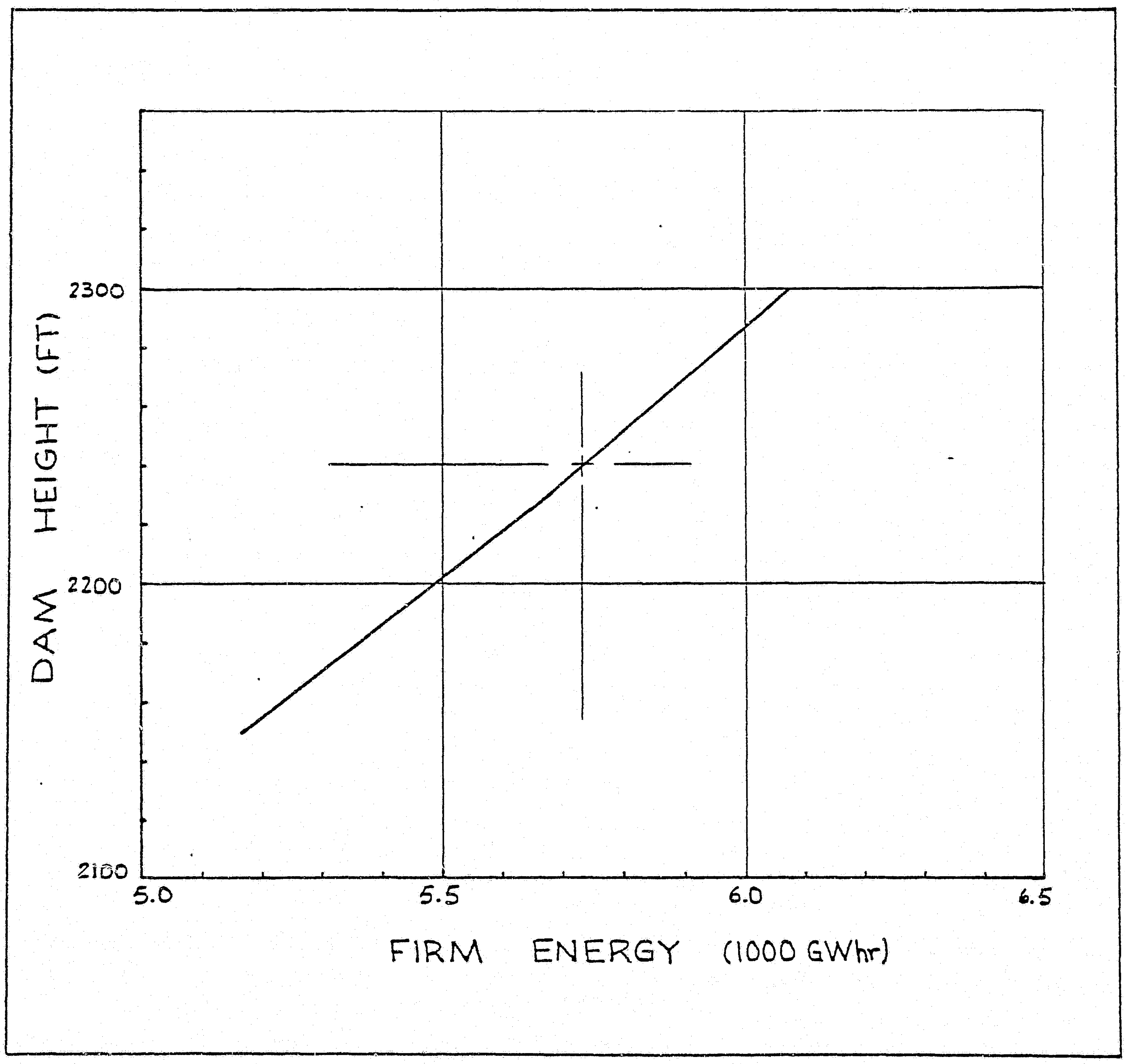
(1) 100% LOAD FACTOR

(2) USING 150 MW UNIT SIZE

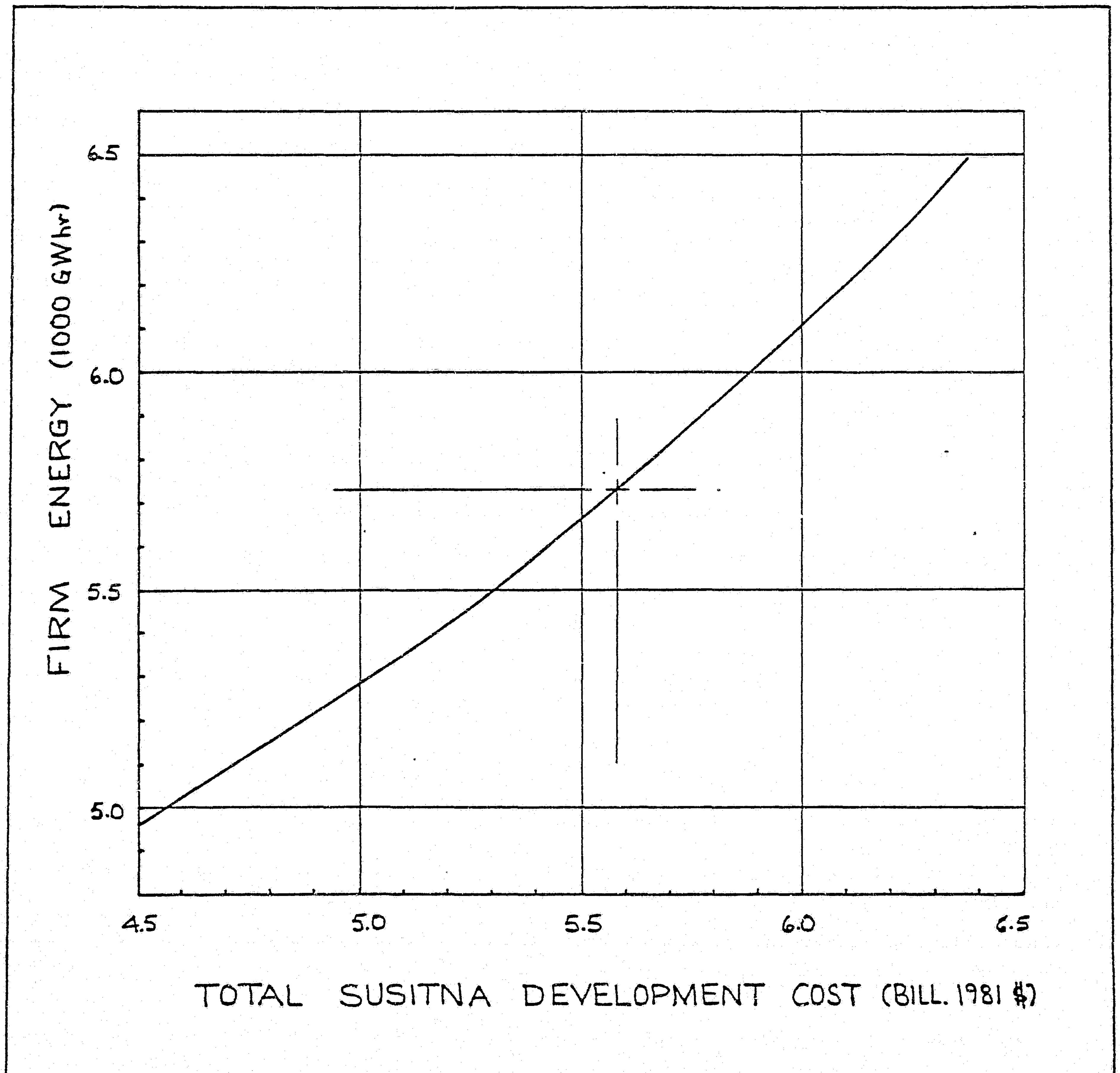
SUSITNA HYDROELECTRIC PROJECT

SUMMARY COMPARISON OF POWERHOUSES AT WATANA

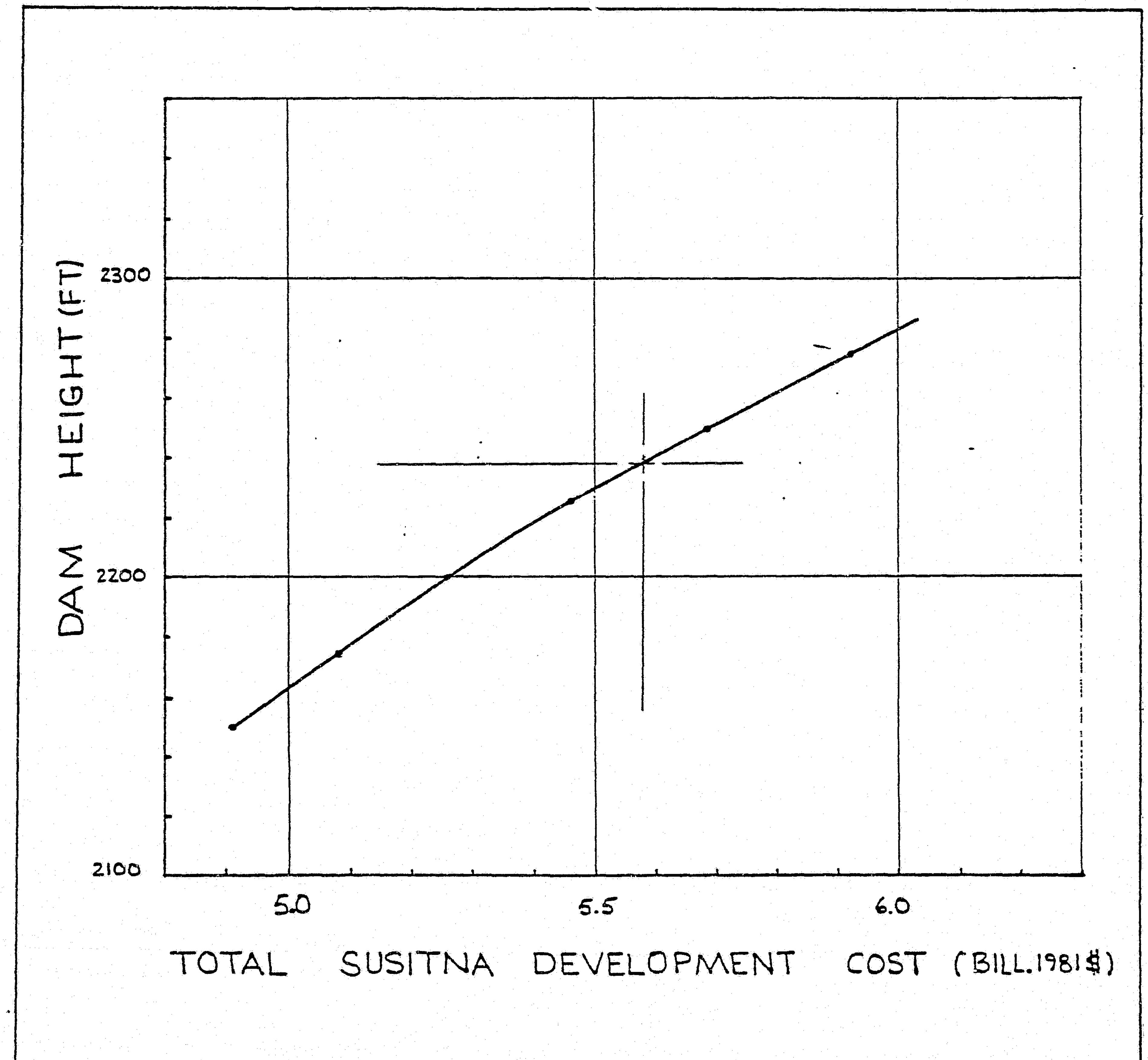
ITEM	SURFACE ($000) 4 x 210 MW	UNDERGROUND ($000) 4 x 210 MW	UNDERGROUND ($000) 6 x 140 MW
CIVIL WORKS			
INTAKES	54,000	54,000	70,400
PENSTOCKS	72,000	22,700	28,600
POWERHOUSE/ DRAFT TUBE	29,600	26,300	28,100
SURGE CHAMBER	NA	4,300	4,800
TRANSFORMER GALLERY	NA	2,700	3,400
TAILRACE TUNNEL	NA	11,000	11,000
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

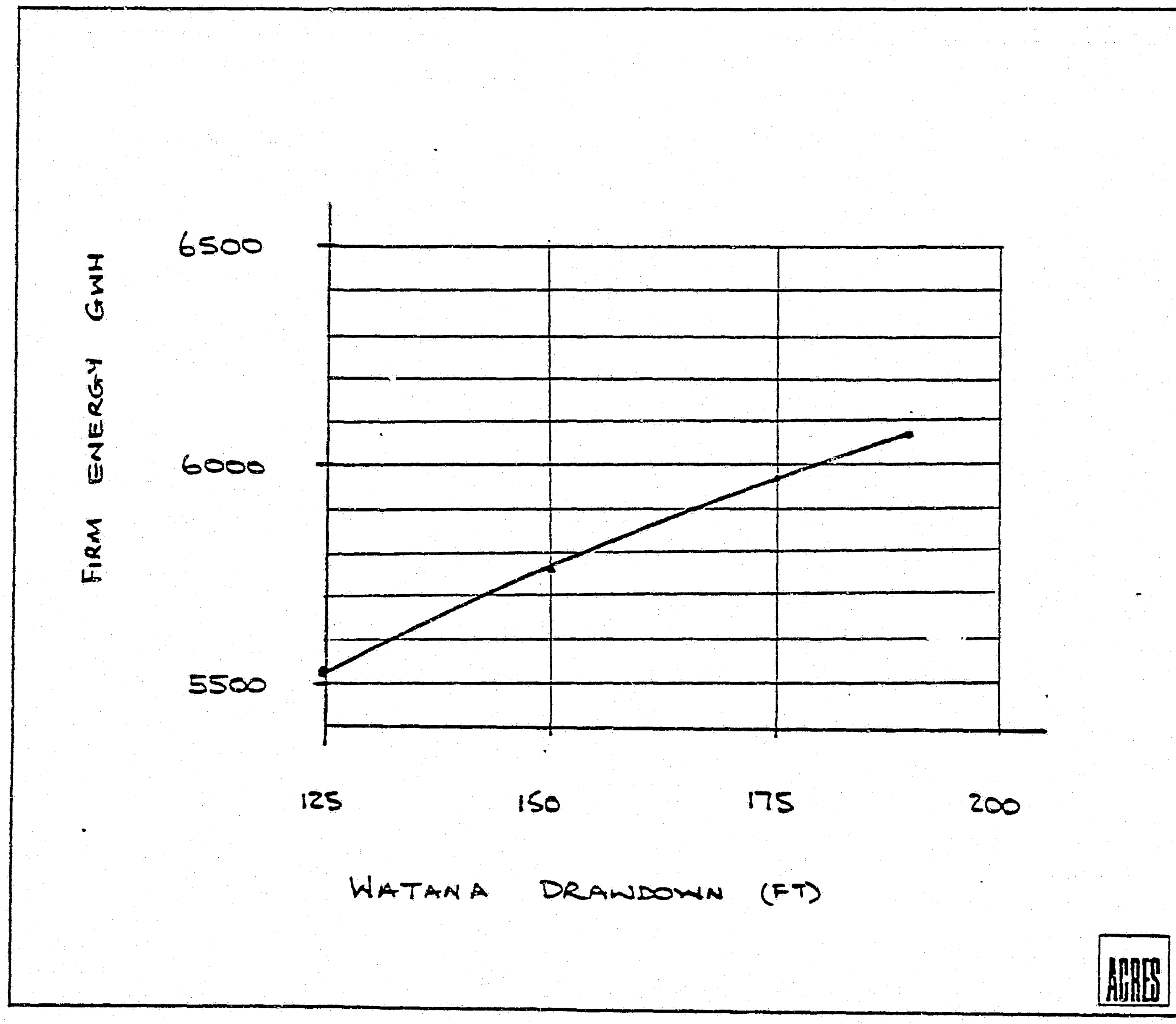


DAM HEIGHT (FT)
2300
2200
2100
5.0
5.5
6.0
6.5
FIRM ENERGY (1000 GWhr)



FIRM ENERGY (1000 GWhr)
6.5
6.0
5.5
5.0
4.5
5.0
5.5
6.0
6.5
TOTAL SUSITNA DEVELOPMENT COST (BILL. 1981 $)


DAM HEIGHT (FT)
2300
2200
2100
5.0
5.5
6.0
TOTAL SUSITNA DEVELOPMENT COST (BILL.1981$)



FIRM ENERGY GWH
6500
6000
5500
125
150
175
200
WATANA DRAWDOWN (FT)
ACRES

ALASKA POWER AUTHORITY P5700.13

SUSITNA HYDROELECTRIC PROJECT

EXTERNAL REVIEW BOARD MEETING #3
OCTOBER 6-8, 1981, BUFFALO, NY

Presentation on Watana Layout Studies - J. Lawrence

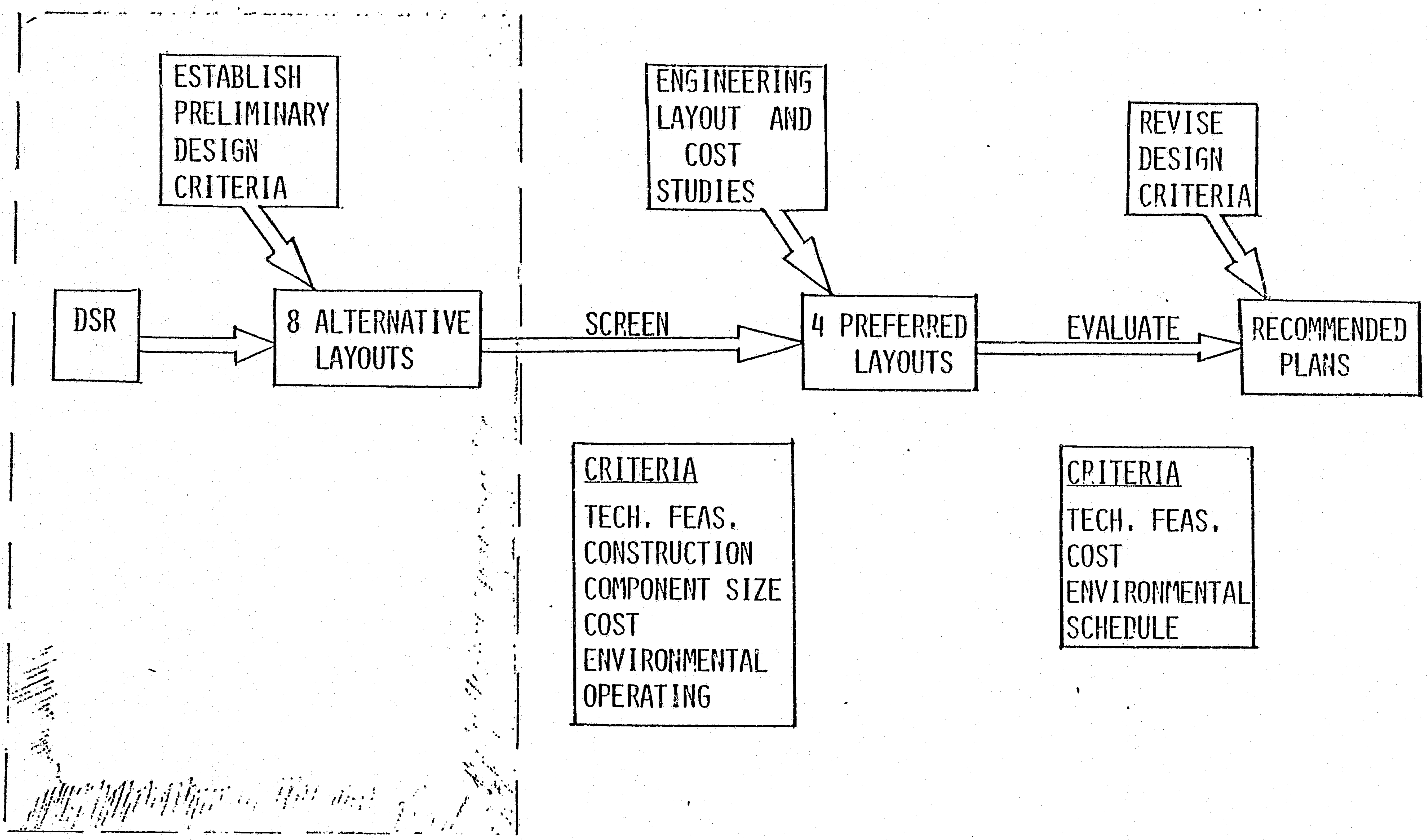
WATANA LAYOUT - DSR
(JUNE, 1981)

- DAM:	EARTH/ROCKFIL
o CREST:	EL. 2225 FT.
o HEIGHT:	880 FT. ABOVE ROCK
o VOLUME:	63 MILLION CU. YDS.
o SLOPES:	2.75H: IV U/S
	2H: IV D/S
o COFFERDAMS:	INTEGRAL
- SPILLWAY	OGEE - 3 GATES
o CAPACITY:	235,000 CFS (PMF)
o TYPE:	CHUTE AND FLIP BUCKET
o LOCATION:	RIGHT BANK
- POWER PLANT:	800 MW (ULT.), LEFT BANK
- DIVERSION:	2 - 35 FT. DIA. TUNNELS, RIGHT BANK

MAJOR DESIGN CONSIDERATIONS

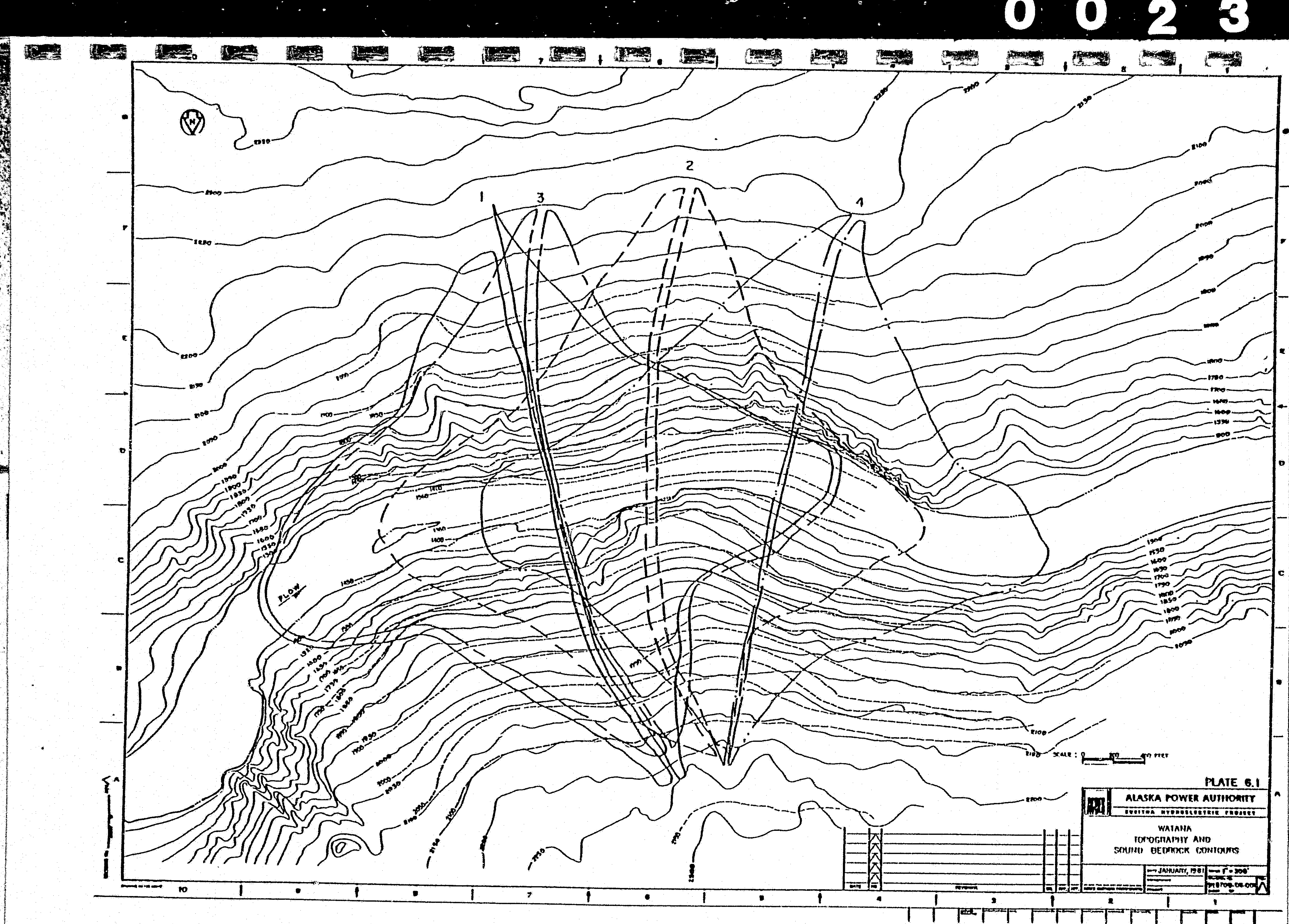
- SEISMIC LOADING
- FLOOD HANDLING CAPABILITY
- EMBANKMENT DESIGN
- ARCH DAM DESIGN
- UNDERGROUND/FOUNDATION CONDITIONS
- RELICT CHANNEL
- RIVER CONDITIONS DOWNSTREAM
- ENVIRONMENTAL DISTURBANCE
- OPTIMUM SIZE & SCHEDULE
- AVAILABILITY OF MATERIALS

WATANA LAYOUT SELECTION PROCESS



DESIGN CONCERNS - WATANA

- DAM FOUNDATION, SLOPES, MATERIALS
- DIVERSION TUNNEL PORTALS, COFFERDAM FOUNDATION
- SPILLWAY DESIGN CONCEPT, CAPABILITY, PERFORMANCE, N_2 SUPERSATURATION
- RESERVOIR LEVEL/FREEBOARD
- LOW LEVEL RELEASES
- RELICT CHANNEL
- POWER DEVELOPMENT LOCATION/SIZE
- COST OPTIMIZATION



0 0 2 3 6
1
2
3
4
FLOW
SCALE : 0 200 400 FEET
PLATE 6.1
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA
TOPOGRAPHY AND
SOUND BEDROCK CONTOURS
JANUARY, 1981
1" = 300'

WATANA ALTERNATIVES

DAM ALTERNATIVES		POWERPLANT		EMERGENCY SPILLWAY		MAIN SPILLWAY	
C/L NO.	SLOPES	LOCATION	TYPE	LOCATION	TYPE	LOCATION	TYPE
1	A	L	UN	-	-	R	CH
2 2A 2B	B	R	SU	-	-	L	CA/S CA/D SB/D
2C	B	R	SU	L	UC	L	SB/D
2D	B	R	UN	-	-	L	CH
3	A	L	UN	R	L	L	CA/S
4	A	L	UN	-	-	L	CH

LEGEND:

A - 2.5:1 U/S, 2:1 D/S
B - 2.25:1 U/S, 2:1 D/S
L - LEFT BANK
R - RIGHT BANK

UN - UNDERGROUND
SU - SURFACE
S - SINGLE
D - DOUBLE

CH - CHUTE & FLIP BUCKET
CA - CASCADE
SB - STILLING BASIN
UC - UNLINED CHANNEL

WATANA DAM ALTERNATIVES (PRELIMINARY)

ALT. NO.	VOLUME (CU. YD.)
1	69.3
2	71.7
3	69.3
4	71.9

WATANA LAYOUT EVALUATIONS

STRUCTURE	DETERMINATION	OBJECTIVE
DAM	- C/L ALTERNATIVE 1	- REDUCE COST EASE CONGESTION
	- DESIGN SECTION	- TECH. FEASIBILITY
	- STEEPEN U/S SLOPE	- REDUCE COST, EASE CONGESTION
DIVERSION	- TWO TUNNELS	- TECH. FEASIBILITY
	- OPTIMIZE SIZE	- REDUCE COST
	- RIGHT BANK	- REDUCE COST/ACCESS
	- INCORPORATE OUTLETS	- ENVIRONMENTAL/FEASIBLE OPERATION
POWER FACILITIES	- UNDERGROUND P/H	- REDUCE COST/OPERATION
	- LOCATE GOOD ROCK	- TECH. FEASIBILITY (COST PENALTY)
SPILLWAY	- SINGLE DISCHARGE UNACCEPTABLE	- TECH. & ENVIR. FEASIBILITY
	- SEPARATE EMERGENCY FAC.	- TECH. FEASIBILITY (COST PENALTY)
	- RIGHT BANK CHUTE/FLIP PREFERRED	- REDUCE COST (ENVIRONMENTAL PENALTY)
	- EVALUATE LEFT BANK CASCADE	- ENVIRONMENTAL BENEFITS (COST PENALTY)

PREFERRED WATANA LAYOUTS

SCHEME NO.	POWERPLANT LOCATION	POWERPLANT TYPE	EMERG. SPILLWAY LOCATION	EMERG. SPILLWAY TYPE	MAIN SPILLWAY LOCATION	MAIN SPILLWAY TYPE
WP1	L	UN	-	-	R	CH
WP2	L	UN	R	UC	R	SB
WP3	L	UN	R	UC	R	CH
WP4	R	UN	-	-	L	CA

ALL SCHEMES:

- DAM C/L ALT. 1; 2.75H:1V U/S, 2H: 1V D/S SLOPES; SEPARATE COFFERDAMS.
- RIGHT BANK DIVERSION 2 - 35 FT DIA. TUNNELS.
- INSTALLED CAPACITY 800 MW, 4 UNITS, 18 FT. DIA. PENSTOCKS, 2 - 30 FT DIA. TAILRACE TUNNELS.

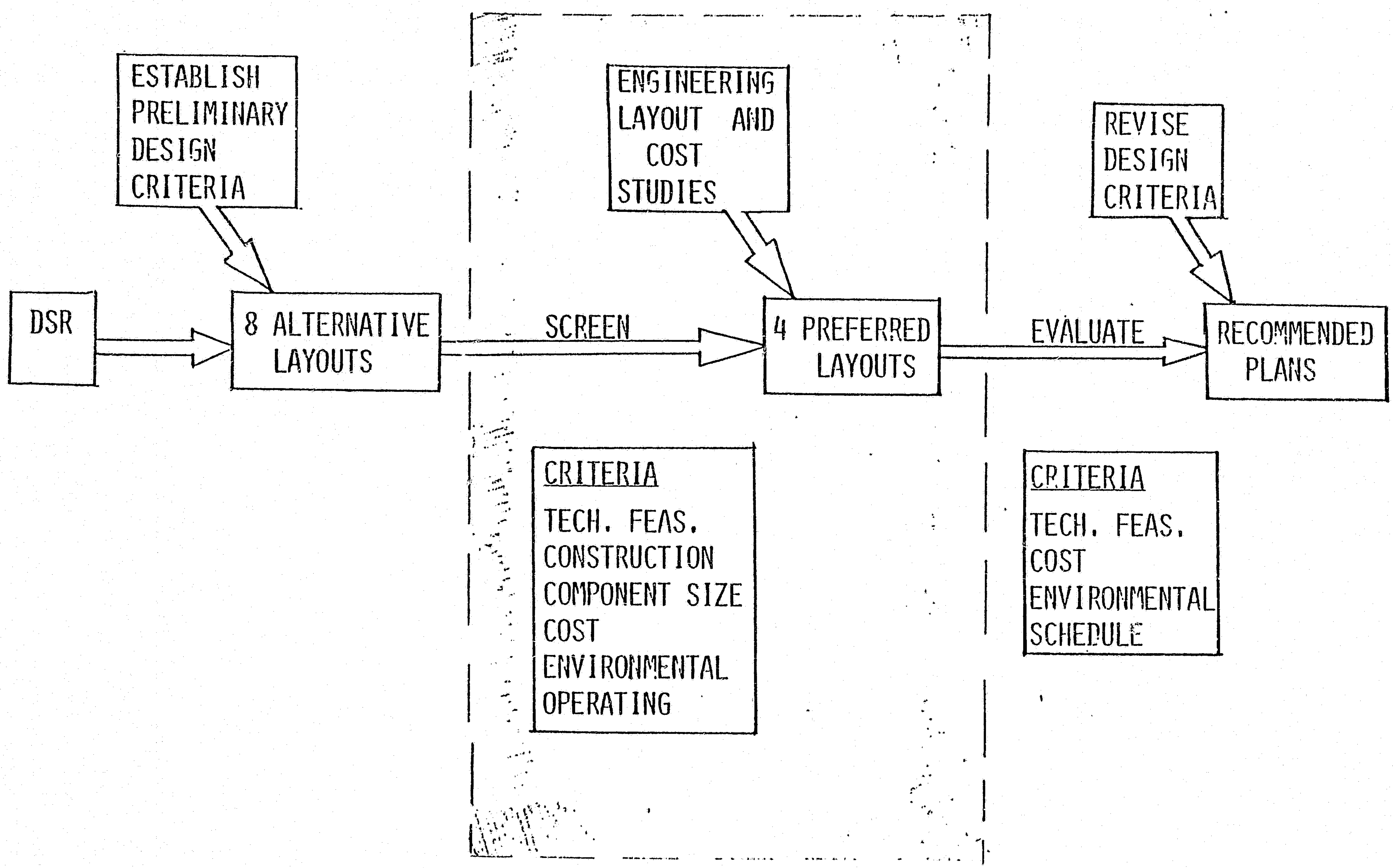
LEGEND:

L - LEFT BANK
R - RIGHT BANK
UN - UNDERGROUND

UC - UNLINED CHANNEL
CH - CHUTE & FLIP BUCKET
SB - STILLING BASIN

CA - CASCADE, DOUBLE GATE STRUCTURE

WATANA LAYOUT SELECTION PROCESS



PREFERRED WATANA LAYOUTS

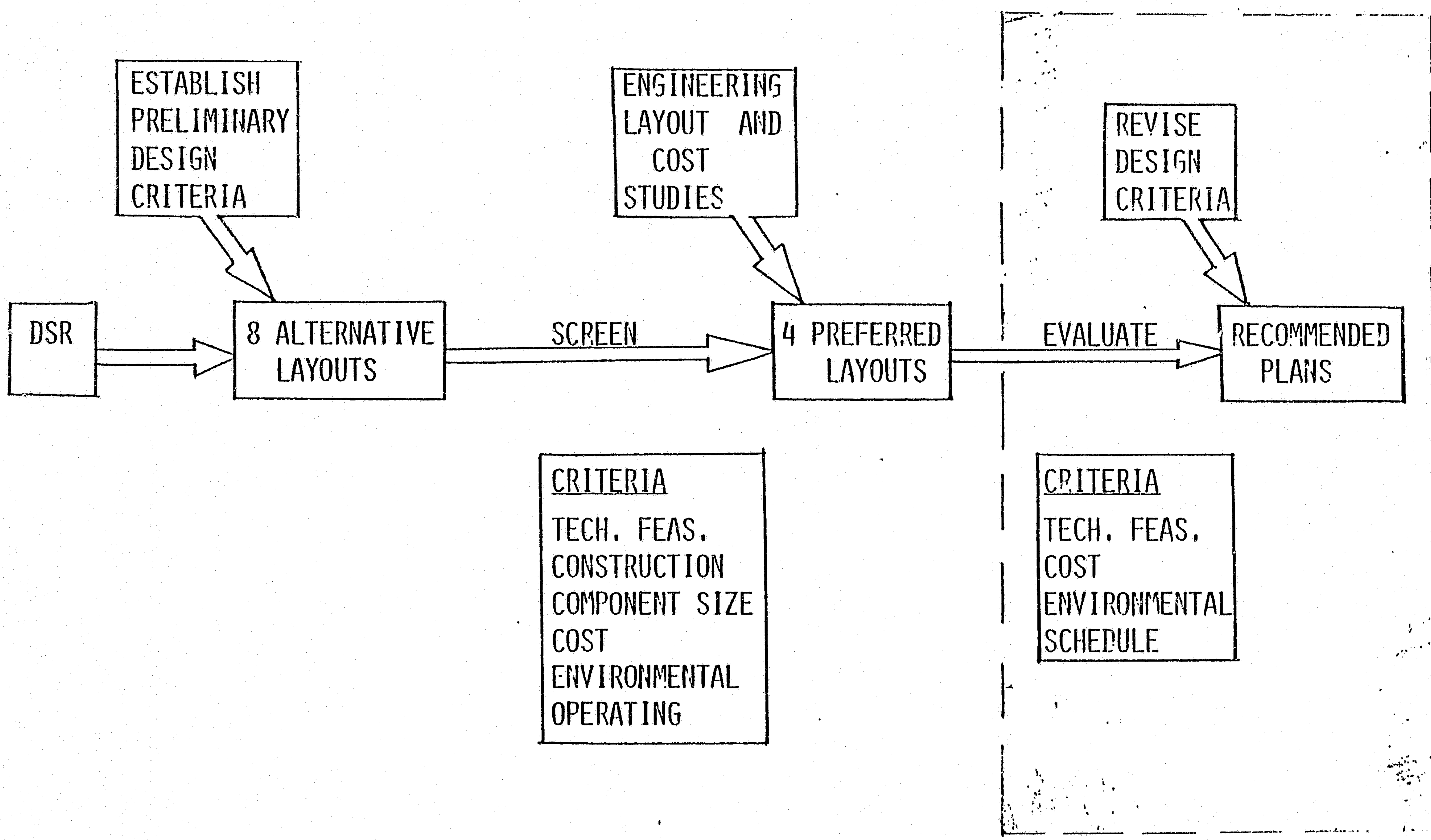
ITEM	WP1	WP2	WP3	WP4
	COST COMPARISONS MILLIONS OF DOLLARS (82)			
LAND & CLEARING	53	53	53	53
DIVERSION	101	113	101	103
MAIN DAM	1,221	1,201	1,214	1,160
MAIN SPILLWAYS	128	208	122	267
EMERGENCY SPILLWAY	-	47	47	-
POWER FACILITIES	288	288	288	283
ROADS & MISC.	83	83	83	83
SUBTOTAL	1,874	1,993	1,908	1,949
CAMP, CONTINGENCY, ETC.*	1,061	1,128	1,079	1,102
TOTAL	2,935	3,121	2,987	3,051

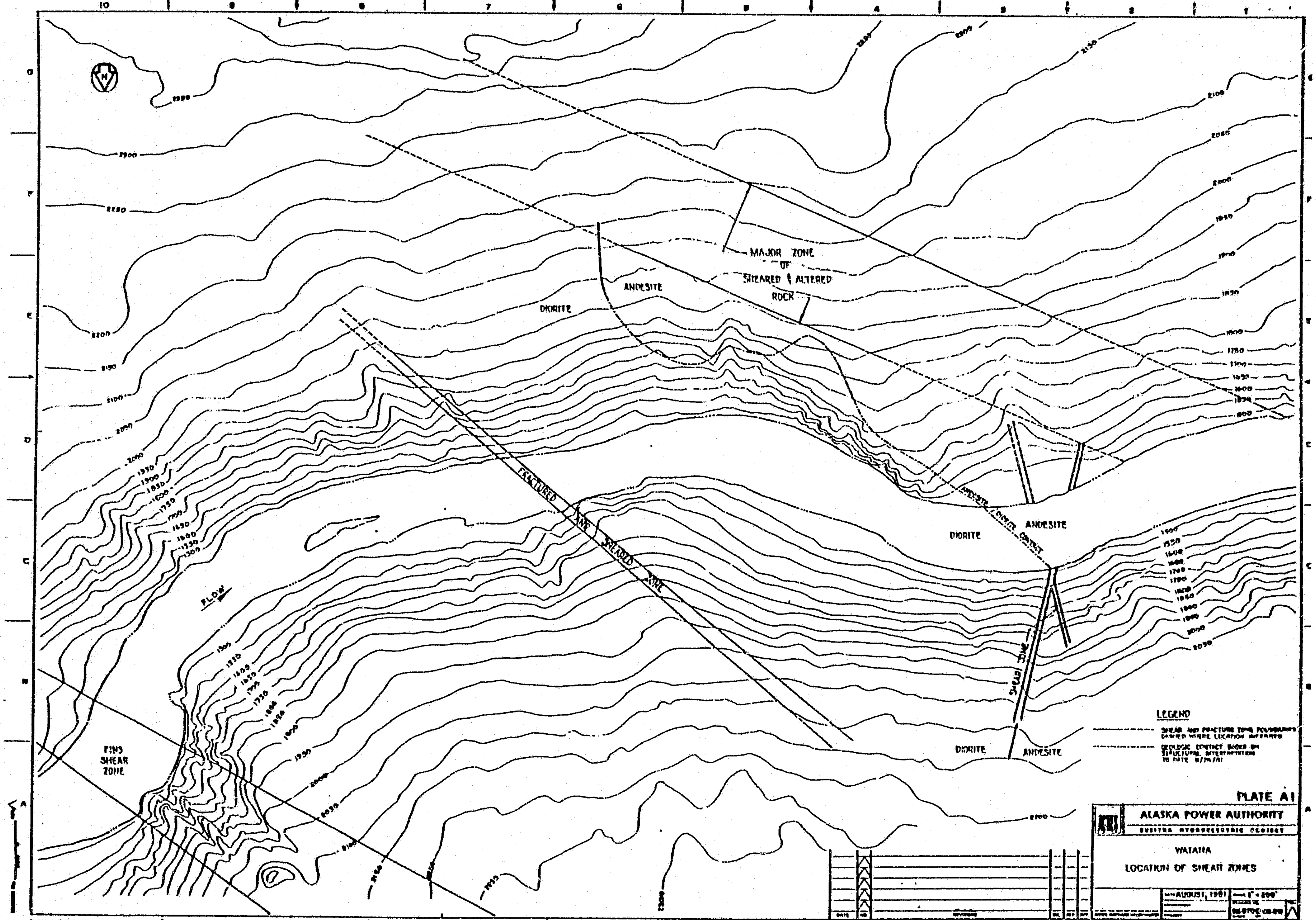
* CAMP & SUPPORT: 16%
CONTINGENCY: 20%
ENGINEERING/OWNER: 12.5%

WATANA PREFERRED LAYOUT EVALUATIONS

STRUCTURE	DETERMINATION	OBJECTIVE
DAM	- OPTIMIZE C/L - STEEPEN U/S SLOPE	REDUCE COST, EASE CONJESTION
DIVERSION	- LOWER COFFERDAM - OPTIMIZE ALIGNMENT	EASE CONGESTION AT PORTALS
	- TWO LEVELS	- FEASIBLE OUTLET DESIGN
POWER FACILITIES	- RIGHT BANK	- TECH. FEASIBILITY, COST
	- OPTIMIZE INSTALLATION	- REDUCE COST
	- OPTIMIZE TAILRACE ALIGNMENT	- EASE CONGESTION
SPILLWAY	- RIGHT BANK CHUTE/FLIP	- REDUCE COST, ENVIRONMENTAL PENALTY
	- RIGHT BANK EMERGENCY	- TECH. FEASIBILITY, COST
	- OPTIMIZE LEFT BANK CASCADE	- POTENTIAL ENVIRONMENTAL BENEFITS, MINIMIZE COST PENALTY

WATANA LAYOUT SELECTION PROCESS





MAJOR ZONE OF SHEARED & ALTERED ROCK
ANDESITE
DIORITE
FRACTURED AND SHEARED ZONE
DIORITE
ANDESITE
SHEAR ZONE
DIORITE
ANDESITE
FLOW
FINS SHEAR ZONE
LEGEND
PLATE A1
ALASKA POWER AUTHORITY
WATANA
LOCATION OF SHEAR ZONES
AUGUST, 1981

ALASKA POWER AUTHORITY P5700.13

SUSITNA HYDROELECTRIC PROJECT
External Review Board Meeting No. #3

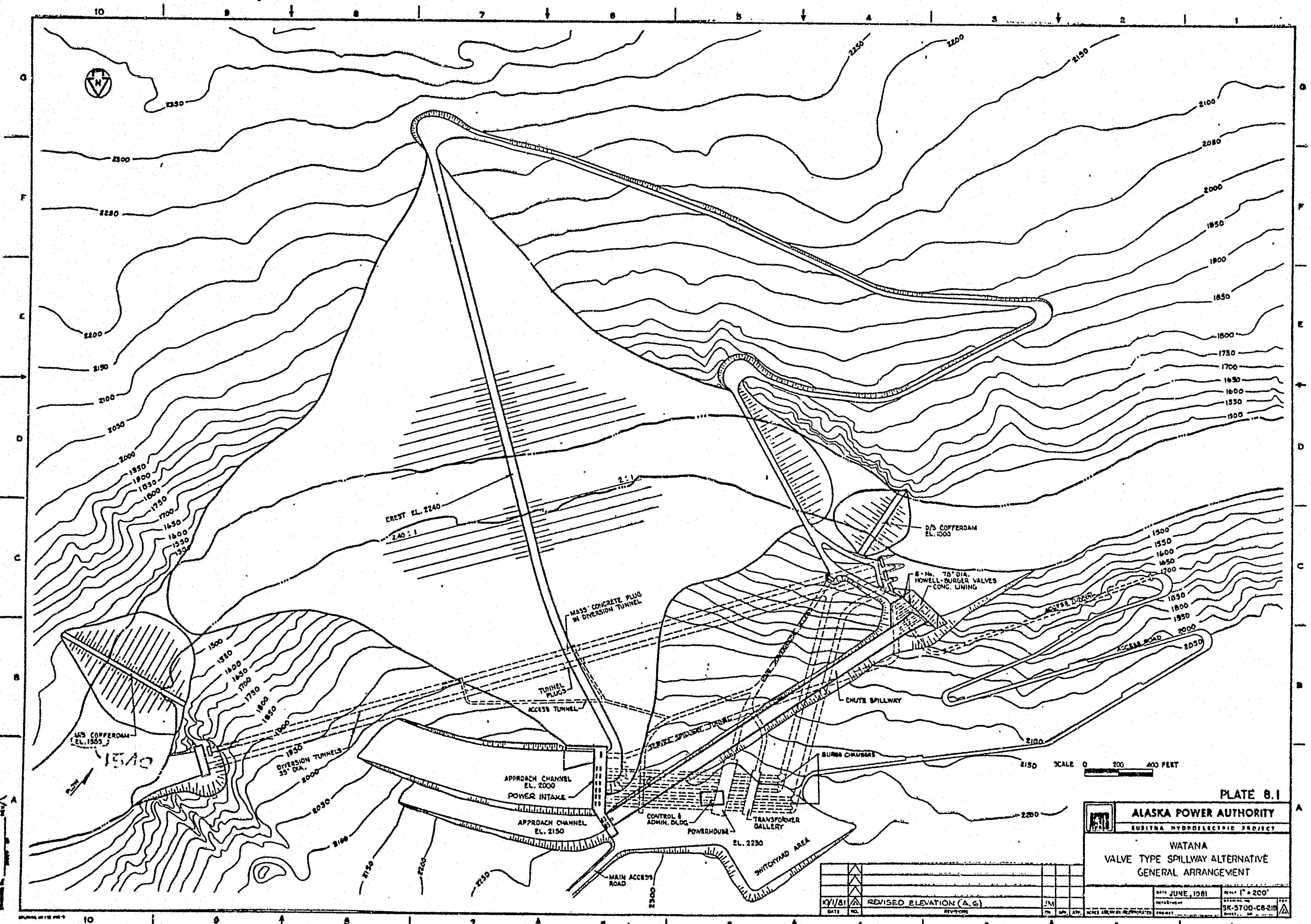
MINUTES OF MEETING HELD ON
October 6 - 8, 1981, BUFFALO, NEW YORK

Presentation on: Watana Low-Level Outlets - R. K. Ibbotson

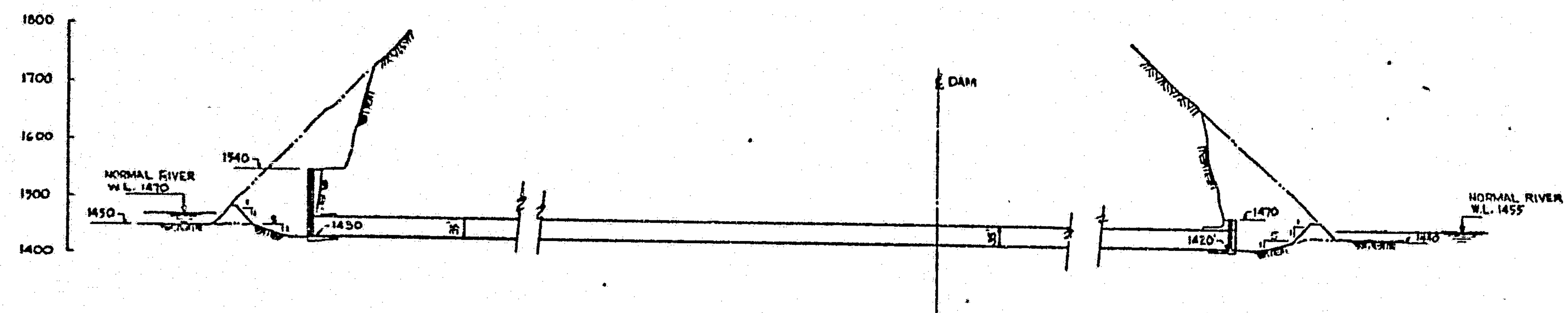
WATANA DIVERSION

PERIOD	FUNCTION	MAX. FLOW (CFS)
CONSTRUCTION	RIVER DIVERSION	76,000
RESERVOIR FILLING	BYEPASS TO PROVIDE D/S DISCHARGES	10,000 C.F.S.
OPERATION	EMERGENCY RESERVOIR DRAWDOWN	30,000 C.F.S.

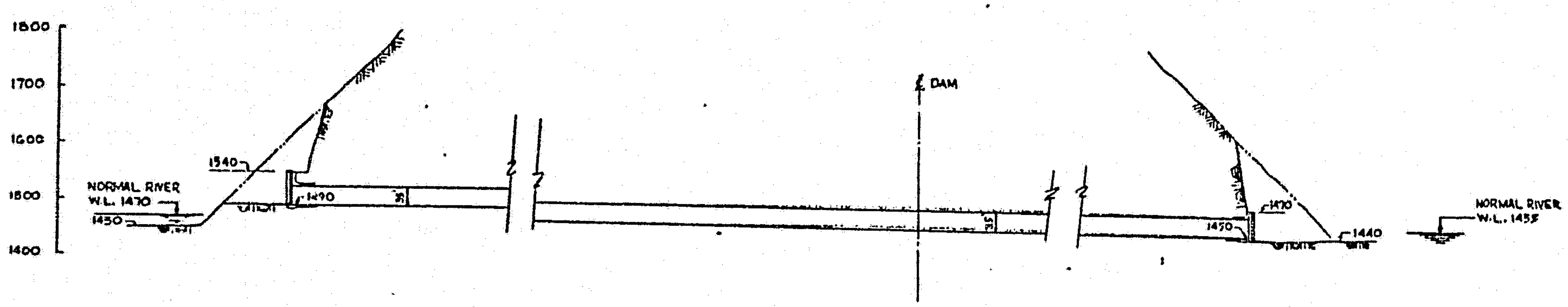
00236



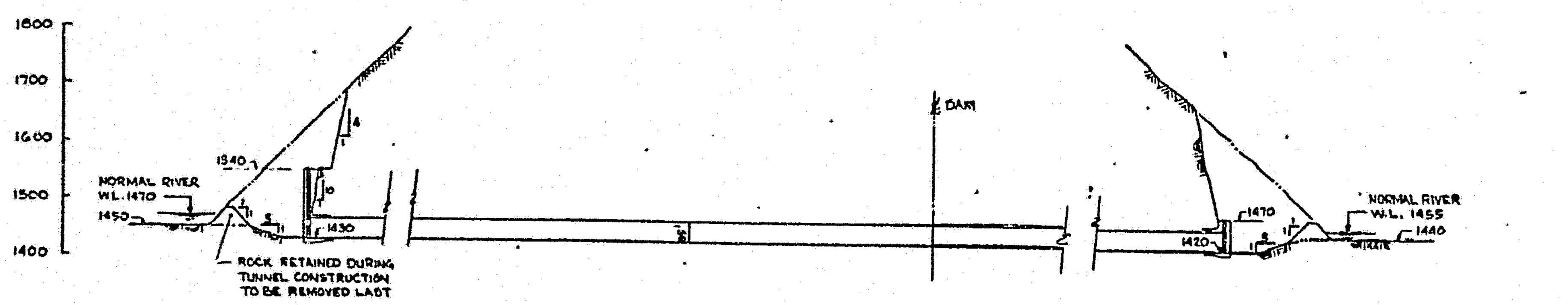
CREST EL. 2240
2.40 : 1
2 : 1
D/S COFFERDAM EL. 1503
U/S COFFERDAM EL. 1555
DIVERSION TUNNELS 35' DIA.
MASS CONCRETE PLUG IN DIVERSION TUNNEL
TUNNEL PLUGS
ACCESS TUNNEL
6 - No. 78" DIA. HOWELL-BURGER VALVES
CONC. LINING
ACCESS TUNNEL
ACCESS ROAD
CHUTE SPILLWAY
EMERGENCY SPILLWAY TUNNEL
SURGE CHAMBERS
APPROACH CHANNEL EL. 2000
POWER INTAKE
APPROACH CHANNEL EL. 2150
CONTROL & ADMIN. BLDG.
POWERHOUSE
TRANSFORMER GALLERY
EL. 2230
SWITCHYARD AREA
MAIN ACCESS ROAD
FLOW
SCALE 0 200 400 FEET
PLATE 8.1
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA
VALVE TYPE SPILLWAY ALTERNATIVE
GENERAL ARRANGEMENT
JUNE, 1981
1" = 200'
SK-5700-C8-21B
10/1/81 REVISED ELEVATION (A, G) JM



LEFT TUNNEL DURING DIVERSION-SUBMERGED OUTLET (ALT. 1)



LEFT TUNNEL DURING DIVERSION-FREE OUTLET (ALT. 2)



RIGHT TUNNEL DURING DIVERSION

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

WATANA
DIVERSION PROFILES

WATANA

DIVERSION TUNNELS

ECONOMIC DIAMETER OPTIMIZATION

PRESSURE TUNNEL

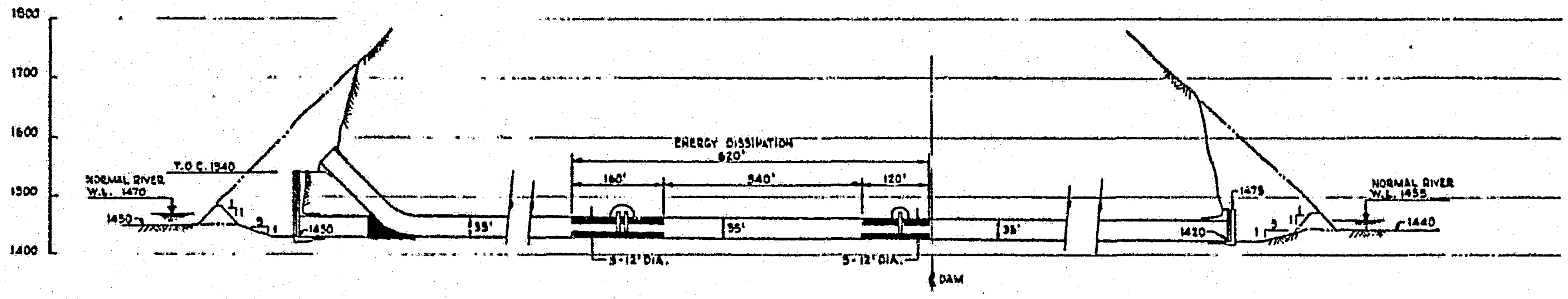
DIAMETER (FT) (2 TUNNELS)	TUNNEL COSTS $ X 1000	COFFERDAM COSTS $ X 1000	TOTAL COSTS(1) $ X 1000
25	47,000	29,500	76,500
30	56,000	10,000	66,000
35	66,500	3,500	70,000
40	83,000	1,500	84,500

FREE FLOW TUNNEL

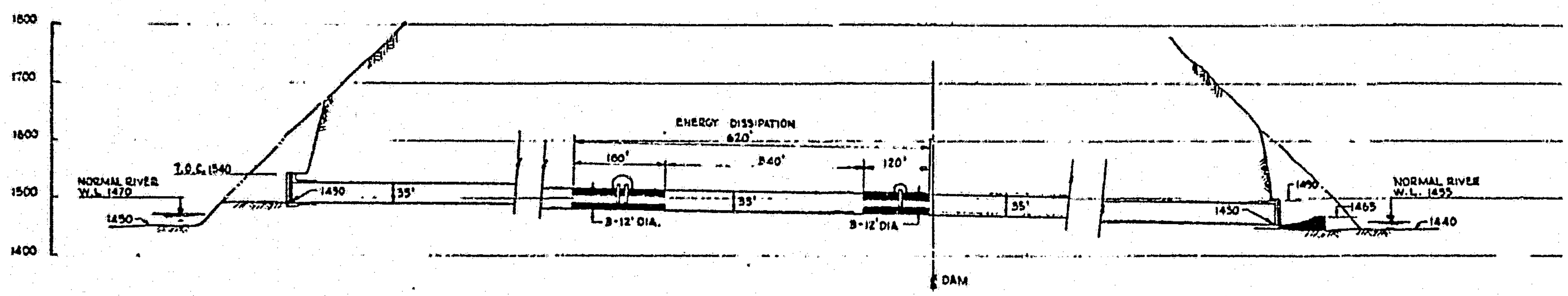
DIAMETER (FT)	TUNNEL COSTS $ X 10000	COFFERDAM COSTS $ X 1000	TOTAL COSTS(1) (2) $ X 1000
30	52,000	17,500	70,000
35	63,500	5,500	69,000
40	80,000	2,500	82,500

(1) TOTAL COSTS DO NOT INCLUDE INTAKE STRUCTURE AND GATES OR OUTLET STRUCTURE.

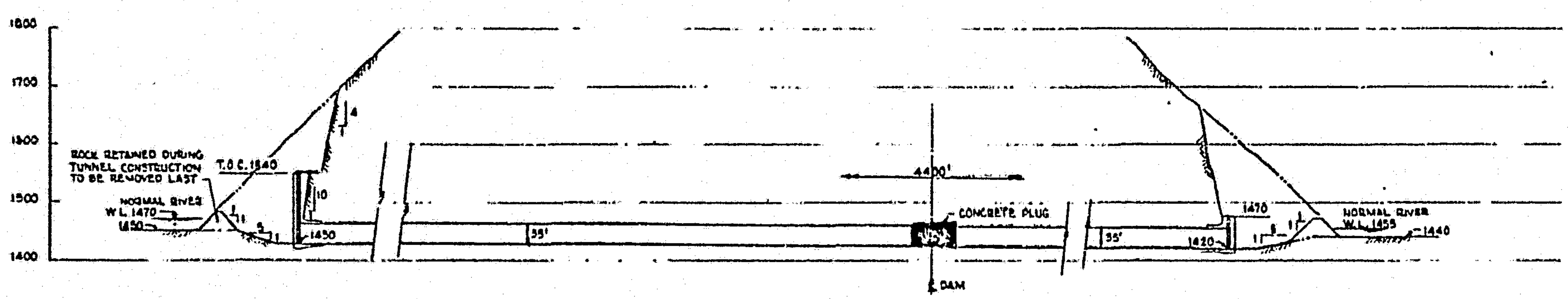
(2) TOTAL COSTS FOR FREE FLOW TUNNEL DO NOT INCLUDE ADDITIONAL COSTS FOR CLOSURE.



LEFT TUNNEL PERMANENT OPERATION - SUBMERGED OUTLET (ALT. 1)



LEFT TUNNEL PERMANENT OPERATION - FREE OUTLET (ALT. 2)

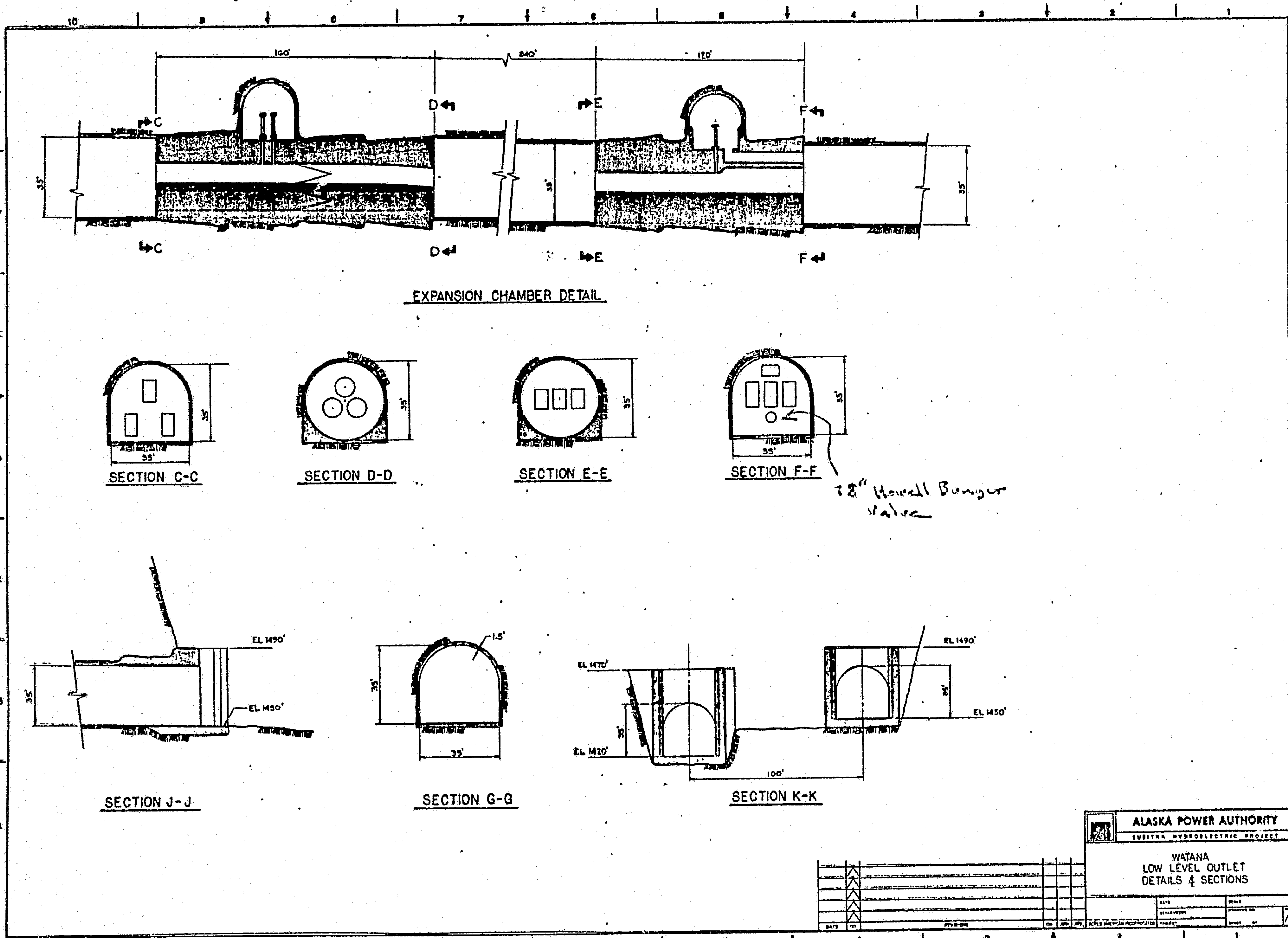


RIGHT TUNNEL PERMANENT OPERATION

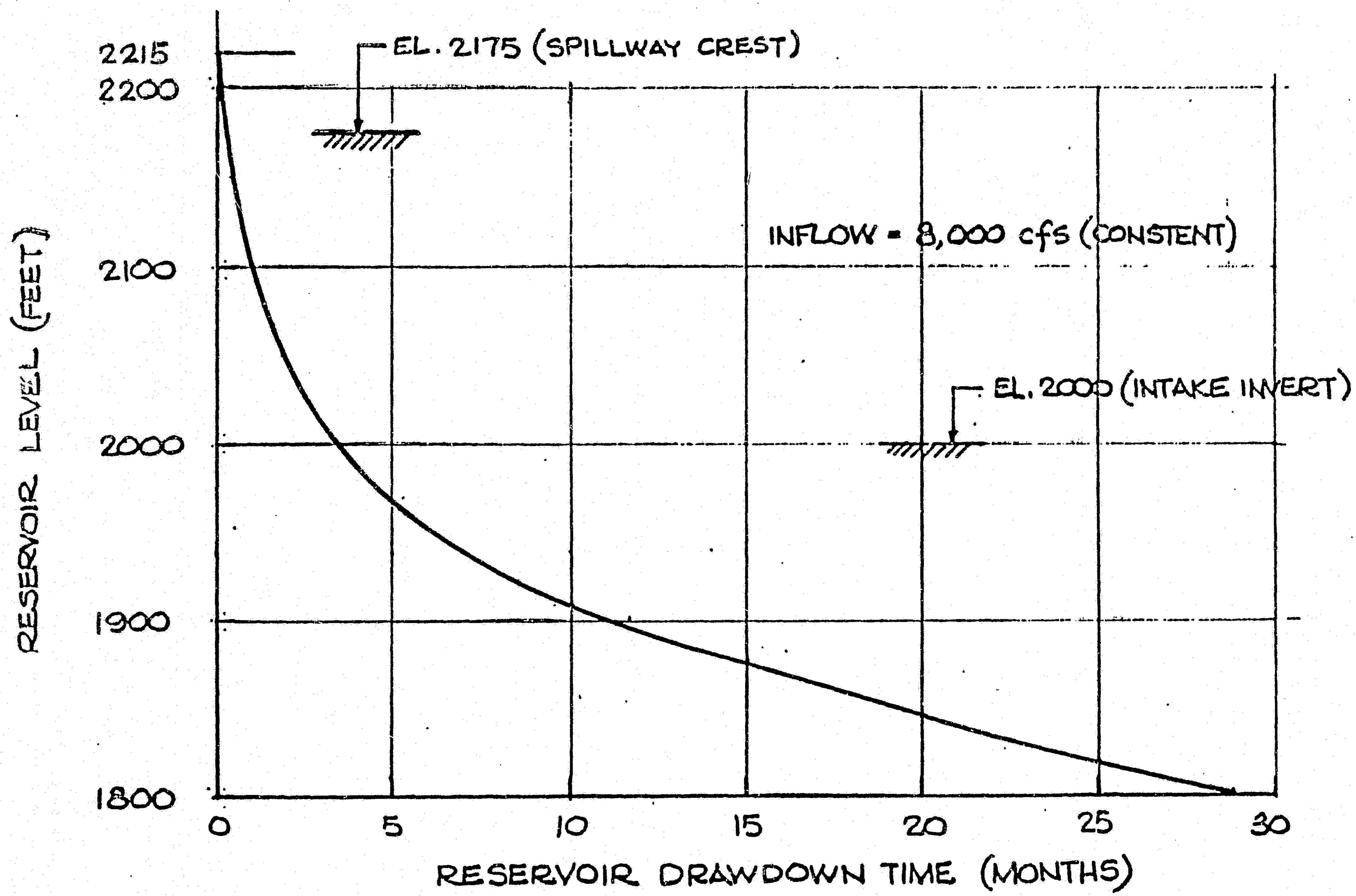
ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

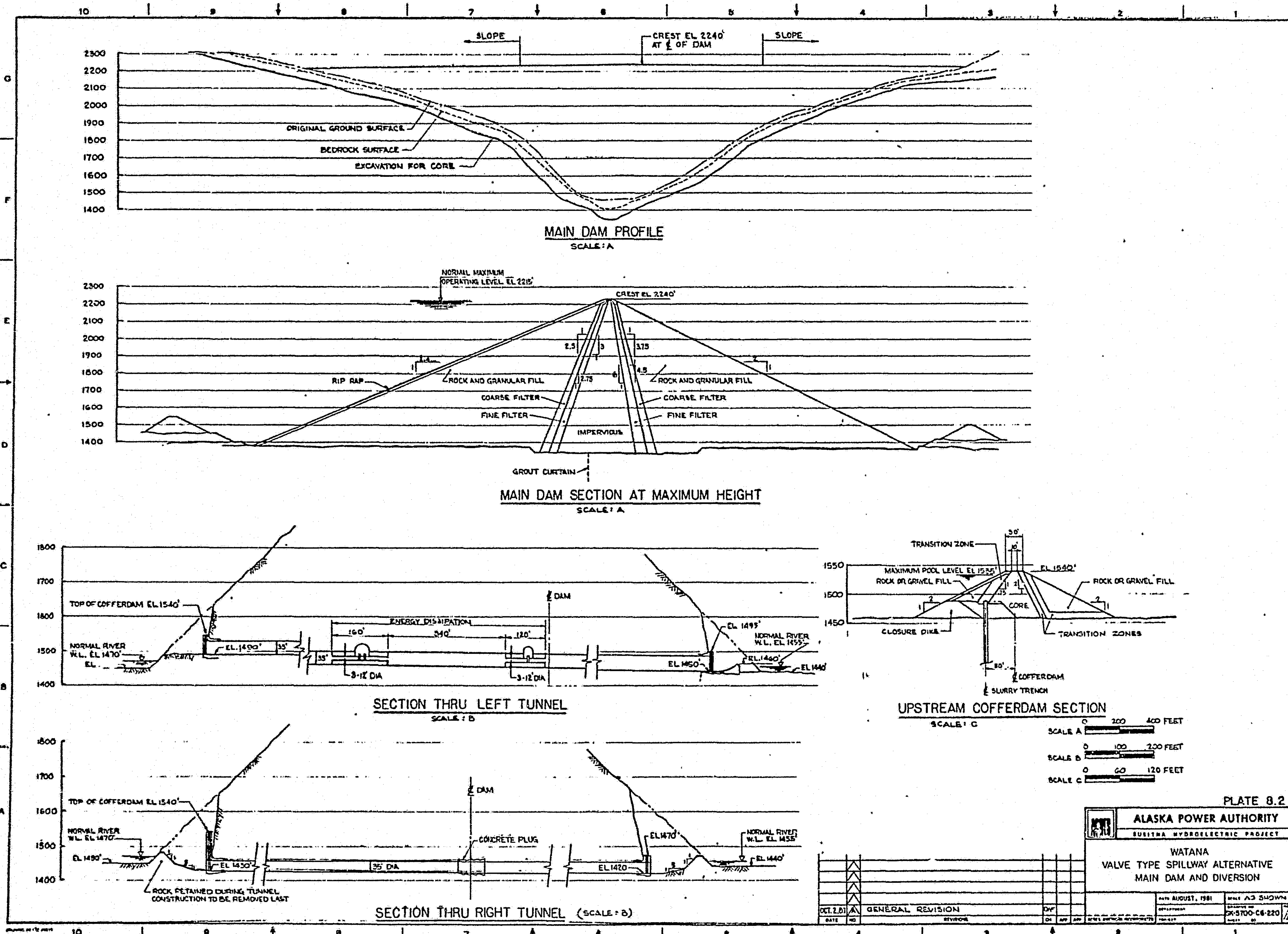
WATANA
DIVERSION PROFILES


160'
240'
120'
C
D
E
F
35'
38'
EXPANSION CHAMBER DETAIL
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
72" Howell Bunger Valve
EL 1490'
EL 1450'
1.5'
EL 1470'
EL 1420'
100'
SECTION J-J
SECTION G-G
SECTION K-K
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA
LOW LEVEL OUTLET
DETAILS & SECTIONS

0 0 2 3 6

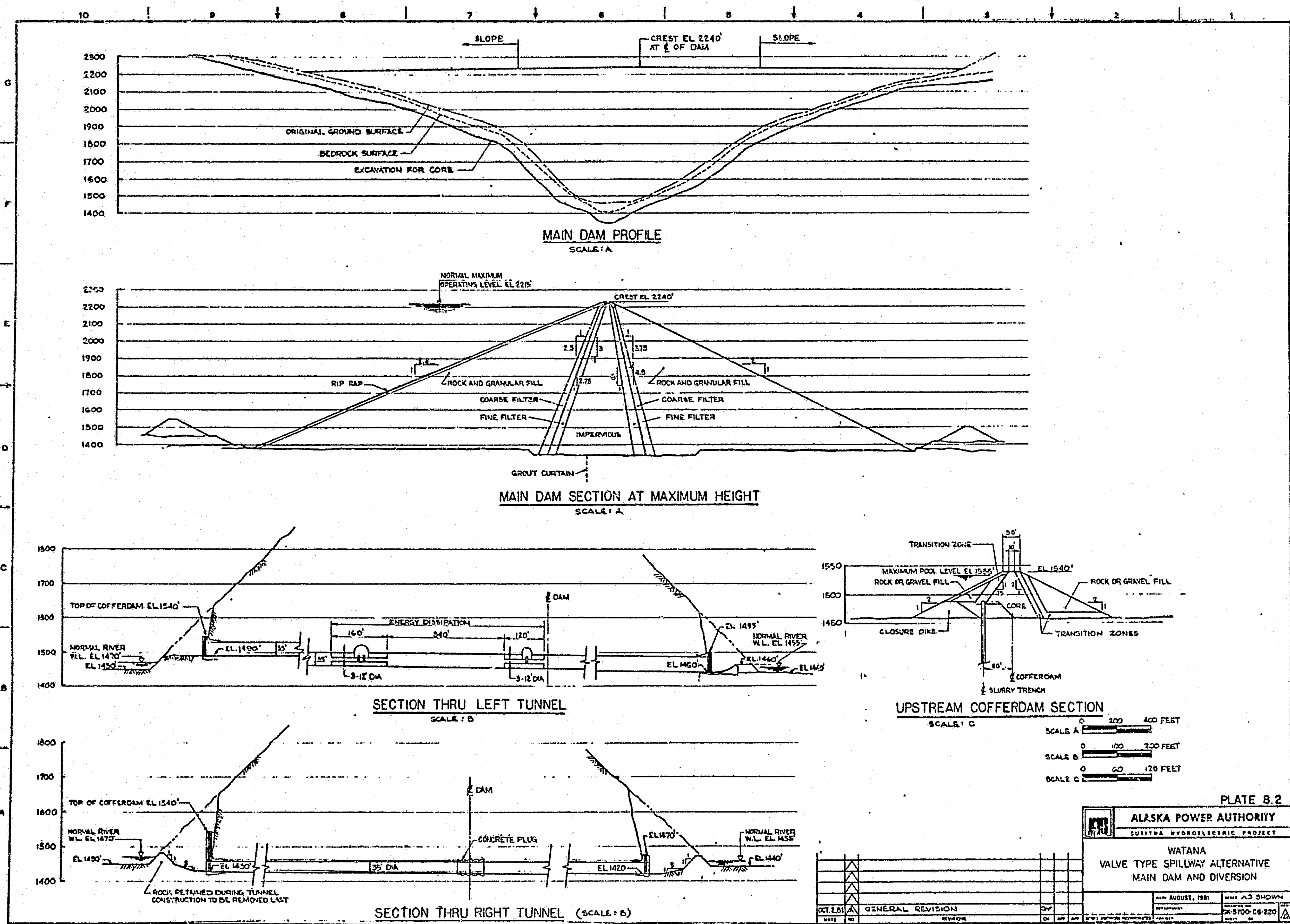


DRAWDOWN TIME FOR LOW LEVEL OUTLET



SLOPE
CREST EL 2240' AT ℄ OF DAM
SLOPE
ORIGINAL GROUND SURFACE
BEDROCK SURFACE
EXCAVATION FOR CORE
MAIN DAM PROFILE
SCALE: A
NORMAL MAXIMUM OPERATING LEVEL EL 2215'
CREST EL 2240'
RIP RAP
ROCK AND GRANULAR FILL
COARSE FILTER
FINE FILTER
IMPERVIOUS
GROUT CURTAIN
MAIN DAM SECTION AT MAXIMUM HEIGHT
SCALE: A
TOP OF COFFERDAM EL 1540'
NORMAL RIVER W.L. EL 1470'
EL 1490'
ENERGY DISSIPATION
160'
540'
120'
3-12' DIA
℄ DAM
EL 1495'
NORMAL RIVER W.L. EL 1455'
EL 1460'
EL 1440'
EL 1450'
SECTION THRU LEFT TUNNEL
SCALE: B
TRANSITION ZONE
MAXIMUM POOL LEVEL EL 1535'
EL 1540'
ROCK OR GRAVEL FILL
CORE
CLOSURE DIKE
TRANSITION ZONES
℄ COFFERDAM
℄ SLURRY TRENCH
UPSTREAM COFFERDAM SECTION
SCALE: C
SCALE A 0 200 400 FEET
SCALE B 0 100 200 FEET
SCALE C 0 60 120 FEET
TOP OF COFFERDAM EL 1540'
NORMAL RIVER W.L. EL 1470'
EL 1450'
EL 1430'
35' DIA
CONCRETE PLUG
EL 1420'
EL 1470'
NORMAL RIVER W.L. EL 1455'
EL 1440'
ROCK RETAINED DURING TUNNEL CONSTRUCTION TO BE REMOVED LAST
SECTION THRU RIGHT TUNNEL (SCALE: B)
PLATE 8.2
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA
VALVE TYPE SPILLWAY ALTERNATIVE
MAIN DAM AND DIVERSION
AUGUST, 1981
AS SHOWN
OCT. 2, 81 GENERAL REVISION

00236



SLOPE
CREST EL 2240' AT ℄ OF DAM
SLOPE
ORIGINAL GROUND SURFACE
BEDROCK SURFACE
EXCAVATION FOR CORE
MAIN DAM PROFILE
SCALE: A
NORMAL MAXIMUM OPERATING LEVEL EL 2215'
CREST EL 2240'
RIP RAP
ROCK AND GRANULAR FILL
COARSE FILTER
FINE FILTER
IMPERVIOUS
GROUT CURTAIN
MAIN DAM SECTION AT MAXIMUM HEIGHT
SCALE: A
TOP OF COFFERDAM EL 1540'
NORMAL RIVER W.L. EL 1470'
EL 1450'
EL 1490'
ENERGY DISSIPATION
℄ DAM
3-12' DIA
EL 1495'
NORMAL RIVER W.L. EL 1455'
EL 1460'
EL 1440'
SECTION THRU LEFT TUNNEL
SCALE: B
TRANSITION ZONE
MAXIMUM POOL LEVEL EL 1535'
EL 1540'
ROCK OR GRAVEL FILL
CORE
CLOSURE DIKE
TRANSITION ZONES
℄ COFFERDAM
℄ SLURRY TRENCH
UPSTREAM COFFERDAM SECTION
SCALE: C
SCALE A 0 200 400 FEET
SCALE B 0 100 200 FEET
SCALE C 0 60 120 FEET
TOP OF COFFERDAM EL 1540'
NORMAL RIVER W.L. EL 1470'
EL 1450'
EL 1430'
35' DIA
CONCRETE PLUG
EL 1420
EL 1470'
NORMAL RIVER W.L. EL 1455'
EL 1440'
ROCK RETAINED DURING TUNNEL CONSTRUCTION TO BE REMOVED LAST
SECTION THRU RIGHT TUNNEL (SCALE: B)
PLATE 8.2
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA
VALVE TYPE SPILLWAY ALTERNATIVE
MAIN DAM AND DIVERSION
OCT. 2.81 GENERAL REVISION
AUGUST, 1981
AS SHOWN

WATANA DIVERSION

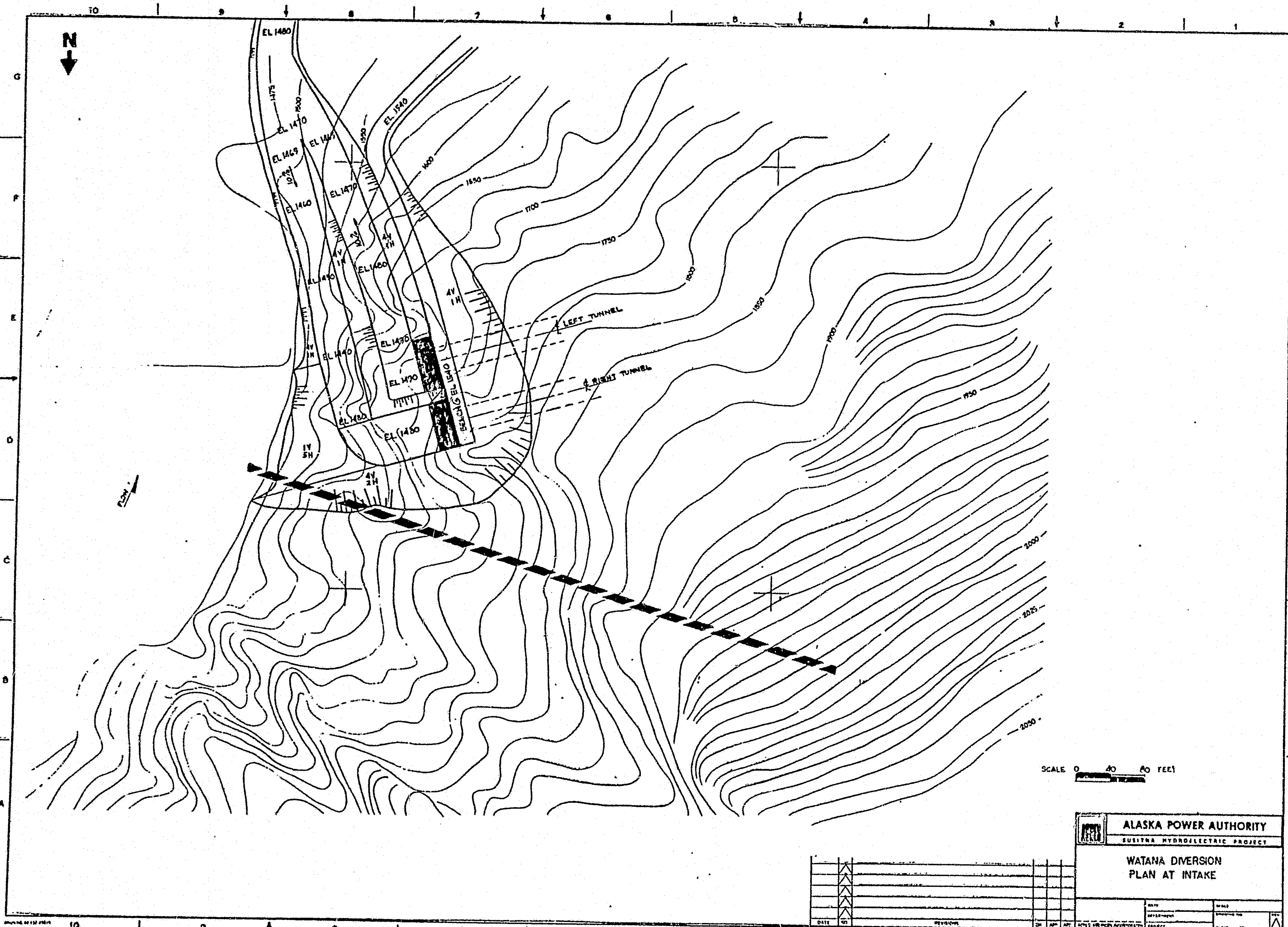
PEAK INFLOW 50 YR RECURRENCE PERIOD DESIGN FLOW	83,000 CFS
PEAK OUTFLOW THROUGH DIVERSION TUNNELS	76,000 CFS
TUNNEL DESCRIPTION	2-35 FT CONCRETE LINED TUNNELS
COFFERDAM HEIGHT	90 FT-CREST EL 1540

CONVERTING ONE TUNNEL TO A LOW LEVEL OUTLET WITH AN EXPANSION CHAMBER FOR ENERGY DISSIPATION.

OUTFLOW WITH RESERVOIR @ EL 2020 (550' HEAD)-30,000 CFS

OUTFLOW WITH RESERVOIR @ EL 1600 (125' HEAD)-15,000 CFS

OUTFLOW WITH RESERVOIR @ EL 1550 (75' HEAD) -11,000 CFS



ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

WATANA DIVERSION
PLAN AT INTAKE

ALASKA POWER AUTHORITY

P5700.13

SUSITNA HYDROELECTRIC PROJECT
External Review Board Meeting No. #3

MINUTES OF MEETING HELD ON
October 6 - 8, 1981, BUFFALO, NEW YORK

Presentation on: Devil Canyon Low-Level Outlets - R. K. Ibbotson

DEVIL CANYON

DIVERSION TUNNELS
ECONOMIC DIAMETER OPTIMIZATION

PRESSURE TUNNEL

DIAMETER (FT) (2 TUNNELS)	TUNNEL COSTS $ X 1000	COFFERDAM COSTS $ X 1000	TOTAL COSTS[1] $ X 1000
20	19,800	10,500	30,300
25	19,000	1,500	20,500
30	23,000	800	23,800

SUBSEQUENT TO OPTIMIZATION 1-35' DIAMETER TUNNEL WAS INVESTIGATED AND FOUND TO BE ADVANTAGEOUS OVER 2-25' DIAMETER TUNNEL.

35	14,000	1,500	15,500

(1) TOTAL COSTS DO NOT INCLUDE COST OF INTAKE STRUCTURE OR GATES AND OUTLET STRUCTURE.

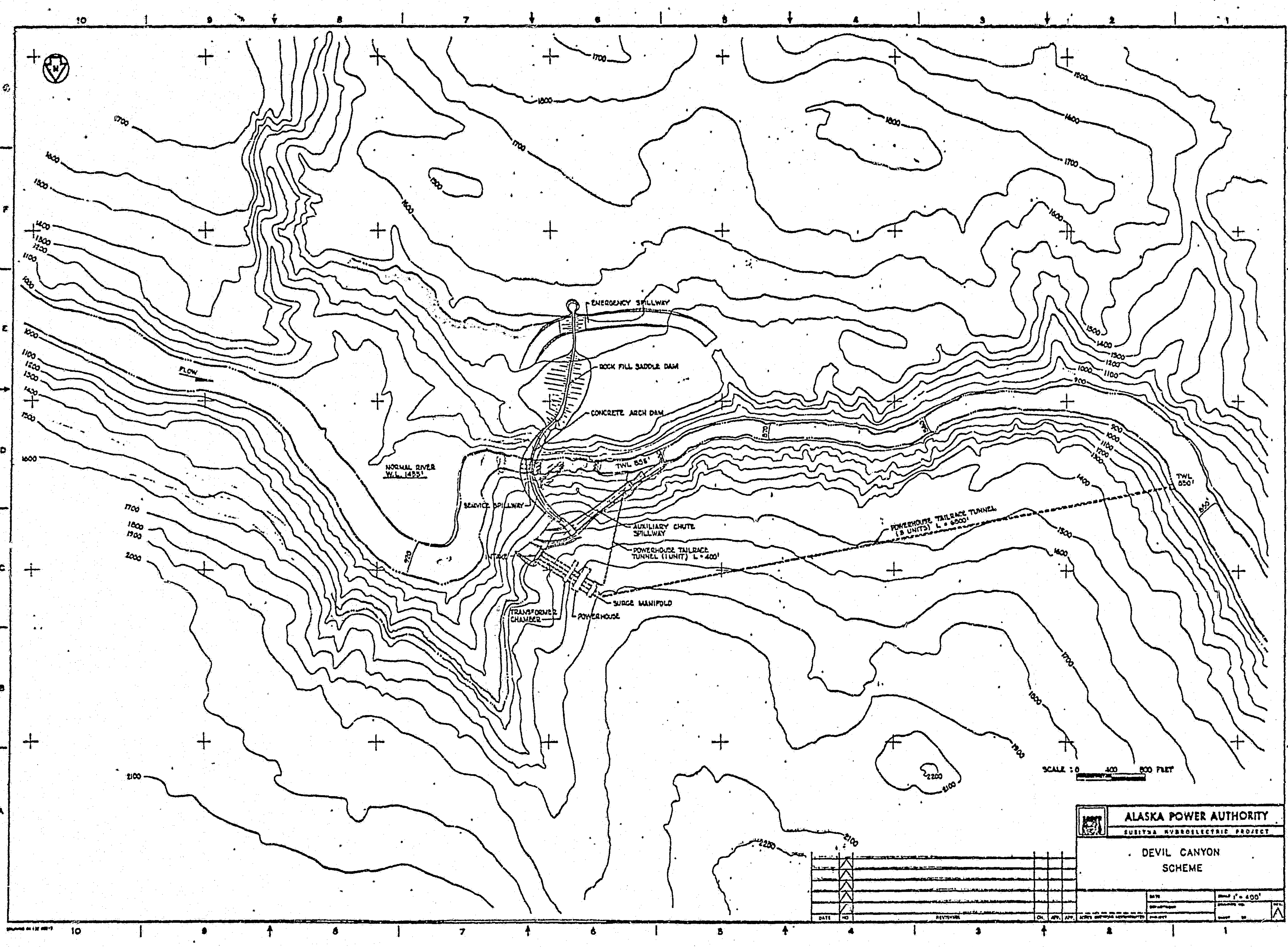
DEVIL CANYON DIVERSION

PEAK INFLOW 50 YR. RECURRENCE PERIOD DESIGN FLOOD ROUTED THROUGH WATANA	52,000 CFS
PEAK OUTFLOW THROUGH DIVERSION TUNNELS	52,000 CFS
TUNNEL DESCRIPTION	1-35 FT CONCRETE LINED TUNNEL
COFFERDAM HEIGHT	50 FT-CREST EL 950

DEVIL CANYON DIVERSION

PEAK INFLOW 50 YR. RECURRENCE PERIOD DESIGN FLOOD ROUTED THROUGH WATANA	52,000 CFS
PEAK OUTFLOW THROUGH DIVERSION TUNNELS	52,000 CFS
TUNNEL DESCRIPTION	1-35 FT CONCRETE LINED TUNNEL
COFFERDAM HEIGHT	50 FT-CREST EL 950

0 0 2 3 6



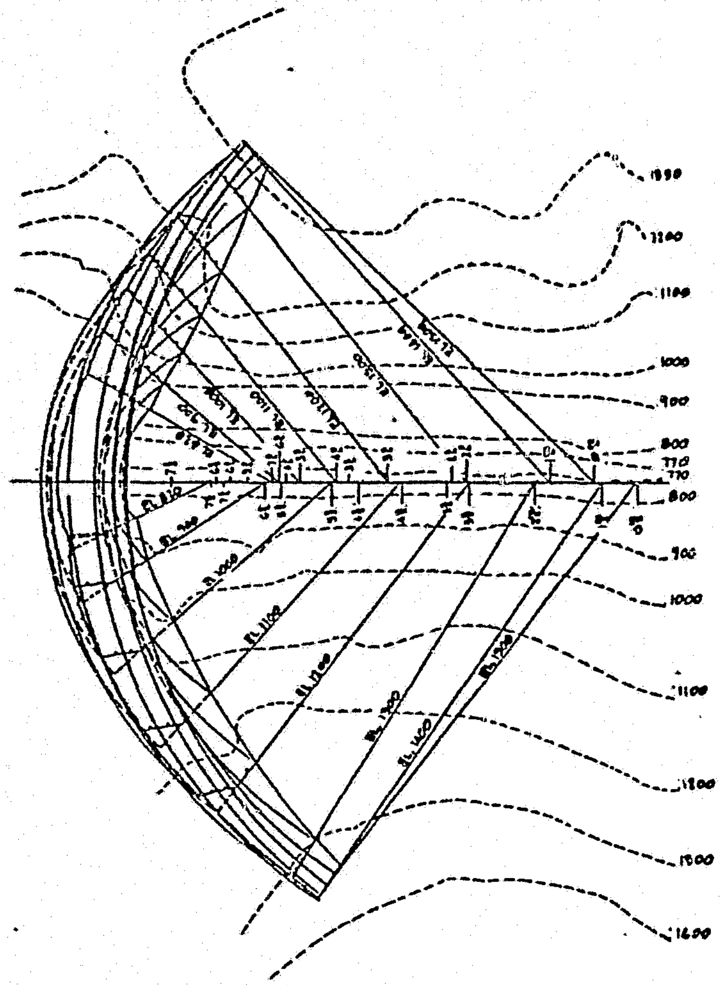
EMERGENCY SPILLWAY
ROCK FILL SADDLE DAM
CONCRETE ARCH DAM
FLOW
NORMAL RIVER W.L. 1455'
TWL 855'
SERVICE SPILLWAY
AUXILIARY CHUTE SPILLWAY
POWERHOUSE TAILRACE TUNNEL (1 UNIT) L = 400'
POWERHOUSE TAILRACE TUNNEL (3 UNITS) L = 6500'
INTAKE
TRANSFORMER CHAMBER
POWERHOUSE
SURGE MANIFOLD
TWL 850'
SCALE : 0 400 800 FEET
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
DEVIL CANYON
SCHEME
SCALE 1" = 400'

ALASKA POWER AUTHORITY P5700.13

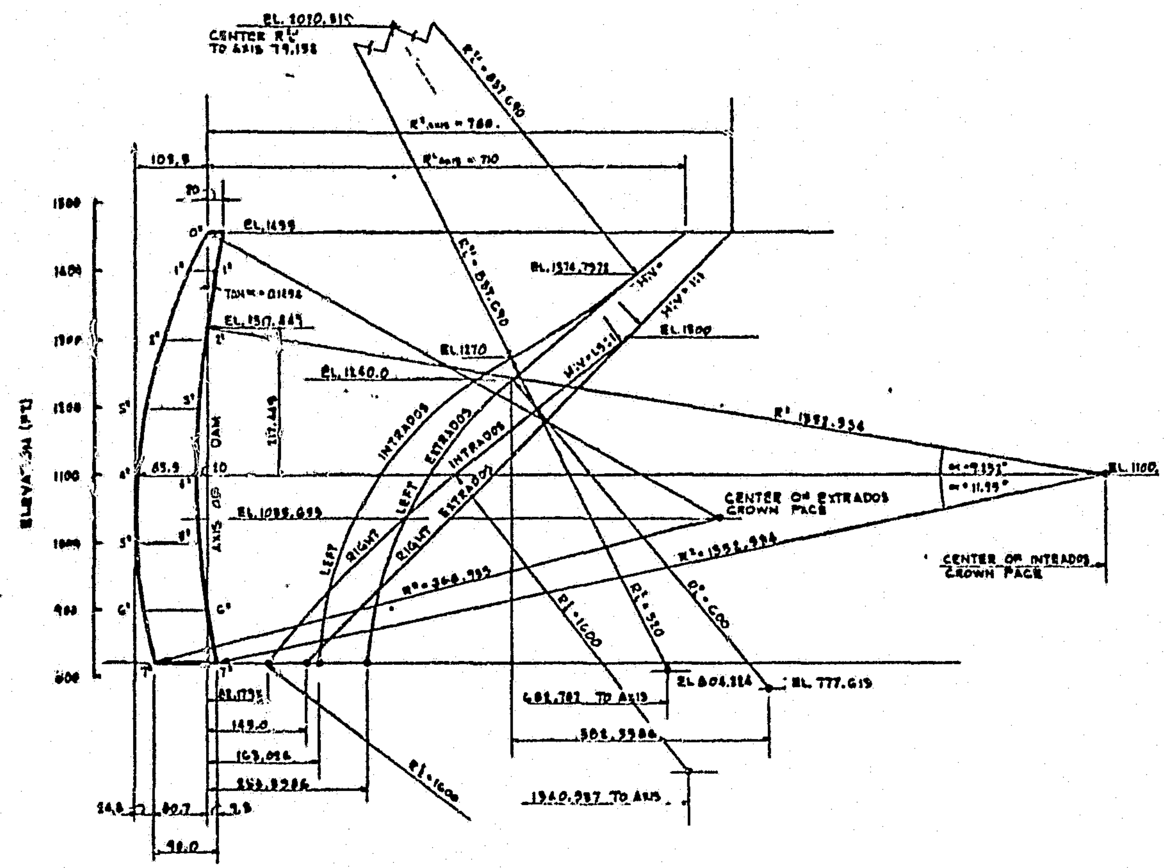
SUSITNA HYDROELECTRIC PROJECT
External Review Board Meeting No. #3

MINUTES OF MEETING HELD ON
October 6 - 8, 1981, BUFFALO, NEW YORK

Presentation on: Devil Canyon Dam Design - R. K. Ibbotson



PLAN OF ARCH



CROWN SECTION GEOMETRY

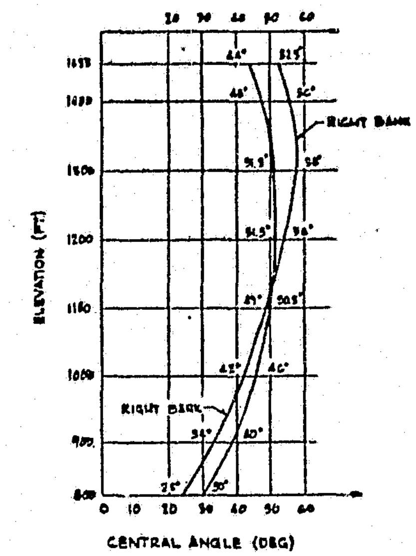


DIAGRAM OF CENTRAL ANGLES

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON
THIN ARCH DAM GEOMETRY

APRIL, 1981

ACRES AMERICAN INCORPORATED

SK-8700-C8-306

MATERIAL PROPERTIES

A) CONCRETE

FROST RESISTANCE CONCRETE STRENGTH (365 DAY)	5,000 PSI
UNIT WEIGHT	150 LB/FT^3
STATIC MODULUS OF ELASTICITY (SUSTAINED)	3×10^6 PSI
DYNAMIC MODULUS OF ELASTICITY (INSTANTANEOUS)	5×10^6 PSI
POISSONS RATIO	0.2
TENSILE STRENGTH:	
STATIC (FOR ESTIMATING CRACKING ONLY) 5% OF STRENGTH	250 PSI
DYNAMIC FLEXURAL 15% OF STRENGTH	750 PSI
THERMAL PROPERTIES:	
CONDUCTIVITY	1.52 BTU/FT/HR/°F
SPECIFIC HEAT	0.22 BTU/LB/°F
COEFFICIENT OF THERMAL EXPANSION	5.6×10^{-6} FT/FT/°
DIFFUSIVITY	0.046 FT^2/HR

B) FOUNDATION ROCK

DEFORMATION MODULUS (SUSTAINED)	2×10^6 PSI
POISSONS RATIO	0.2

TEMPERATURES (°F)

(BASED ON AVERAGE BETWEEN SUMMIT AND TALKEETNA)

AIR TEMPERATURE:

MEAN ANNUAL	28.9
HIGH MEAN MONTHLY	55.0
LOW MEAN MONTHLY	4.4

RESERVOIR WATER TEMPERATURE

DEPTH BELOW SURFACE (FT)	MONTH 4	5	6	7	8	9	10	11	12	1	2	3
0 - 50	32	32	46	57	53	45	39	32	32	32	32	32
70 TO RESERVOIR BOTTOM	39	39	39	39	39	39	39	39	39	39	39	39

GROUTING TEMPERATURE OF VERTICAL CONSTRUCTION JOINTS: 39°F

LOAD COMBINATION			COMBINATION CLASS	USUAL				UNUSUAL	EXTREME	
			COMBINATION NUMBER	UL-1	UL-2	UL-3	UL-4	UNL-1	EL-1	EL-2
BASIC LOAD CASES	STATIC LOADS	DEAD LOAD		X	X	X	X	X	X	X
		AIR & RESERVOIR	FEB.			X				
		WATER TEMPERATURES	APR.				X			
		RESERVOIR WATER	1,445	X		X			X	X
			1,455					X		
		LEVELS	1,295		X		X			
	DYNAMIC LOADS	MAXIMUM CREDIBLE	0.5 G 5% DAMP						X	
		EARTHQUAKE	0.4G 10 DAMP.							X

EXTREME STRESSES

AT ROCK/CONCRETE INTERFACE

LOADING COMBINATION (STRESSES IN PSI)

	UL-1
ARCH	
MAX	792 (D. El 1100)
MIN	23 (U. El 1000)
CANTILEVER	
MAX	722 (D. El 820)
MIN	-27 (D. El 1370)

- INDICATES TENSION

D INDICATES DOWNSTREAM FACE

U INDICATES UPSTREAM FACE

MAXIMUM STRESSES

ABOVE FOUNDATION

	UL-1
ARCH	
MAX	958 (U. El 1100)
MIN	182 (D. El 1000)
CANTILEVER	
MAX	575 (D. El 1000)
MIN	0 (D. El 1455)

EXTREME STRESSES

AT ROCK/CONCRETE INTERFACE

LOADING COMBINATION (STRESSES IN PSI)

	UL-1
ARCH	
MAX	792 (D. El 1100)
MIN	23 (U. El 1000)
CANTILEVER	
MAX	722 (D. El 820)
MIN	-27 (D. El 1370)

\- INDICATES TENSION

D INDICATES DOWNSTREAM FACE

U INDICATES UPSTREAM FACE

MAXIMUM STRESSES

ABOVE FOUNDATION

	UL-1
ARCH	
MAX	958 (U. El 1100)
MIN	182 (D. El 1000)
CANTILEVER	
MAX	575 (D. El 1000)
MIN	0 (D. El 1455)

DEVIL'S CANYON ARCH DAM LOAD: Hydrostatic & Gravity

ARCH STRESSES PARALLEL TO THE FACE OF THE DAM
LOOKING UPSTREAM

ELEV	STA	1714.71	1710.99	1638.50	1526.35	1393.57	1259.68	1143.68	1000.00	812.86	753.95	679.59	604.24	524.12	461.56	454.76
	TAU	12.														-20.
1455.	E	267.	274.	303.	324.	406.	484.	516.	467.	386.	371.	344.	311.	354.	479.	501.
	I	607.	576.	342.	417.	438.	366.	307.	313.	412.	446.	462.	448.	399.	550.	585.
		TAU	11.												-2.	TAU
1370.		E	110.	206.	295.	416.	593.	707.	642.	405.	355.	504.	282.	277.	261.	
		I	374.	413.	498.	518.	396.	258.	255.	455.	508.	550.	542.	470.	378.	
			TAU	76.										71.	TAU	
1285.			E	174.	237.	392.	621.	822.	799.	449.	362.	281.	233.	271.		
			I	433.	558.	587.	467.	282.	258.	521.	582.	622.	628.	545.		
				TAU	162.								145.	TAU		
1200.				E	174.	298.	562.	851.	919.	487.	357.	230.	171.			
				I	602.	654.	540.	319.	266.	598.	674.	743.	759.			
					TAU	260.						210.	TAU			
1100.					E	177.	372.	744.	958.	430.	237.	106.				
					I	704.	620.	357.	244.	609.	727.	792.				
						TAU	292.				227.	TAU				
1000.						E	110.	517.	873.	258.	23.					
						I	708.	421.	182.	532.	665.					

EXTREME STRESSES

AT ROCK/CONCRETE INTERFACE

(STRESSES IN P.S.I.)

LOADING COMBINATION

	UL-3 (POINT)
ARCH	
MAX	747 (E EL 900)
MIN	-182 (E EL 1455)
CANTILEVER	
MAX	689 (D EL 820)
MIN	-393 (D EL 1370)

MAXIMUM STRESSES

ABOVE FOUNDATION

LOADING COMBINATION

	UL-3 (POINT)
ARCH	
MAX	1180 (E EL 1200)
MIN	-134 (I EL 1000) (E EL 1455)
CANTILEVER	
MAX	515 (U EL 900)
MIN	-75 (D EL 1370)

DEVIL'S CANYON ARCH DAM

LOAD: Hydrostatic & Gravity
Uniform & Linear Temperature

CANTILEVER STRESSES PARALLEL TO THE FACE OF THE DAM
LOOKING UPSTREAM

ELEV	STA	1710.99	1638.58	1526.35	1393.57	1259.00	1143.68	1000.00	812.06	753.95	679.59	604.24	524.12	461.56	
	TAU	0.												0.	TAU
1455.	U	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
	D	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
	TAU	49.												37.	TAU
1370.	U	485.	192.	166.	143.	146.	140.	126.	147.	150.	156.	183.	208.	434.	
	D	-393.	-60.	-24.	10.	16.	26.	41.	15.	8.	-4.	-39.	-75.	-329.	
		TAU	83.										87.	TAU	
1285.		U	287.	234.	214.	218.	207.	172.	210.	229.	258.	283.	313.		
		D	-47.	30.	70.	85.	110.	151.	89.	58.	11.	-37.	-99.		
			TAU	195.								156.	TAU		
1200.			U	213.	244.	238.	237.	192.	256.	303.	354.	316.			
			D	177.	158.	191.	218.	279.	161.	90.	7.	29.			
				TAU	328.						225.	TAU			
1100.				U	225.	251.	287.	255.	371.	422.	415.				
				D	373.	332.	318.	302.	186.	105.	90.				
					TAU	407.				265.	TAU				
1000.					U	252.	351.	384.	361.	496.					
					D	555.	401.	400.	138.	198.					
						TAU	389.		230.	TAU					
900.						U	403.	515.	679.						
						D	594.	393.	201.						
							TAU	139.							
820.							U	334.							
							D	689.							

DYNAMIC ANALYSIS - CANTILEVER STRESSES (PSI)
EARTHQUAKE ACTING UPSTREAM

0.5G GROUND ACC'N - 5% DAMPING

ELEVATION	CROWN CANTILEVER FACE	CROWN CANTILEVER STRESS
1455	U	0
	D	0
1370	U	-581
	D	653
1285	U	-729
	D	1021
1200	U	-629
	D	1111
1100	U	-435
	D	1110
1000	U	-142
	D	1026
900	U	- 19
	D	988
820	U	-402
	D	1541

U - UPSTREAM
D - DOWNSTREAM

DYNAMIC ANALYSIS - ARCH STRESSES (PSI)
EARTHQUAKE ACTING UPSTREAM

0.5G GROUND ACC'N - 5% DAMPING

EL. 1455 FT

	STATION				
FACE	1714	1711	1526	1259	1000
E	2574	2513	2033	2948	3404
I	2478	2409	2566	2749	1943

EL. 1370 FT

E		1220	1188	2461	3657
I		1444	2383	2247	949

E - EXTRADOS
I - INTRADOS

DYNAMIC ANALYSIS - CANTILEVER STRESSES (PSI)
EARTHQUAKE ACTING DOWNSTREAM

0.5G GROUND ACC'N - 5% DAMPING

ELEVATION	CROWN CANTILEVER FACE	CROWN CANTILEVER STRESS
1455	U	0
	D	0
1370	U	799
	D	-561
1285	U	925
	D	-577
1200	U	711
	D	-307
1100	U	639
	D	- 22
1000	U	638
	D	124
900	U	785
	D	90
820	U	1012
	D	- 97

U - UPSTREAM
D - DOWNSTREAM

DYNAMIC ANALYSIS - ARCH STRESSES (PSI)
EARTHQUAKE ACTING DOWNSTREAM

0.5G GROUND ACC'N - 5% DAMPING

EL. 1445 FT

FACE	STATION 1714	1711	1526	1259	1000
E	-2040	-1965	-1385	-1980	-2470
I	-1267	-1257	-1732	-2017	-1630

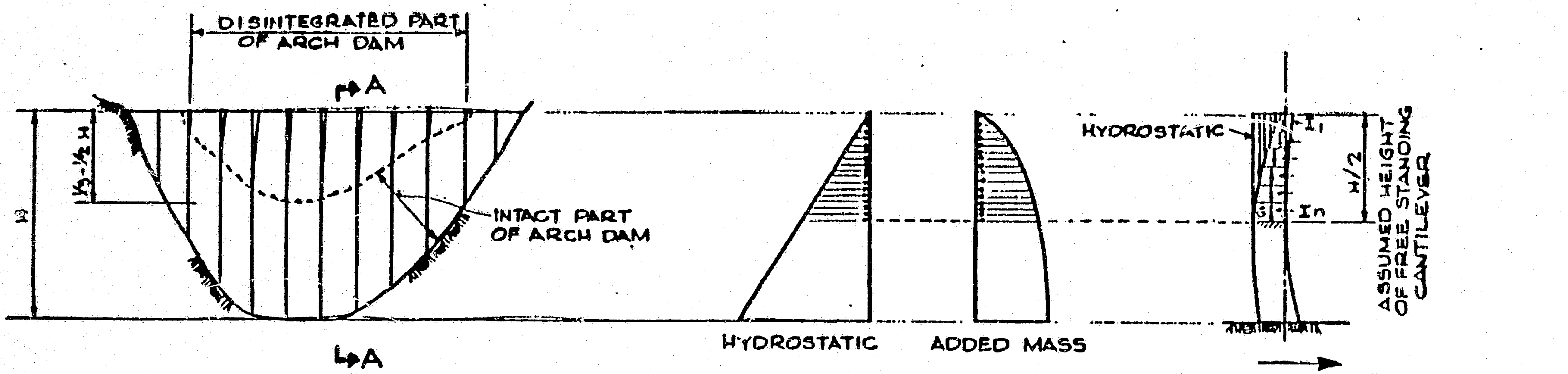
EL. 1370 FT

FACE	1714	1711	1526	1259	1000
E		-1000	- 598	-1275	-2373
I		- 701	-1387	-1455	- 439

E - EXTRADOS
I = INTRADOS

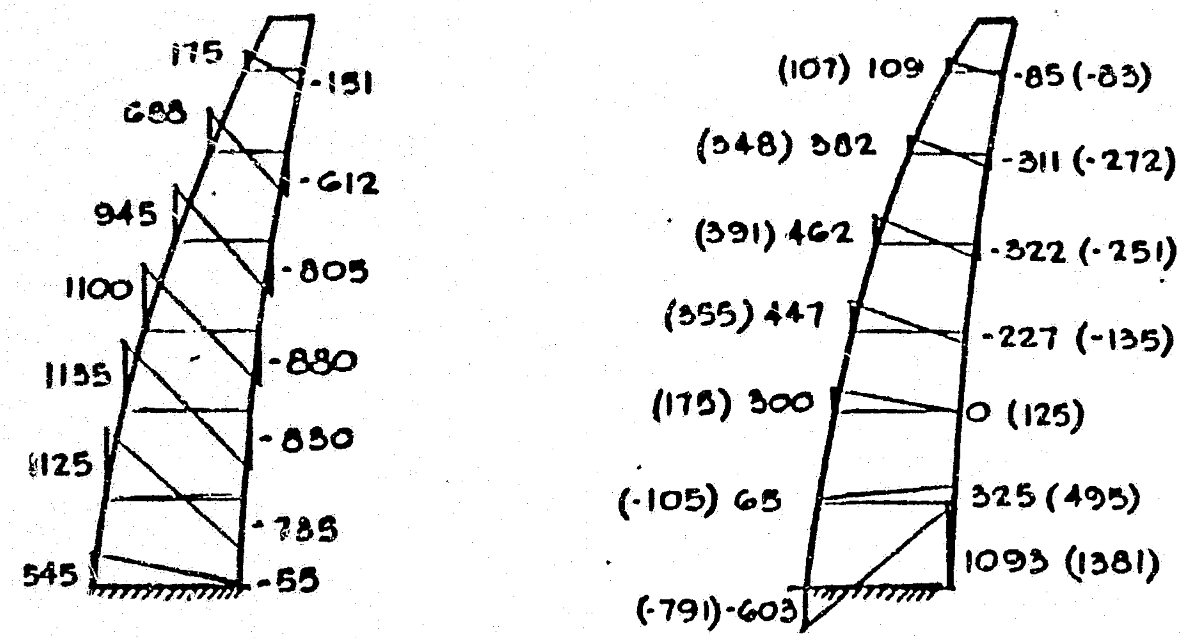
DYNAMIC ANALYSIS - ARCH STRESSES (PSI)
EARTHQUAKE ACTING DOWNSTREAM

EARTHQUAKE	ELEVATION OF ARCH (FT)	FACE OF DAM	CROWN 1000	STATION 1143	1394	1638	ABUTMENT 1714
0.5G	1455	U	-2470	-2197	-1686	- 985	-2040
		D	-1630	-1690	-2143	-1548	-1267
5% DAMP	1370	U	-2373	-1808	- 803	- 659	-1000
		D	- 439	-1081	-1522	-1153	- 701
0.4G	1455	U	-1392	-1203	- 919	- 512	-1149
		D	- 720	- 957	-1196	- 855	- 757
10% DAMP	1370	U	-1267	- 887	- 355	- 341	- 592
		D	- 185	- 589	- 774	- 578	- 306



ASSUMED SCHEME OF ANALYSIS

NOTE:
⊖ (MINUS) INDICATES TENSILE STRESS
● (PLUS) INDICATES COMPRESSIVE STRESS.



0.5 G & 5% DAMPING
100% ADDED MASS

0.4 G & 10% DAMPING
100% ADDED MASS (& 50% IN BRACKETS)

CANTILEVER STRESSES (PSI)

SECTION A-A

DEVIL CANYON ARCH DAM
EARTHQUAKE DYNAMIC ANALYSIS

ALASKA POWER AUTHORITY P5700.13

SUSITNA HYDROELECTRIC PROJECT

EXTERNAL REVIEW BOARD MEETING #3
OCTOBER 6-8, 1981, BUFFALO, NY

Presentation on Devil Canyon Layout Studies - J. Lawrence

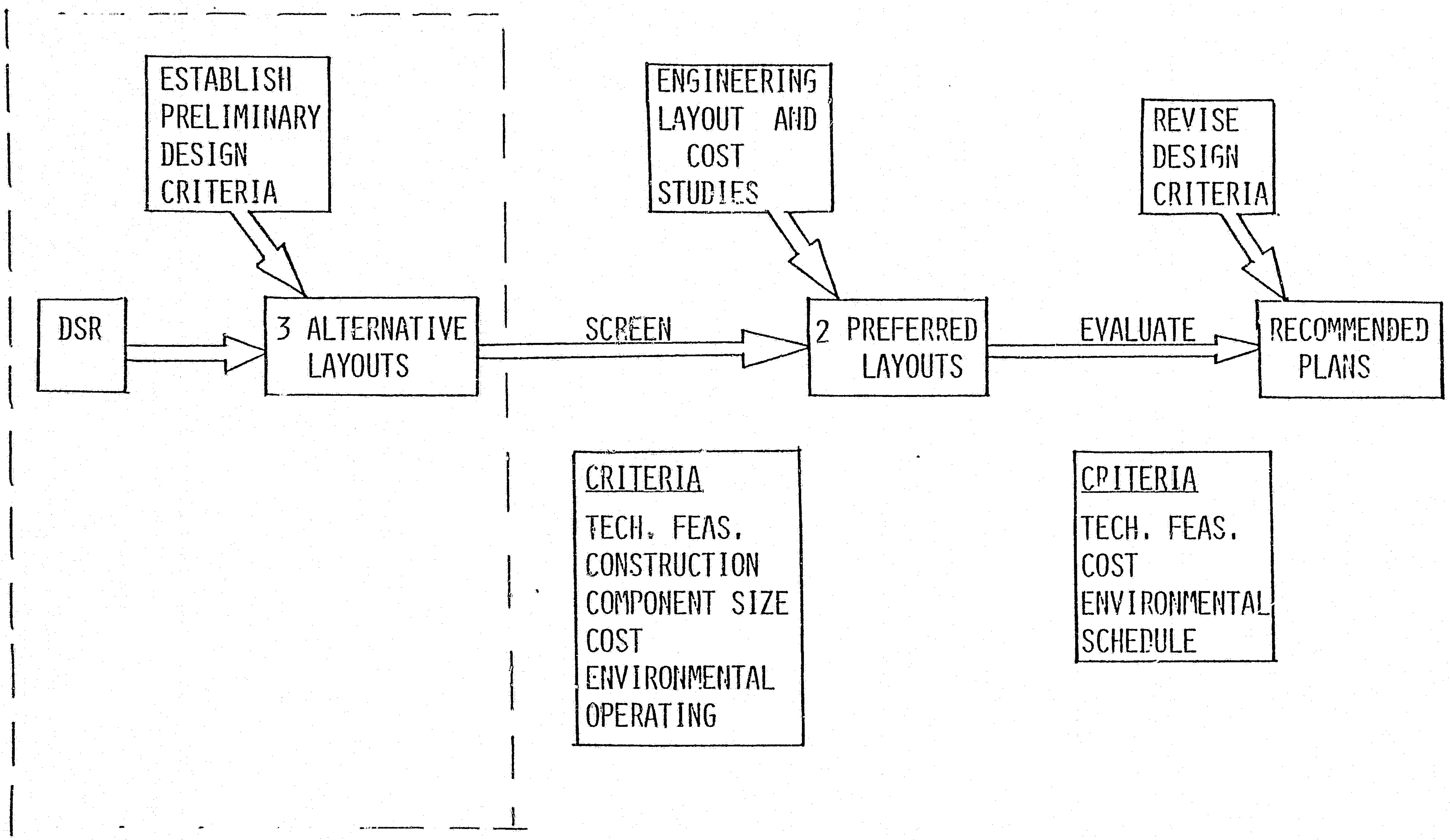
DEVIL CANYON LAYOUT - DSR
JUNE, 1981)

- DAM:	THIN ARCH/EARTHFILL SADDLE (LEFT)
o CREST:	EL. 1460 FT.
o HEIGHT:	650 FT.
- MAIN SPILLWAY:	OGEE - 3 GATES
o CAPACITY:	90,000 CFS
o TYPE:	CHUTE AND FLIP BUCKET
o LOCATION:	RIGHT BANK
- AUXILIARY SPILLWAY:	ORIFICE - 3 GATES
o CAPACITY:	40,000 CFS
o TYPE:	CONC. LINED PLUNGE POOL
o LOCATION:	THRU DAM (15' X 15')
- EMERGENCY SPILLWAY:	FUSE PLUG
o CAPACITY:	100,000 CFS MAX.
o TYPE:	UNLINED CHANNEL
o LOCATION:	LEFT BANK
- POWER PLANT:	400 MW, RIGHT BANK, UNDERGROUND
- DIVERSION:	2 - 26 FT. DIA. TUNNELS LEFT BANK, EARTH/ROCKFILL COFFERDAMS

MAJOR DESIGN CONSIDERATIONS

- SEISMIC LOADING
- FLOOD HANDLING CAPABILITY
- EMBANKMENT DESIGN
- ARCH DAM DESIGN
- UNDERGROUND/FOUNDATION CONDITIONS
- RELICT CHANNEL
- RIVER CONDITIONS DOWNSTREAM
- ENVIRONMENTAL DISTURBANCE
- OPTIMUM SIZE & SCHEDULE
- AVAILABILITY OF MATERIALS

DEVIL CANYON LAYOUT SELECTION PROCESS



DESIGN CONCERNS - DEVIL CANYON

- DAM DESIGN, SEISMIC CONDITIONS
- ABUTMENT AND FOUNDATION INTEGRITY
- SPILLWAY DESIGN CONCEPT, CAPABILITY, PERFORMANCE, N_2 SUPERSATURATION
- POTENTIAL SCOUR CLOSE TO DAM
- RESERVOIR LEVEL/FREEBOARD
- LOW LEVEL RELEASES
- SADDLE DAM MATERIALS/FOUNDATION
- POWER DEVELOPMENT LOCATION/SIZE
- COST OPTIMIZATION

DEVIL CANYON ALTERNATIVES

SCHEME	MAIN SPILLWAY		AUX. SPILLWAY		EMERG. SPILLWAY	
	LOCATION	TYPE	LOCATION	TYPE	LOCATION	TYPE
1	R	CH	D	0	L	UC
2	L	CH	D	0	L	UC
3	R	SB	D	0	L	UC

LEGEND:

L: LEFT BANK
R: RIGHT BANK
D: IN DAM

CH: CHUTE/FLIP BUCKET
SB: STILLING BASIN
UC: UNLINED CHANNEL/FUSE PLUG

POWERPLANT, ALL SCHEMES: RIGHT BANK, 400 MW, 4 UNITS, UNDERGROUND
DIVERSION, ALL SCHEMES: LEFT BANK 2 - 26′ DIA. TUNNELS.

DEVIL CANYON
COMPARATIVE ESTIMATE SUMMARY - COSTS

($000 JANUARY 1982)	SCHEME 1	SCHEME 2	SCHEME 3
COMPARED ITEMS			
DIVERSION	32,100	32,100	35,000
SERVICE SPILLWAY	46,800	53,300	85,200
SADDLE DAM	20,000	18,600	20,000
EMERGENCY SPILLWAY (COMMON IN ALL SCHEMES)	25,200	25,200	25,200
TOTAL COMPARED ITEMS	124,100	129,200	165,400
TOTAL ITEMS CONSIDERED COMMON TO ALL SCHEMES	757,900	757,900	757,900
SUBTOTAL	882,000	887,100	923,300
16% CAMP & SUPPORT 20% CONTINGENCY 12.5% OWNER COST, ENGINEERING	499,200	502,100	522,600
PROJECT TOTAL	1,381,200	1,389,200	1,445,900

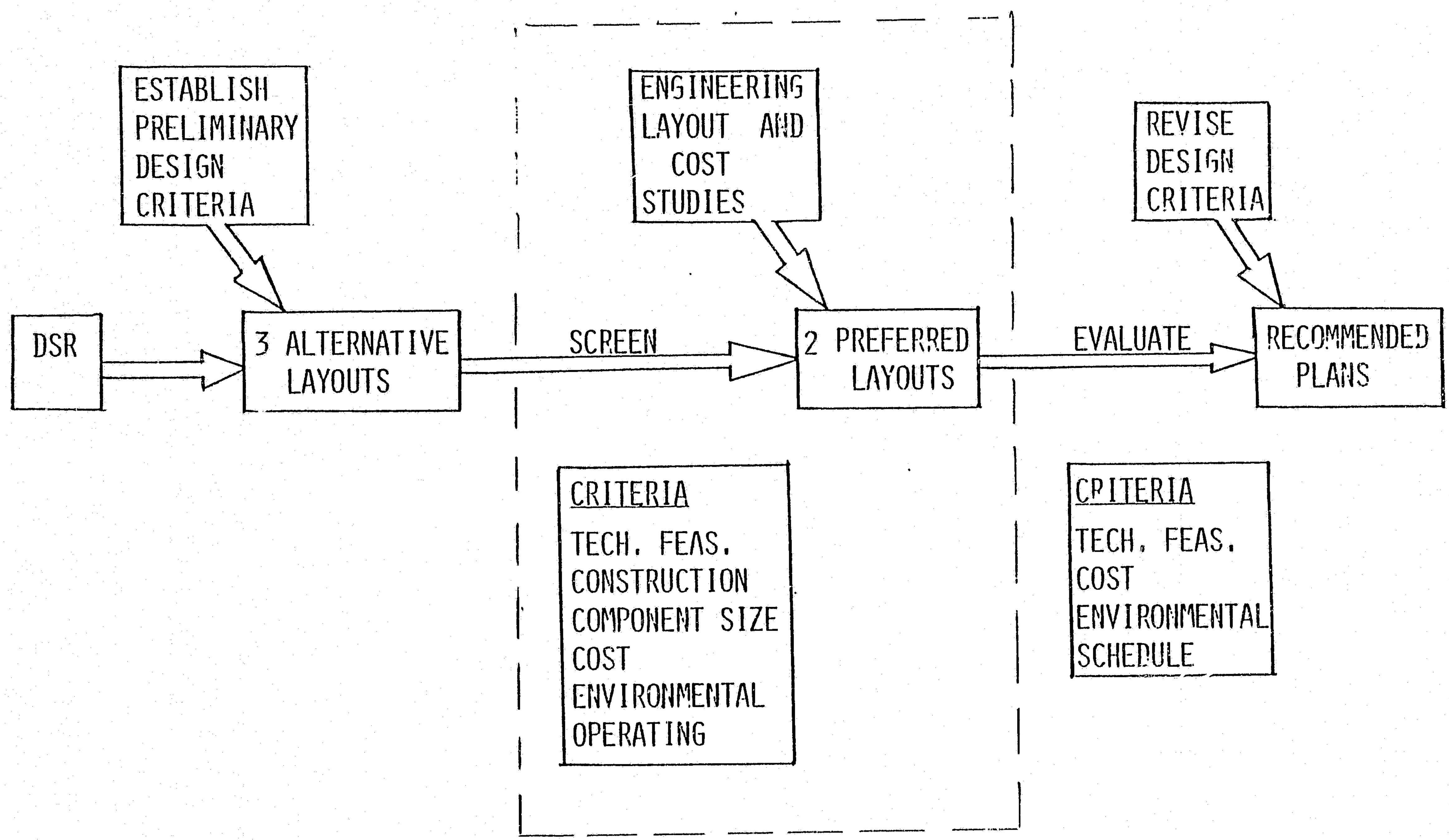
NOTE: UPPER LIMIT ESTIMATE IN JANUARY 1982 DOLLARS - $1,595,000,000*

* INCLUDED EXTENSION OF TAILRACE TO PORTAGE CREEK AND AUXILIARY POWERHOUSE

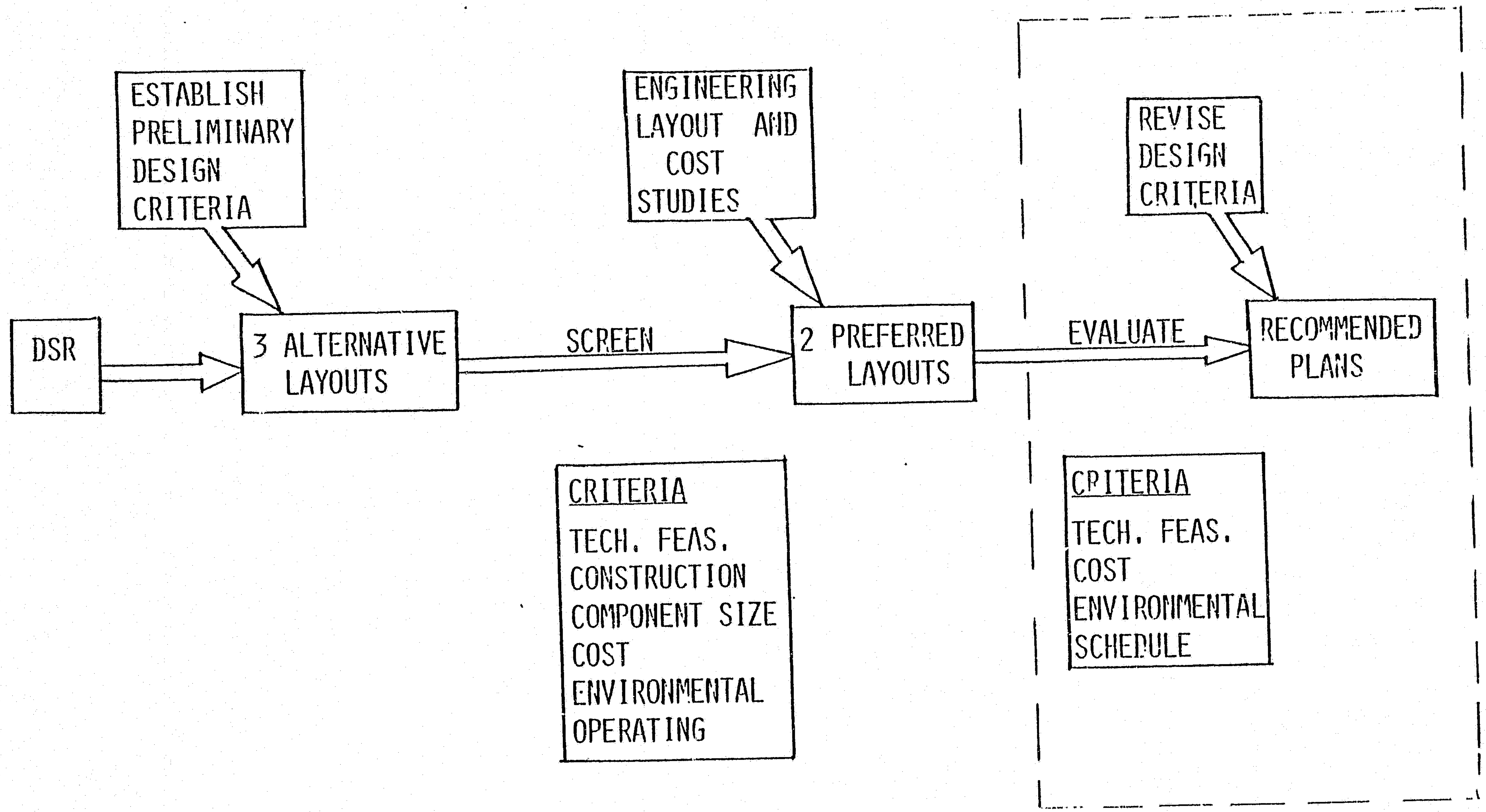
DEVIL CANYON LAYOUT EVALUATIONS

STRUCTURE	DETERMINATION	OBJECTIVE
DAM	- THIN ARCH DESIGN	- TECH. FEASIBILITY/COST
	- ELIMINATE ORIFICE SPILLWAY	- TECH. FEASIBILITY
POWER FACILITIES	- LOCATE GOOD ROCK - OPTIMIZE ORIENTATION	- TECH. FEASIBILITY
	- OPTIMIZE SIZE - EVALUATE TAILRACE EXTENSION	- REDUCE COST
SPILLWAYS	- RIGHT BANK MAIN SPILLWAY - SEPARATE EMERG. FAC.	- TECH. FEASIBILITY
	- EVALUATE CHUTE/FLIP - EVALUATE STILLING BASIN	- COST/SCOUR/ENVIRONMENTAL TRADE-OFFS

DEVIL CANYON LAYOUT SELECTION PROCESS



DEVIL CANYON LAYOUT SELECTION PROCESS



ALASKA POWER AUTHORITY

P5700.13

SUSITNA HYDROELECTRIC PROJECT
External Review Board Meeting No. #3

MINUTES OF MEETING HELD ON
October 6 - 8, 1981, BUFFALO, NEW YORK

APPENDIX B Report of External Review Board

October 8, 1981

SUSITNA HYDROELECTRIC PROJECT

EXTERNAL REVIEW PANEL

REPORT NO. 3

DRAFT

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 a 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 will be due to the following sources:

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	*	*	*

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 which 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 those conclusions.

* Information to be provided in Final WCC Report

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.

In the 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 crusted 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 channnels 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-silky-clay, there is a danger of deleterious stress redistribution due to differential settlements. Thus consideration should be given to minimizing this possibility 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 exacavation of frozen foundations 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 50-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 SPILLWAY

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 its greater rigidity makes it more suitable for high-head operation. The smaller spillway/chute flows 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 one question discussed 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 streamed 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 an alternate plan of 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 1 1/4 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 Meeting 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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Jacob H. Douma	H. Bolton Seed