L. Moken 3

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

REPORT ON SECOND SPECIALIST CONSULTANTS PANEL MEETING, BUFFALO, N.Y.

FEBRUARY 17 & 18, 1981

ACRES

Acres American Incorporated
1000 Liberty Bank Building
Main at Court
Buffalo, New York 14202
Telephone (716) 853-7525

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

REPORT ON SECOND SPECIALIST CONSULTANT PANEL MEETINGS, BUFFALO, N.Y.

FEBRUARY 17 & 18, 1981

ACRES AMERICAN INCORPORATED
1000 Liberty Bank Building
Main at Court
Buffalo, New York 14202
Telephone (716) 853-7525

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

REPORT ON SECOND SPECIALIST CONSULTANT PANEL MEETING

TABLE OF CONTENTS

1. OBJECTIVES

The objectives of this series of meetings are to update the panel on work completed since the last meetings in October 1980 and to review:

- -Results of seismic studies to date as reported by Woodward-Clyde
- -Proposed seismic studies for 1981
- -Results of geotechnical exploration to date
- -Recommendations of the Power Authority's External Review Board (January 24, 1981)
- -Proposed geotechnical exploration for 1981
- -Acres recommendations for Susitna development selection
- -Status of general arrangement studies at Devil Canyon and Watana
- -Status of arch dam analyses at Devil Canyon
- -Status of earth fill dam design at Watana
- -Schedule further meetings to tie in with Acres continuing studies and APA External Board meetings scheduled for March 19-21, June 3-6 and October 5-9, 1981

2. February 17, 8:30 a.m. - 10th Floor Conference Room, Buffalo

8:30	Opening remarks	J. D. Lawrence
9:00	Development selection	J. W. Hayden
9:45	Geological studies update	S. N. Thompson
10:15	Coffee	
10:30	Seismic studies - proposed 1981 program	V. Singh
11:00	Discussion	
11:30	Geotechnical exploration - results to date	V. Singh
12:00	Lunch (brought in)	
1:00	Geotechnical exploration - proposed 1981 program	V. Singh
2:00	Discussion	
4:00	Adjourn	

(Dr. J. Douma accompanied by I. Hutchison visit Acres Laboratories in Canada to view hydraulic model.)

3. February 18 - 8:30 a.m. - 10th Floor Conference Room, Buffalo

8:30	Devil Canyon general arrangements	R. Ibbotson
9:15	Devil Canyon arch dam analyses	R. Ibbotson
10:00	Coffee	
10:15	Watana general arrangements	R. Ibbotson
11:00	Watana dam design	V. Singh
12:00	Lunch	
1:00	Divide into working groups to review (see item 4): -Arch dam design -Geotechnical (including Watana Dam) -Hydraulics/hydrology -Generation planning	
2:30	Panel meets to prepare report	
4:00	Final summary and adjourn	

4. Group organizations:

Topic	Consultants	Moderator	Location
Arch dam	M. Copen	R. Ibbotson	9th Floor Small Conference Room
Geotechnical (incl. Watana Dam)	R. Peck A. Hendron	V. Singh	Graphics area (10th Floor)
Hydraulics/ hydrology	J. Douma	I. Hutchison	J. Lawrence's office (10th Floor)
Generation Planning	R. Mohn	J. Hayden	10th Floor Conference Room

5. MINUTES OF MEETING
held at the offices of
Acres American Incorporated
Buffalo, on February 17-18, 1981

SUSITNA HYDROELECTRIC PROJECT
Second Specialist Consultants Panel Meeting

PRESENT:

Consultants Panel

Dr. R.B. Peck
Mr. M.D. Copen
Dr. A.J. Hendron Jr.
Dr. L. Sykes (2/17 only)

Alaska Power Authority Panel

Mr. J. Douma

Acres American Inc.

J.D. Lawrence
C. Debelius
J.W. Hayden
S.N. Thompson
V. Singh
I. Hutchison
A. Burgess
R. Henschel
J.D. Gill
G. Krishnan
S. Bahadur
H. Eichenbaum
R. Ibbotson
D. McDonald
L. Duncan

Alaska Power Authority

R. Mohn

(a) Presentation by J. Hayden

- Brief review of Task 6 Development Selection Studies which have been completed to date.

- Based on analyses, a combination of Watana and Devil Canyon provides the most cost effective development of the Upper Susitna River Basin. Also concluded that Watana is the first development for the basin.

(b) Presentation by S. Thompson

- Brief review of regional and site geology by previous investigations.
- Summary of 1980 mapping program objectives and scope of work.
- Updated geologic maps and overburden thickness maps of both sites.
- Review of special features at Watana and Devil Canyon. Included "Fins" and "Fingerbuster" shear zones, relict channel, possible fault in river and low velocity anomaly on right abutment at Watana, and large open joints (striking northwest), bedding of argillites, buried channel, possible fault through alluvial fan area, possible fault in river channel, and granodiorite encountered at depth in BH-2 at Devil Canyon.

(c) Presentation by V. Singh

- Brief review of WCC scope of work and program for 1980.
- Discussed Talkeetna terrain and relationship of features to plate tectonic model. Assigned magnitude 8.5 to Benioff zone.
- Review of historical earthquake data.
- Microseismic network objectives and data obtained. No apparent relationship between epicenter locations of micro earthquakes and known features at both sites. However, data clearly shows decoupled zone below sites with subductive plate about 50-70 km deep.
- Review of WCC screening process for lineaments and field studies. Identification of four features at Watana (Talkeetna thrust, Susitna feature, Fins and KD3-7) and nine features at Devil Canyon site for further detailed study in 1981.
- Studies indicate that reservoir induced seismicity is very likely to occur for both reservoirs.
- 3 primary ground motion sources identified:

Benioff Zone	8.5M	Watana 30km (0.41g)	D. Canyon 60km (0.37g)
Denali Fault	8.5M	Watana 70km (0.21g)	D. Canyon 70km (0.21g)
Castle Mtn. Fault	7.4M	Watana 105km (0.06g)	D. Canyon 105km (0.05g)

- General feeling that 8.5M on Benioff is controlling earthquake, but that this can be refined downward with additional work.
- Reviewed earthquake magnitudes and associated accelerations at sites from 13 identified features in the event that they prove to be active. Could result in significant design changes. 1981 program has to be aimed at these features.
- Presented proposed WCC 1981 program (typed sheets - handout) point by point discussion of program by panel.

- General discussion as to what items had highest priority for 1981 WCC program.

(d) Presentation by V. Singh

- Brief review of 1980 geotechnical investigation. Included mapping, borings, seismic refraction work, etc.

- Look at special features at both sites.

- Reviewed proposed borrow sources and material properties.

- Presented proposed 1981 diamond drilling program (Acres panel considered this a minimal program) for both dam sites.

- Reviewed borrow areas exploration for 1981.

- Discussed relict channel and additional work proposed by APA panel. Acres plan of additional seismic lines and flow net analysis to characterize channel.

- Proposed seismic refraction surveys across river channel to define quantity of alluvium for construction.

- Discussed proposed additional hole(s) in powerhouse area. Powerhouse location not finalized yet.

(e) General Discussion

- WCC seismic trenching program - difficult to get definitive cost on trenches due to logistics and constraints on equipment. Best time is spring or winter but doesn't fit design schedule very well.
  J. Gill - practical to do trenching at Devil Canyon or Fins in summer but can't get to Talkeetna or Susitna feature until November.
  J. Lawrence - question if data is still usable in November.

- J. Lawrence - main concern is activity along Talkeetna thrust. If not confirmed early, then have to assume active and design for .76g (assuming 354 mi length). No problem with Watana dam but affects concrete structures.
  J. Gill - sufficient mapping may eliminate need for trenching.
  L. Sykes - even if Talkeetna Thrust is not connected to Broxon Gulch Fault, can still get magnitude 7.6 ± earthquake.
  J. Hayden - concern that data may be too late. Design for 0.46g and later get 0.76g may endanger the technical feasibility.
  C. Debelius - agree that FERC won't issue license.
  R. Mohn - APA wants to be conservative in license application.
  R. Peck - any significance to lack of micro earthquake data along Talkeetna?
  L. Sykes - no, historical data shows earthquakes associated with Talkeetna outside 100km radius. Left with mapping and trenching to define it. Feeling that a lot can be gained by showing that Talkeetna has not moved in the past 10,000 years.

- S. Thompson - concern about floating earthquakes.
  L. Sykes - no matter what you do you will still have a floating earthquake with at least 6.25M.
  A. Hendron - use probablistic analysis to assess 6.5M event occurring under site. Design for 0.4g for earthquake on Benioff zone. Floating earthquake of 6.25M has to be within about 6.6 miles of site to give > 0.4g.
  R. Ibbotson - probably won't have significant overall cost impact to design for 0.7g as opposed to 0.4g.
  R. Peck - may get some failures of appurtenant structures but not critical to schemes.
  J. Lawrence - general feeling that 0.4g could be used for preliminary design and be safe. Question is what APA will have to do to satisfy opponents of project.
  R. Mohn - maybe should be conservative now.

- R. Peck - what steps do we have to take to live with big earthquake. No doubt that we can design economic dam that will survive. Not worried about powerhouse or other structures. Design dam for maximum earthquake and other structures for lower magnitude.
  H. Eichenbaum - may need to add low level outlet for drawdown.
  R. Peck - overall cost will be slightly higher to design dam for 0.7g and other structures for 0.4g but not prohibitive.
  J. Lawrence - use Oroville cross section?
  R. Peck - agree, if use gravel. It should be adequate. If use rockfill you have to be more conservative. Feel that section can be improved upon somewhat. Should be able to handle any earthquake you come up with.

- J. Lawrence - question of need for WCC calibration trench.
  R. Peck - feel it should be considered "out of scope". Not characteristic of site terrain and may be quite different. Don't feel it is necessary.
  V. Singh - Dr. Seed was also opposed to the idea and was going to talk to WCC directly.

(f) Responses by Panel

- A. Hendron - question, which layout at Devil Canyon (arch or earthfill) was used for costing in Task 6 studies?
  J. Hayden - both layouts were looked at and cost is about the same. Arch dam is preferred.

- A. Hendron - question, why isn't "Fingerbuster" shear included in features to be looked at by WCC in 1981?
  J. Lawrence - was not identified during their lineament studies, but has been pointed out to them for inclusion.

- A. Hendron - question, what field evidence to say KD3-7 is not continuous to Devil Canyon?
  J. Gill - rock exposure between Watana and Devil Canyon, no expression of feature in these areas.

- Proposed 1981 WCC program discussion. (Attachment 1)

  - Item 3 - refine MCE on Benioff zone - not considered warranted by panel. Take out.

  - Items 4 & 5 - evaluation of historical earthquakes - considered to be worthwhile. Expected that this could be done for about $5,000.

  - Item 6 - evaluate stress regime - some disagreement.
    L. Sykes - good data to have, low cost.
    R. Peck - money better spent on setting up microseismic network.

  - Item 7 - A. Hendron - question, why we need to evaluate MCE on active faults in Talkeetna terrain. Have already assigned magnitude to Denali Fault which is active.

  - Item 8 - low priority, take out of program.

  - Item 9 - A. Hendron - concern about time involved in looking at Denali Fault. Waste of effort. Look at other features local to site.
    R. Peck - feel that most of work on refining and evaluating this (MCE on Denali) is wasteful. Knew answers to some items last time panel met.
    A. Hendron - willing to go with what we have on Denali now. No need to refine it and lower it.
    L. Sykes - Benioff Zone is still likely to control design.
    J. D. Lawrence - Conclusion of Panel that nothing is to be gained by studying the Denali further.

  - Item 10 - permanent seismic network. Agree on "Like to Have" it, but do not feel it is absolutely necessary to install it this year. Plan on installing in Phase II. Agreed to postpone until 1982.

  - Items 11 through 14 - okay

  - Item 15 - revise attenuation relationship.
    L. Sykes - do not feel there will be much difference from present case. Take out of program.

  - Items 16 through 18 - okay

- General discussion as to what should be in WCC 1981 program.

  - A. Hendron - need to look at floating earthquake and Talkeetna thrust.

  - L. Sykes - most effort has to go to items 1 and 2 (study of 13 features), and floating earthquake. 8.5M on Benioff is too large, but probably will not drop below 7.8. Minimal effort to refine this.
    V. Singh - about 50% of budget is for Items 1 and 2.

. Discussion on criteria for determining recent displacement.

R. Peck - do not feel that 100,000 year is a good criteria. have a good chance of dating features as being younger or older than 10,000 years (Glacial) but poor chance of getting 100,000 year confirmation. Need to look at features and determine what data exists to put an age on it, and not worry about a specific age.
S. Thompson - feel that it will be almost impossible to put 100,000 year date on features because of terrain.
R. Peck - what age can we put on reatures:
10,000 years - Glacial evidence
35,000 years - Carbon dating
Geologic data to date very old features
V. Singh - if no criteria on age (100,000 years), will this affect exposure analysis?
A. Burgess - feels that it can be accommodated in probablistic analysis.
J. Gill - first activity in 1981 will be to determine if any units can be identified which will give dates between 10,000 and 100,000 years (Quaternary geology studies).
A. Hendron - at some point it becomes more economical to accept higher earthquake risk and get on with it.
H. Eichenbaum - yes, but higher earthquake risk affects design of dams, equipment costs, etc.

. J. Lawrence - have to look at Talkeetna thrust and put it to rest.

A. Hendron - define difference between Talkeetna thrust, Fins and other features shown on photographs. Talkeetna and Fins exist, others may not.
J. Hayden - feel part of 1981 program should lay to rest all 13 features as to fault or not, and age where possible.
V. Singh - feels we will still have indeterminate features after 1981.
R. Peck - should start at the site, develop geology and then work outwards.

- A. Hendron - concerned about origin of andesites. It may be extrusive and flowed down old weathered valleys. Potential problem for tunnels.

- R. Mohn - can Watana stand alone as cost effective scheme if Devil Canyon is not built later?
J. Hayden - yes, still cost effective (> 1.7 benefit ratio). But High Devil Canyon is probably the best single development scheme.

- A. Hendron - all proposed holes for 1981 are aimed at disproving faults!
J. Lawrence - not true, holes are based on recommendations of this Panel in October.
V. Singh - holes designed to pickup rock quality as well as faults.

- A. Hendron - do not see need of BH-11 in Fins structure. Drilling could be used to better advantage elsewhere.
V. Singh - determine permeability, continuity, characterize zone, etc.

- R. Peck - possibility of terrace deposits infilling relict channel at Watana being exploitable for shell materials.
- R. Henschel - possible, but materials are quite variable and the extent is unknown.

- J. Gill - require layout schemes so that scheduling of drilling can be completed.

6. Minutes of Meeting - February 18, 1981

Present: As for February 17, 1981, except for L. Sykes.

(a) Presentation on general arrangements and layouts - R. Ibbotson

- Presentation of design criteria for Watana
  - for initial layout
  - for remainder of project
  - for multiple spillways arrangement.

· High velocity in chute - 175 fps. J. Douma stated precedents for 150 fps at Tarbela, Mica and in Iran. Need aeration to avoid damage. Only expected to operate few times, once in 20 years. Maybe able to accept some cavitation. Also have to keep nitrogen saturation in mind - won't lose it in Devil Canyon reservoir. Add to it in Devil Canyon Dam, but may lose some in rough stretches of river - suggest discuss with Milo Bell. Use Flip Bucket aimed directly downstream, but have to avoid potential erosion problems.

· R. Ibbotson - problem is aggravated in Devil Canyon due to narrow gorge and possibility of under-cutting slope. Low level drawdown capability. Period of 12 months assumed to empty reservoir - is this acceptable time frame? 20,000 cfs discharge required.

· J. Douma - if failure imminent - can't drawdown fast enough, 12 months may not be of any use. May want to use low level outlet and also discharge through diversion tunnel - e.g. Mica Dam. Standard COE practice to install drawdown capability even if can't justify need. COE criteria is to drawdown half of reservoir in three months.

· J. Lawrence - Don MacDonald and I. McCaig are doing in-house search on drawdown practices at existing dams - will make recommendation.

· R. Peck - need to look at risk from severe earthquake event - wouldn't expect to have to drawdown entire reservoir - damage may be restricted to upper section of dam.

· M. Copen - USBR has past cases where rapid drawdown saved dam - not something to overlook at. Gates likely to be damaged by severe earthquake.

· R. Peck - blastable plugs rather than gates in diversion tunnels may be something to look at. Gates likely to be damaged by severe earthquake.

· R. Ibbotson - three level intake with gates or shutters being considered.

· M. Copen - shutters used with three - level intake at Flaming Gorge - works fine.

- Presentation of design criteria for Devil Canyon - for preliminary layouts (4)

- A. Hendron - have you looked at stiffness of rock?
  V. Singh - varied between 1 x 10^6 psi and 3 x 10^6 psi

- Discussion on design factor of safety. M. Copen says that stresses due to earthquake will not exceed strength of concrete. Dam will not fail in tension - will crack - can only fail in compression if strength of concrete is exceeded.

- Presentation of Watana layouts (see Attachment 2)

  - COE dam layout with Acres revised spillway, intake and toe of dam location.

  - Layout 1 - Conservative, single spillway, designed for PMF.

    R. Peck - how high is upstream cofferdam - (about 100 feet, not designed yet). If slopes of dam are flattened, may push upstream toe into Fins area. Problem also of being able to excavate alluvium.
    J. Hayden - Enough seismic lines proposed under dam area to get picture of alluvium.
    J. Lawrence - should bear in mind that this is only 1 of 11 alternative layouts that have been looked at - still being refined. We will be revising sections, center line location, spillway location etc. before finalizing layout.
    R. Peck - not knowing alluvium thickness and dam slopes - hurts you later when you need more room and tunnels become longer, etc.

  - Layout 2 -

    J. Hayden - how much problem with diversion tunnels, etc. passing through "Finger Buster"?
    V. Singh - feel that south abutment is better than North - will know better after drilling.
    R. Ibbotson - water passages longer on south - have to pull dam centerline upstream to get powerhouse downstream of dam centerline.
    J. Hayden - intake needs to be unconstrained by 150' drawdown - lower intake will be required.
    J. Gill - why pull centerline downstream on left - R. Ibbotson - to shorten spillway.
    R. Peck - Use longer cascade spillway - unlined - get more rockfill for dam.
    J. Hayden - problem of locating spillway so it doesn't cross shear zones. Problem of putting downstream shell on shear zone and spillway in good rock.
    R. Peck - exploration should be aimed at 'static geotechnics' of site to define problems for layout of dam - not seismic studies.

  - Layout 3 -

    R. Ibbotson - very economical spillway excavation.
    R. Peck - project section more downstream.
    J. Douma - cascade spillway also helps N_2 problem.
    J. Hayden - will still be passing about 12,000 cfs through powerhouse if spilling, with about 50% dilution of N_2.

J. Douma - erosion will be on right side of spillway - channel will flow more to that side. Will also raise tailwater level.
J. Hayden - should use stepped spillway to help this.

- Layout 4 - Very constrained in vicinity of Fins - 2.5:1 upstream slope on dam.

R. Peck - if flatter slopes are used there could be a severe problem locating structures clear of the Fins and Fingerbuster features downstream.
R. Ibbotson - this arrangement allows a favorable layout for main spillway.
J. Hayden - proposing to design main spillway for 1:100 year flood, then probably will not be a problem with surface flume.
J. Douma - the flow would still be 50,000 cfs.
R. Ibbotson - we may want to use emergency spillway - until Devil Canyon is built to eliminate N_2.
H. Eichenbaum - 2 spillway scheme has good flexibility.

10:10 - Coffee

- Presentation of Devil Canyon Layouts - (see Attachment 2)

  - Devil Canyon earthfill dam layout.

  - Layout 1 - thin arch

    Problems - with spillways and discharge and concrete gravity dam along top of left abutment - not very economical or practical.

  - Layout 2 - (should be thin arch rather than "thick" shown on drawing)

  - Layout 3 - Optimum spillway location and alignments (Plan and sections presented)

    J. Hayden - what about N_2 problem under normal operation of spillway?
    J. Douma - not enough information yet. If flume is designed to discharge at surface, should eliminate N_2 problem, but may have lateral erosion problem.
    A. Hendron - have you looked at thick arch with powerhouse in dam and spillway on right abutment?
    M. Copen - would have to go to gravity section to do that, better to have surface powerhouse in that case.
    R. Peck - emergency spillway on left abutment way have problems of discharging into relict channel which may erode material under the saddle dam - may have to strengthen downstream section of spillway to prevent this.
    J. Hayden - any problem with gates and plunge pool at toe of dam?
    M. Copen/J. Douma - No! Has been done at Morrow Point with a 60' deep lined pool. Devil Canyon has 90' depth of water, unlined.

M. Copen - may be okay. Look at putting intermediate level intake on diversion tunnel to act as emergency spillway - several existing dams did this with considerable cost savings.
R. Ibbotson - with high flows expected, it may not be economical to enlarge small diversion tunnels during initial construction.
J. Hayden - should check economics - may be cheaper to enlarge surface spillway unless low level drawdown capability is required.
J. Lawrence - any thoughts on emergency spillway fuse plugs in general? Are they currently out of favor?
J. Douma - no problem, as long as they go out when required - proposing one on Nippawan Dam now in Canada - may require model testing to optimize. Not too many in existence, only used for PMF.
M. Copen - Don't see my problem with them.
J. Douma - should be designed to save structure from overtopping.
T. Burgess - if flooding occurs in spring, won't fuse plug be frozen and not easily eroded?
J. Douma - will be exposed to warm water and sunlight. Considerable thawing by then, should be okay if well-drained.
D. MacDonald - on Nelson River - frosting to 18' - 20' until August!
J. Douma - may be problem. Have to consider it.
M. Copen - dropping water 700+ feet into plunge pool at toe of dam - may be problem. Should be dispersed by air during fall.
J. Douma - plunge pool very dependent on rock quality. If highly fractured will erode quickly.
M. Copen - gates required for spillway.
J. Douma - should consider using cost of gates and plunge pool in dam in boosting capacity of main spillway to handle most of flow, and then use fuse plug spillway more frequently.
I. Hutchison - system will be spilling very frequently - might not be cost effective.

- Thin Arch Dam - geometry presented.
  Assymetrical arrangement gives better stress distribution in abutments.

11:00 - Break into discussion groups:

(b) Arch Dam - M. Copen/R. Ibbotson/H. Eichenbaum

- Review of latest results of stress analyses and design assumptions. No significant comment.

(c) Watana Dam Design - R. Peck/A. Hendron/ V. Singh

- Presentation of Watana embankment sections - original COE layout.
- Acres proposal for slight u/s - d/s slope on core. (see Attachment 3)

- Portion of u/s shell constructed of cobbles. U/s - d/s slopes of shells vary from 1.75:1 to 3.5:1 u/s and 1.7:1 to 2.8:1 d/s - assume alluvium u/s to be used in shell - use all available gravel shells.

- Dr. Seed - has suggested core should be sloped more upstream. Also recommended making slopes similar to Oroville - for seismic shaking. This increases volume and cost.

- Some preliminary static analyses undertaken. Limited information on materials - used .4g earthquake acceleration. Results indicated a few inches of slumping. (no low strength materials in section). Allowing about 12' settlement for seismic considerations. Planning on removal of riverbed materials under entire dam. Will also look downstream for more alluvium to use as fill.
  R. Peck - any chance of getting gravel materials out of buried channel area?
  J. Lawrence - may be possible, but elevation in borrow area D is not much higher than reservoir level.
  L. Duncan - low point is El. 2204 - will require a saddle dam.
  R. Peck - what will be used for core? - (V. Singh - processed till materials from Borrow Areas D or H.)
  R. Peck - should put< ½" in core, remainder in shells. At Portage Mountain - used this splitting of material - a good dam resulted - may also reuse alluvium from under dam with processing - will probably be more expensive than rockfill, but a better dam.
  V. Singh - concern about % fines in alluvium.
  R. Peck - definitely rather see more gravel in upstream shell than rockfill, have to see what material is available and go from there. Beneficial to compensate for steeper slopes with better compaction. If flat slopes - don't. Suggest steeper slopes in section of cobbles in upstream shell from that shown which will tend to crack. Steeper section will have more tendency to crack further upstream.
  A. Hendron - like idea of leaving core where it is. More stable than sloping upstream.

- Presentation of Oroville Section

  R. Peck - don't want to duplicate core sections of Oroville - Acres section better in that respect.

- Presentation of possible failures caused by earthquake (Seed)

  A. Hendron - has tectonic tilting been considered in freeboard?
  V. Singh - allowed 12', don't have good handle yet on features which could cause tectonic tilting.
  J. Lawrence - currently (without looking in detail) have assumed it won't happen.
  V. Singh - need to review regional tilting from 1964 earthquake.
  L. Duncan - take MCE in region, calculate settlements and project to damsite.
  R. Mohn - has Acres looked at all items other than tilting?
  V. Singh - currently based on generic list, not all will apply.
  J. Lawrence - haven't looked at design for overtopping.

- Presentation of features to be included in dam to make it more resistant to earthquake (Seed)

  R. Peck - stability analyses should show that location of core and flattening of slopes upstream can be varied within a fairly narrow range before F.S. decreases and potential instability becomes evident.

· Discussion on foundation treatment (preliminary, prior to group discussion)

R. Peck - must expect to have grouting and drainage - adequate funding should be allowed.
J. Hayden - will the 150-200' drawdown cycle cause any problems?
R. Peck - should already be accounted for in design. Drawdown not rapid.
C. Debelius - will there be freeze/thaw and ice shelving problems?
J. Douma - may cause deteroration of rip-rap.
L. Duncan - at Curry - rock was very resistant < .1% @ 250 cycles - no reactivity.
R. Peck - also will have rather thick rip-rap section.

(d) Geotechnical Discussion Group - R. Peck/A. Hendron/V. Singh

- Discussion of grouting galleries at Watana/Devil Canyon

R. Peck - at James Bay, grouted from surface after cleaning - need wide blanket grouting - which can't be done from gallery. Not good to blast rock for gallery. Question: What do you do about grouting and permafrost?
L. Duncan - CRREL work - 2-3 meters - pumped river water through rock.
R. Peck - should strip abutments.

- Discussion of drainage galleries

R. Peck - Desirable, work up abutments as you go.
A. Hendron - can see advantages to drainage galleries.
R. Peck - discharge drains into shells.
J. Gill - do you need to have access to drains?
R. Peck - don't feel that drains are likely to clog up.
D. MacDonald - chief purpose of galleries is to get back in later.
A. Hendron - galleries useful to show where seepage is coming from.
R. Peck - design system based on geology and requirements. Rather see galleries in abutments than under dam. Don't like raised gallery through fill. Some concern about stress relief features under valley bottom. Need not make decision now, but allow funds to cover drainage and refine later when you have more data. Show galleries in abutments and holes under dam for now, but may end up with just holes in foundation.
A. Hendron - is there a drainage gallery under spillway chute?
D. MacDonald - yes, center gallery with drain holes - primarily to drain underside of slab.
R. Peck - another potential problem - open joints running parallel to grout curtain - may have to angle holes upstream.
L. Duncan - the COE design assumed combined drainage and grouting galleries. COE also worried about not being able to get back in to grout if leakage occurred and that instrumentation would not survive to 800' depth.
R. Peck - this type of arrangement worked fine at Mica. Really need to do good foundation preparation - and schedule for it (e.g. James Bay).

- Discussion on cofferdams - need berms into excavation and drainage system - also cutoff wall.

  R. Peck - there will be a drainage system anyway.

Meeting Adjourned

7. ATTACHMENT I

PROPOSED WCC 1981 ACTIVITIES

TASK 4

ATTACHMENT 1

PRELIMINARY BUDGET LAYOUT FOR 1981 ACTIVITIES

ACTIVITY	BUDGET STANDARD	WATANA EMPHASIS	TOTAL	OUT OF SCOPE	COMMENTS
1) Study significant features at Watana Site; active or inactive fault	$ 50,000	$ 50,000	$ 50,000	20-30,000	Quaternary geology
	28,000DC 42,000W	14,000 56,000	70,000	20,000	Field Mapping
2) Study significant features at Devil Canyon Site; active or inactive fault	13,000DC 37,000	--- 50,000	50,000	50,000	Trenches (Contract 8) (Proposed 4) 1 - DC 2 - Talkeetna Thrust 1 - Susitna Feature 1 - Fins
				15,000	Calibration
	12,000DC 18,000W	6,000DC 24,000W	30,000	20,000 ----------	Remote Sensing Geophysics & Seismic Refraction Survey
			28,000		Review & Travel
3) Refine MCE on the Benioff Zone and how close to site			10,000 (90% conf. level)	10,000	To include evaluation of low seismicity zones, 1964 earthquake & Japanese S.A. data

TASK 4 - PRELIMINARY BUDGET LAYOUT FOR 1981 ACTIVITIES (Continued)

ACTIVITY	BUDGET				COMMENTS
	STANDARD	WATANA EMPHASIS	TOTAL	OUT OF SCOPE	
4) Evaluate location and sources of mod. to large historical earthquakes in Talkeetna Terrain			$ 10,000 (incl. trip to UAGI)	$ 20,000	To include other events
5) Evaluate location and sources of mod. to large historical earthquakes north of Talkeetna Terrain			7,000		
6) Evaluate stress regime within the Talkeetna Terrain			5,000	5,000	To include more events
7) Estimate the MCE for active faults in the Talkeetna Terrain	Budget included under (1) & (2) and (18)				
8) Continue evaluation of the of RIS on the maximum credible earthquake			10,000		
9) Refine MCE on the Denali Fault			20,000		

TASK 4 - PRELIMINARY BUDGET LAYOUT FOR 1981 ACTIVITIES (Continued)

ACTIVITY	BUDGET STANDARD	BUDGET WATANA EMPHASIS	BUDGET TOTAL	BUDGET OUT OF SCOPE	COMMENTS
10) Install and operate seismic network in 1981				$100,000 to 200,000	
11) Determine ground motions for design at Watana Site			$ 27,000	7,000 to 8,000	---------- To develop time history
12) Determine ground motions for design at Devil Canyon Site					
13) Evaluate dam stability			2,000		
14) Assess stability conditions along transmission line row and roads			5,000		
15) Revise attenuation relationship			8,000		Only for Benioff Zone
16) Redo exposure analysis	Included under (11) and (12)				
17) Prepare a seismic network installation & operations manual			35,000		
18) Prepare final report			112,000		

8. ATTACHMENT 2

PRELIMINARY PROJECT LAYOUTS

SUSITNA - APA SPECIALIST CONSULTANTS MEETING
FEBRUARY 17 & 18, 1981

Watana

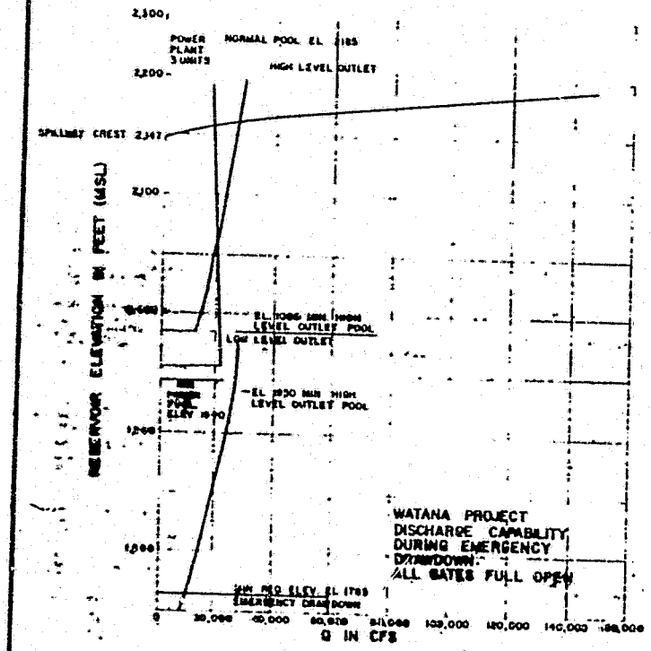
Rockfill Dam	-	Corps Layout
	-	Acres Layout - Staged
	-	Acres Layout 1
	-	Acres Layout 2
	-	Acres Layout 3
	-	Acres Layout 4

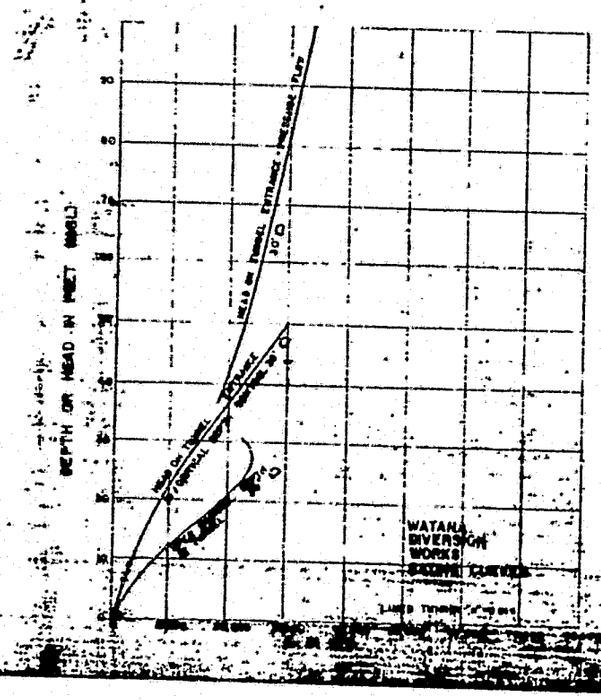
Devil Canyon

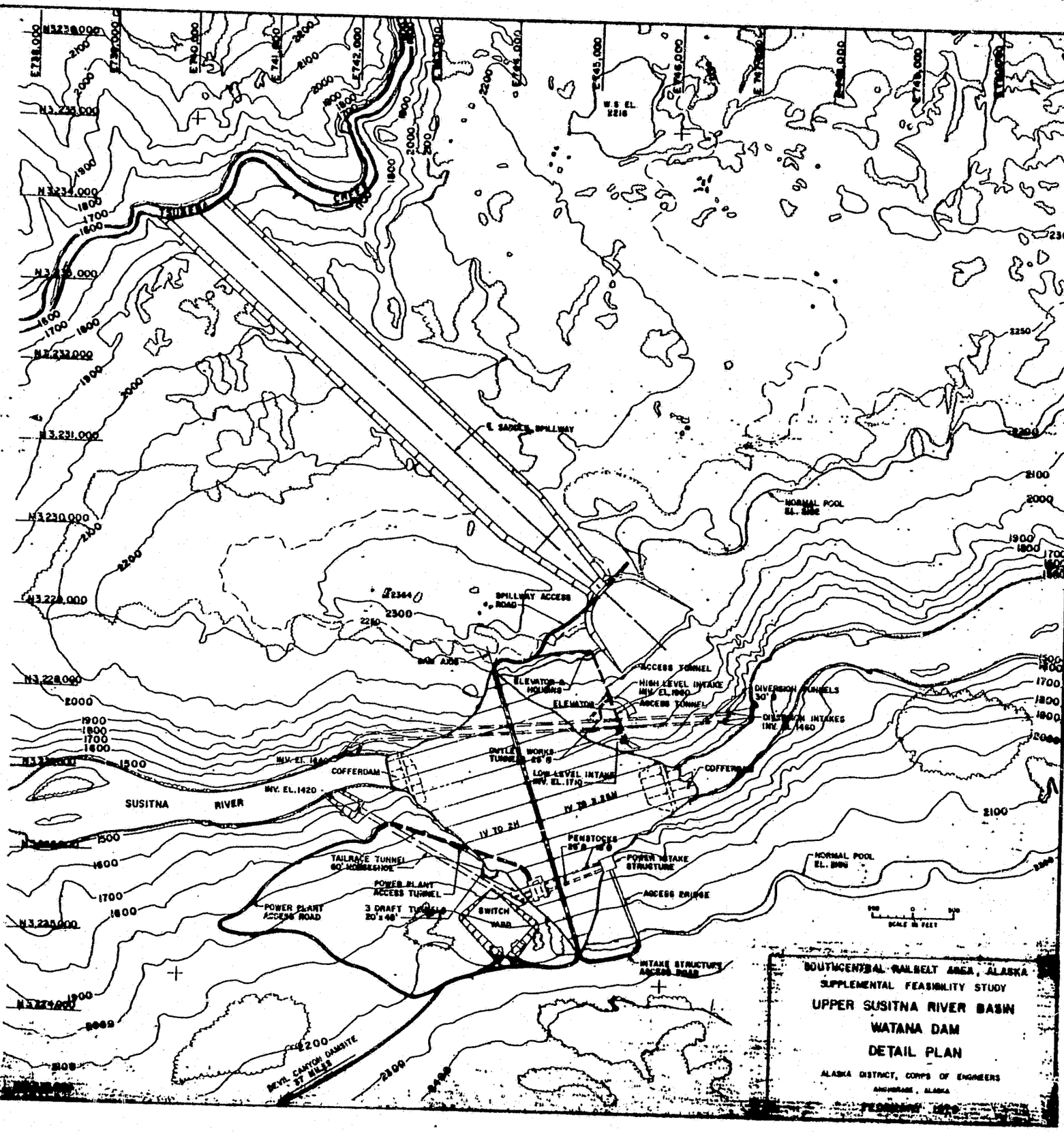
Rockfill Dam	-	Acres Layout
Arch Dam	-	Acres Layout 1
	-	Acres Layout 2
	-	Acres Layout 3
	-	Sections for Layout 3
Arch Dam	-	Geometry

NOTES:

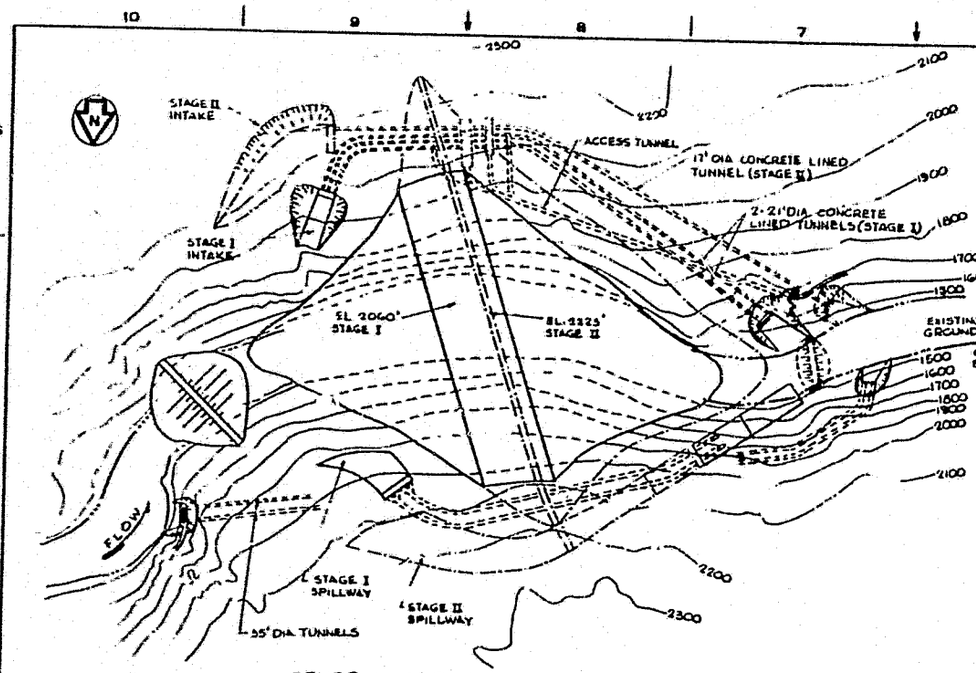
1. TOPOGRAPHIC CONTOURS ARE BASED ON AERIAL PHOTOGRAPHY DATED 10 JUNE 1978. VERTICAL DATUM IS MEAN SEA LEVEL (MSL)



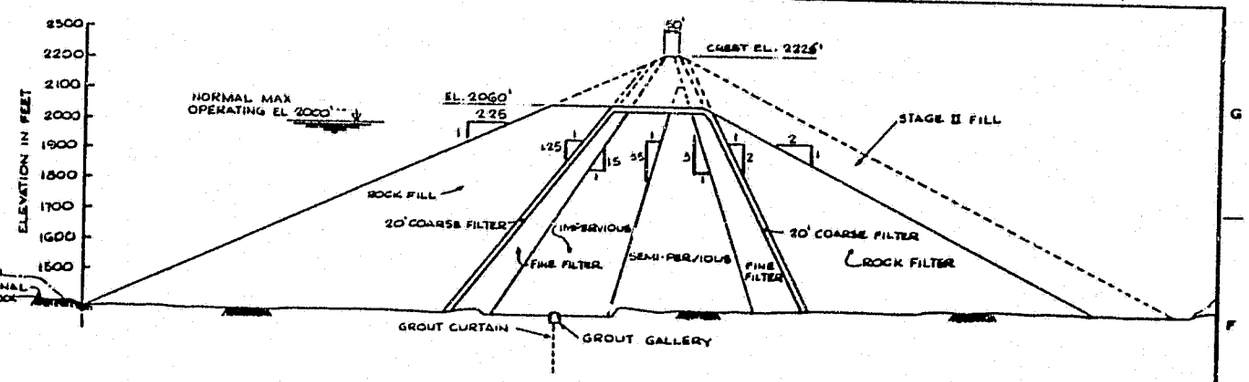




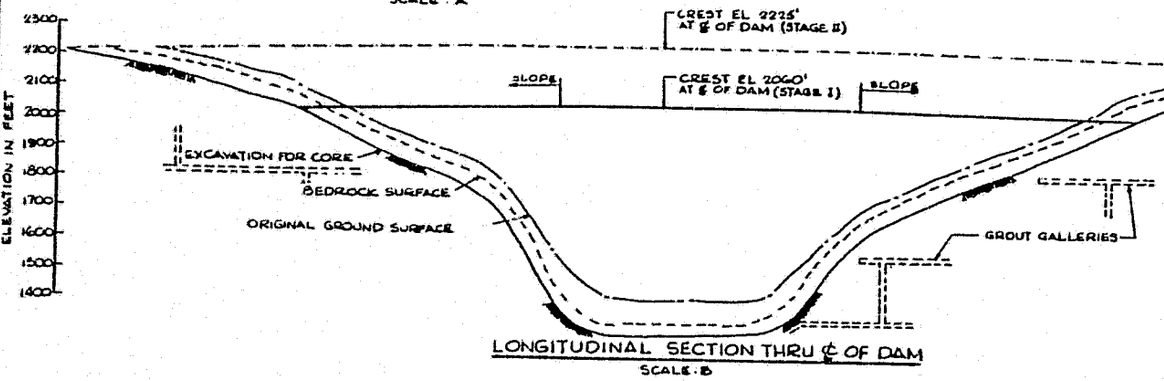
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAM
DETAIL PLAN
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA



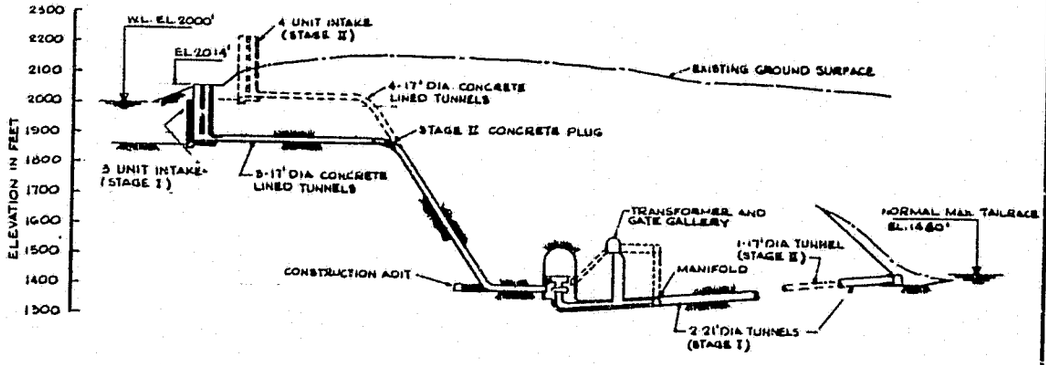
GENERAL ARRANGEMENT
SCALE : A



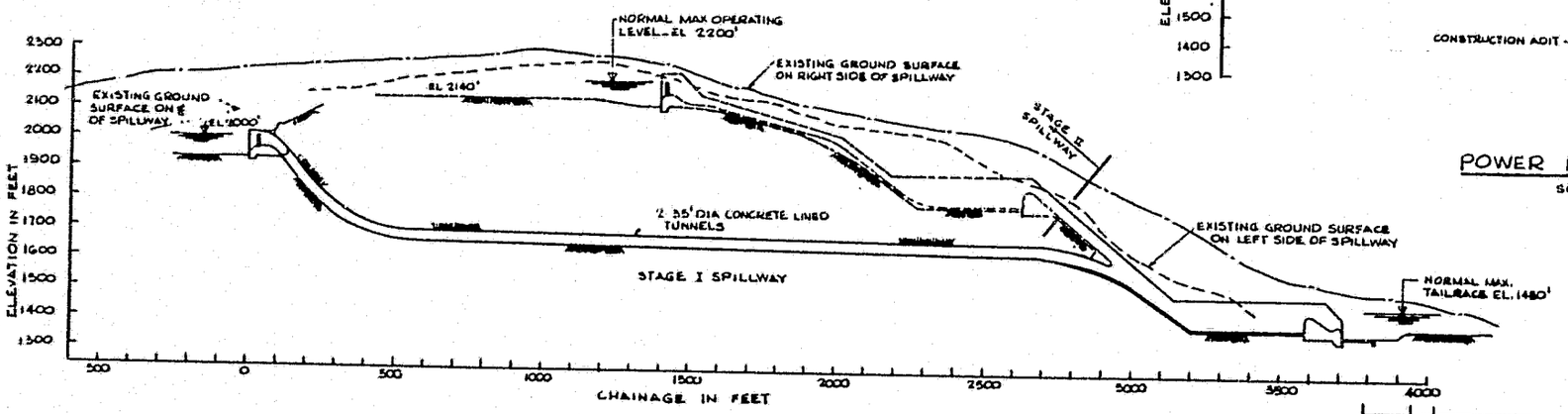
SECTION THRU DAM
SCALE : B



LONGITUDINAL SECTION THRU ℄ OF DAM
SCALE : B



POWER FACILITIES PROFILE
SCALE : B



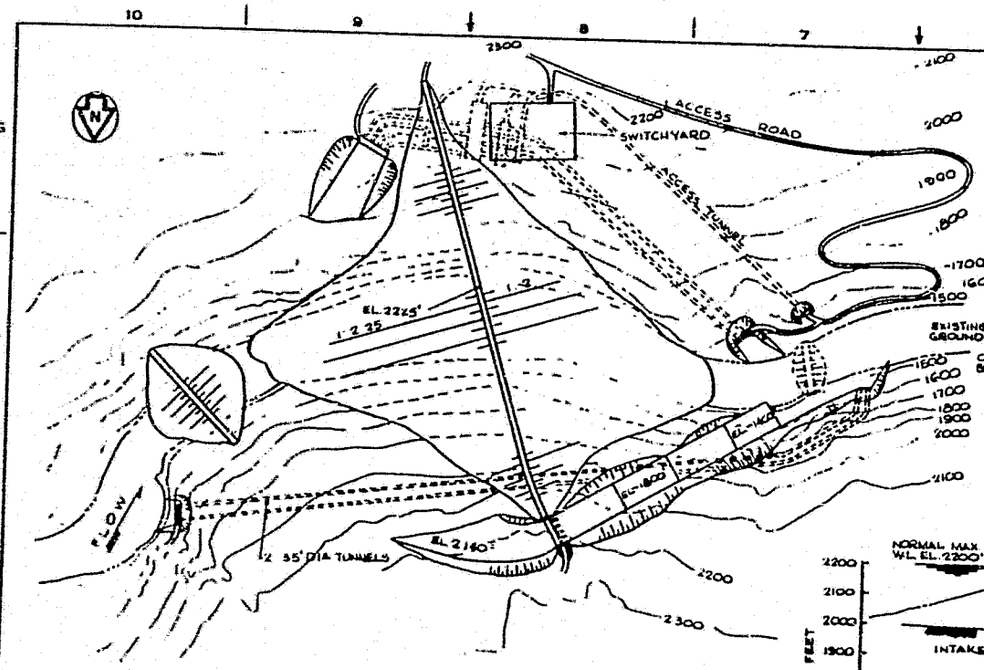
SPILLWAY PROFILE
SCALE : B

SCALE A 0 500 1000 FEET
SCALE B 0 200 400 FEET

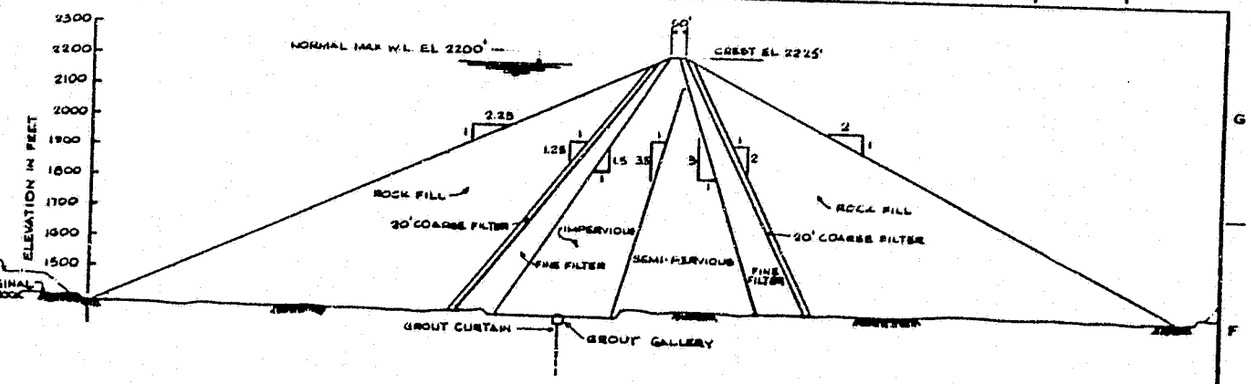
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

STAGED WATANA ROCKFILL DAM HYDRO DEVELOPMENT PLAN AND SECTIONS

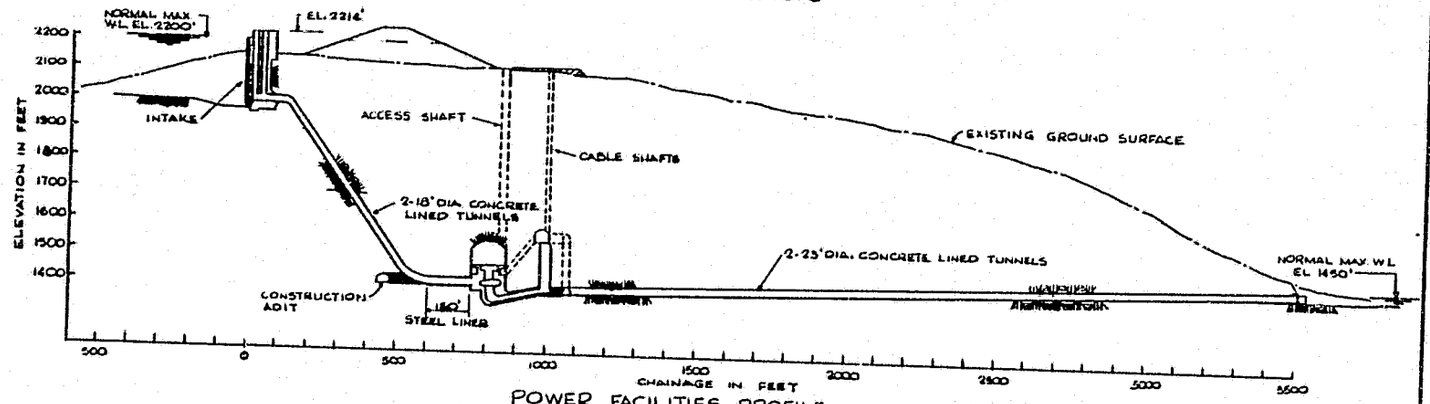
DATE
SCALE AS SHOWN
DRAWING NO
SHEET OF
REV



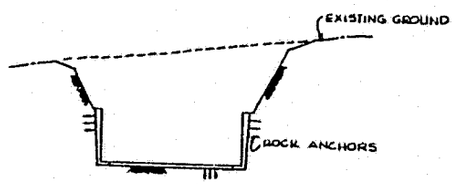
GENERAL ARRANGEMENT
SCALE: A



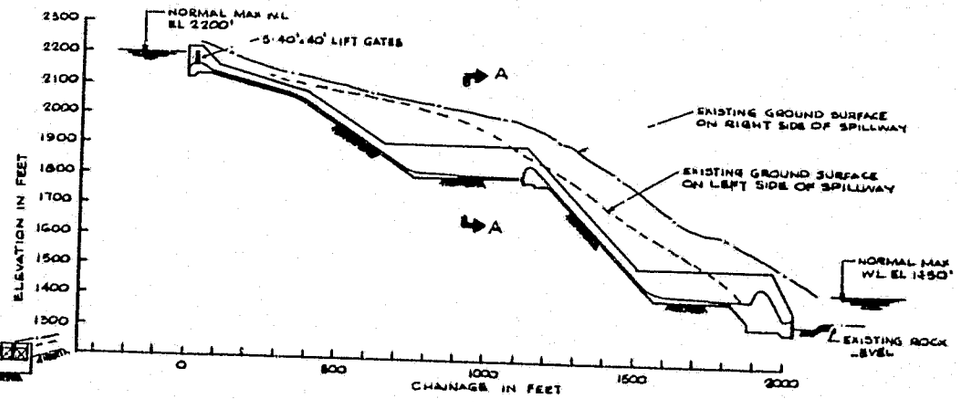
SECTION THRU DAM
SCALE: B



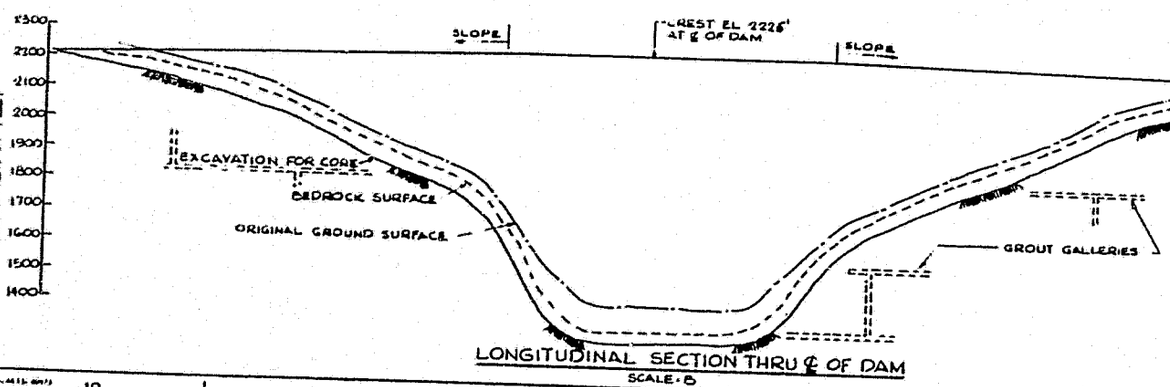
POWER FACILITIES PROFILE
SCALE: B



SECTION A-A
SCALE: C



SPILLWAY PROFILE
SCALE: B

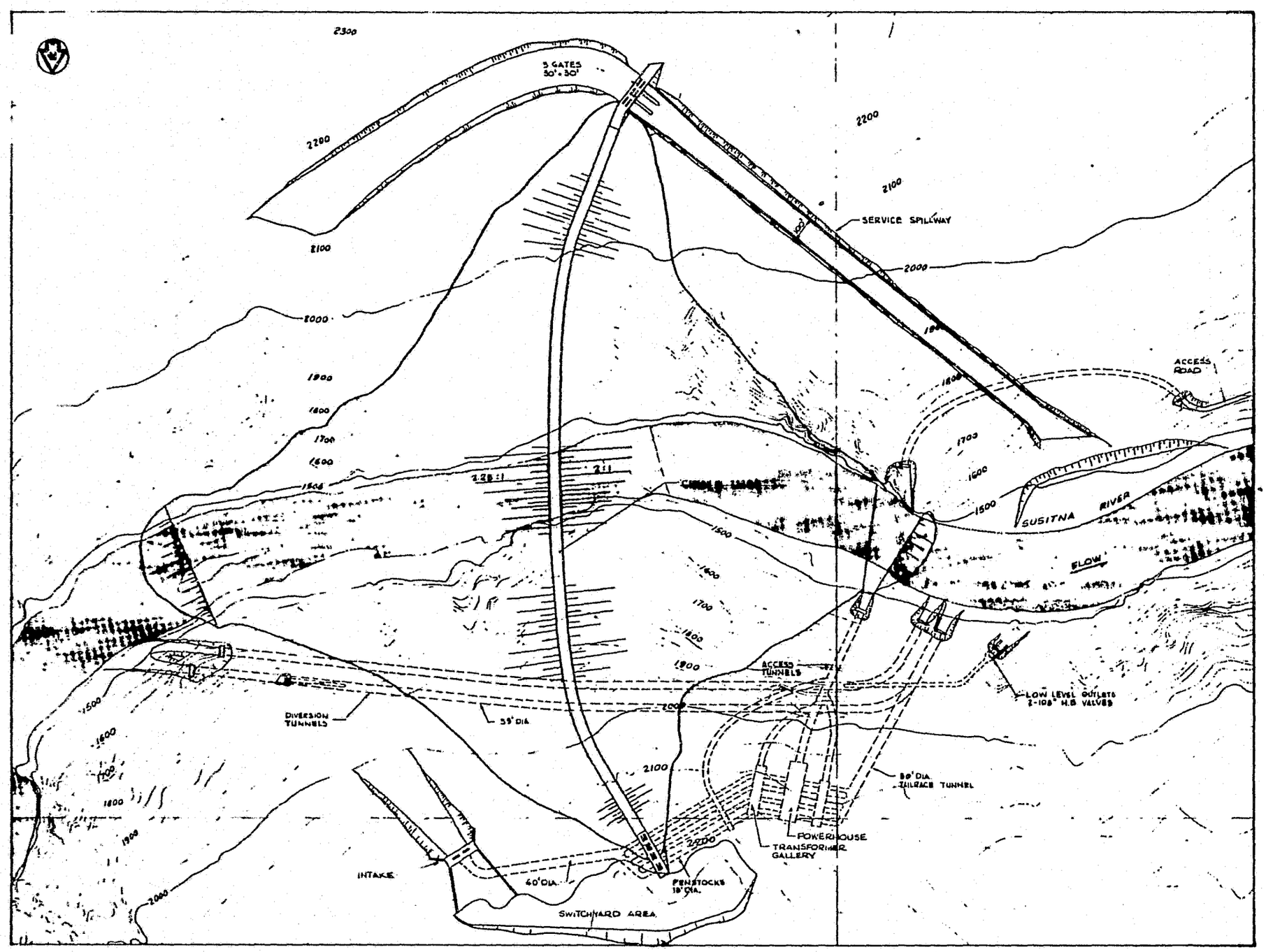


LONGITUDINAL SECTION THRU ℄ OF DAM
SCALE: B

SCALE A 0 500 1000 FEET
SCALE B 0 200 400 FEET
SCALE C 0 100 200 FEET

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA ROCKFILL DAM (CREST EL 2226)
HYDRO DEVELOPMENT
PLAN AND SECTIONS
DATE NOV 18, 1980
SCALE AS SHOWN

LAYOUT 1



SCALE 0 200 400 FEET

ALASKA POWER AUTHORITY

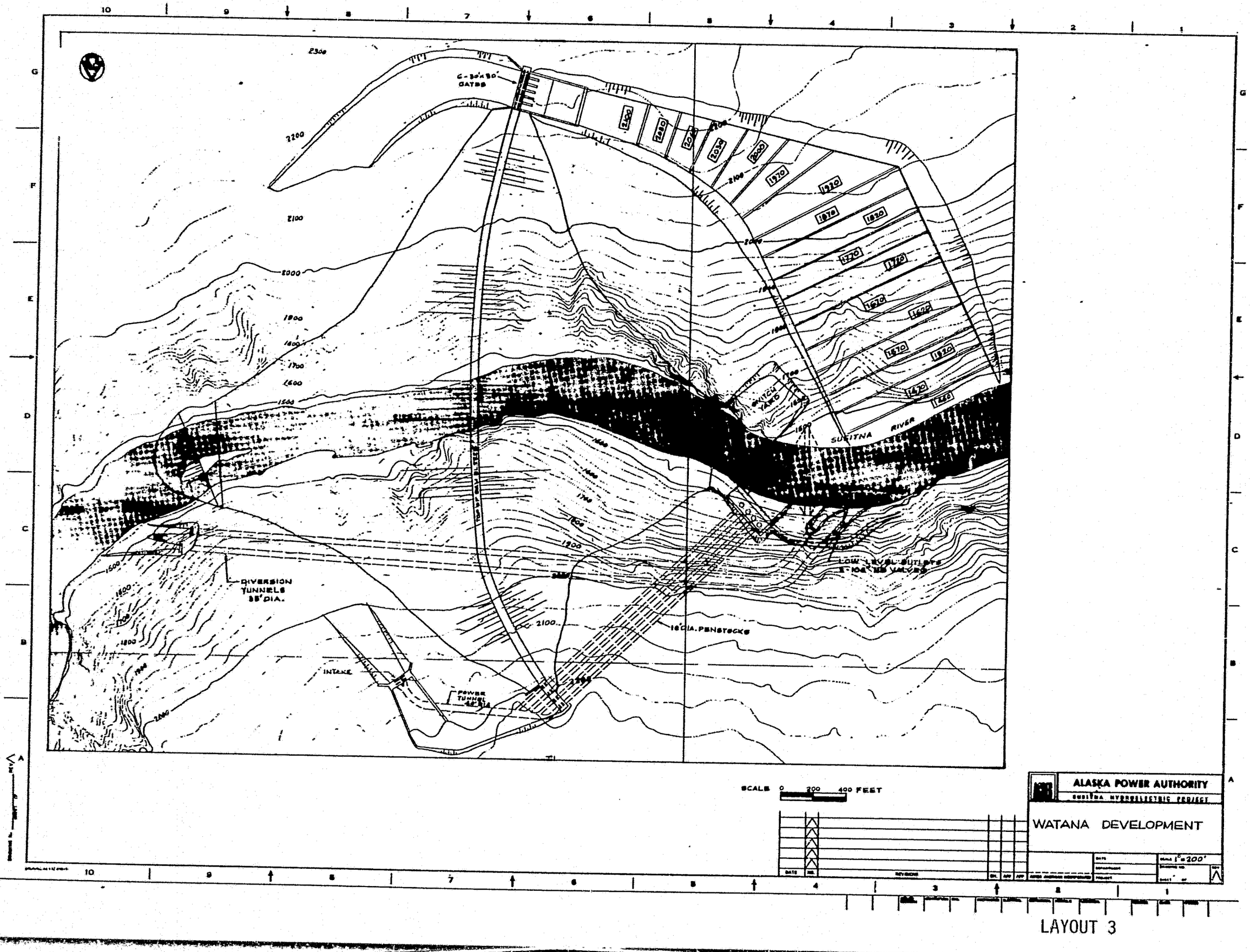
SUSITNA HYDROELECTRIC PROJECT

WATANA DEVELOPMENT

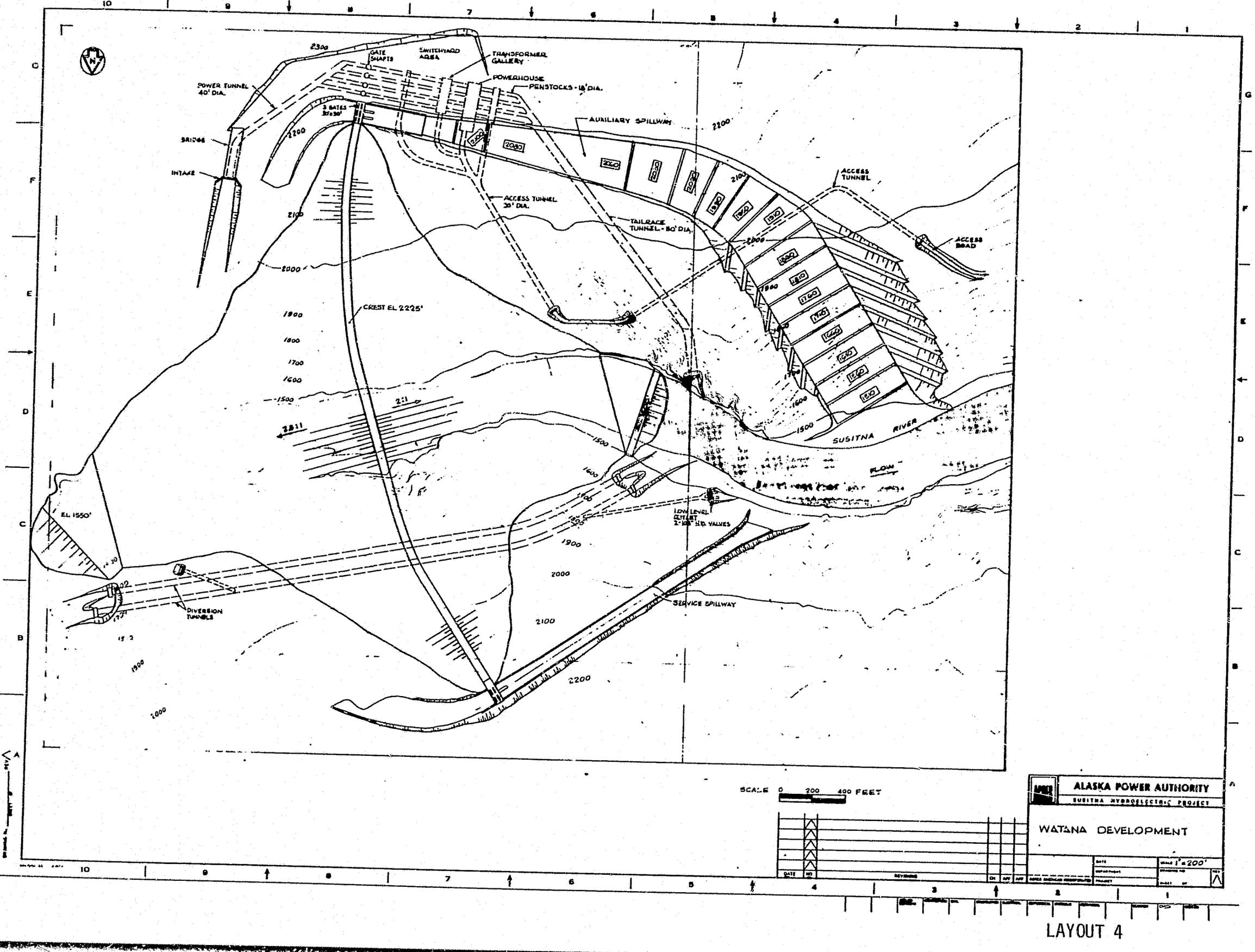
SCALE 1"=200'

REVISIONS

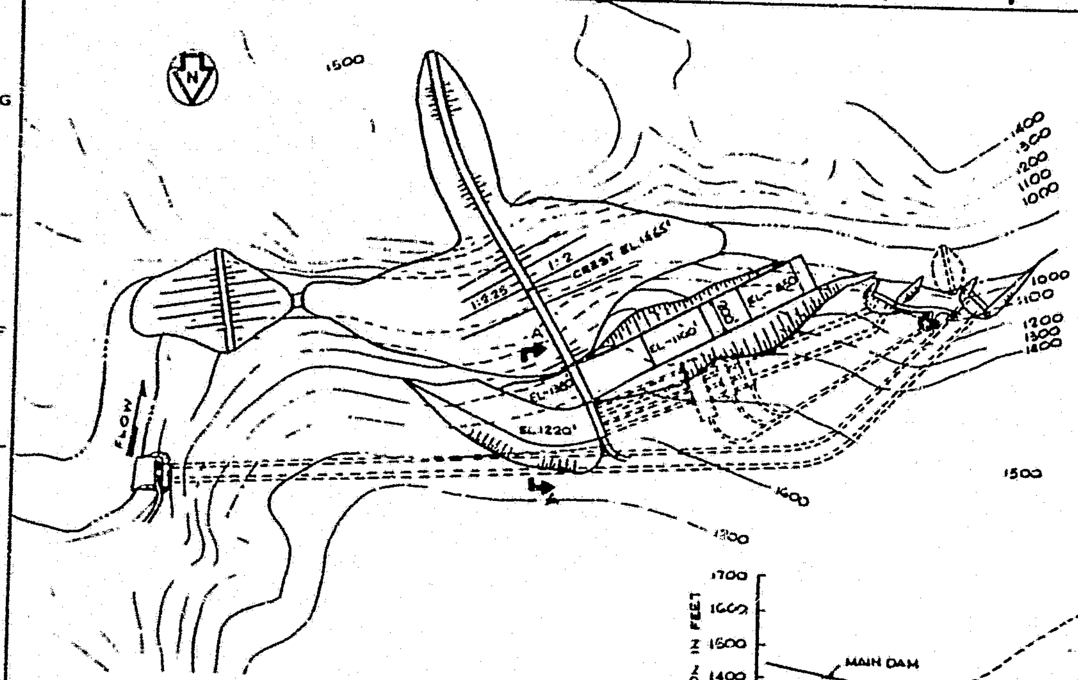
LAYOUT 2


G-30'x30' GATES
DIVERSION TUNNELS 38' DIA.
INTAKE
POWER TUNNEL 42' DIA.
18' DIA. PENSTOCKS
LOW LEVEL OUTLETS 5'-10" HOWELL VALVES
SURGE TANK
SUSITNA RIVER
BRITCH YARD
SCALE 0 200 400 FEET
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA DEVELOPMENT
1" = 200'

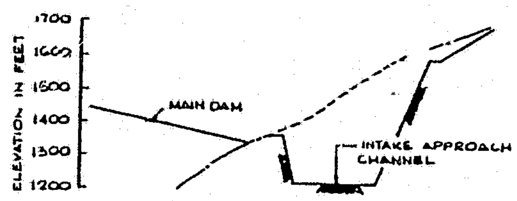
LAYOUT 3


GATE SHAFTS
SWITCHYARD AREA
TRANSFORMER GALLERY
POWERHOUSE
PENSTOCKS - 18' DIA.
POWER TUNNEL 40' DIA.
3 GATES 31'x30'
AUXILIARY SPILLWAY
SPRING
INTAKE
ACCESS TUNNEL 30' DIA.
TAILRACE TUNNEL - 50' DIA.
ACCESS TUNNEL
ACCESS ROAD
CREST EL 2225'
SUSITNA RIVER
FLOW
LOW LEVEL OUTLET 2'-10" H.D. VALVES
EL 1550'
DIVERSION TUNNELS
SERVICE SPILLWAY
SCALE 0 200 400 FEET
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA DEVELOPMENT

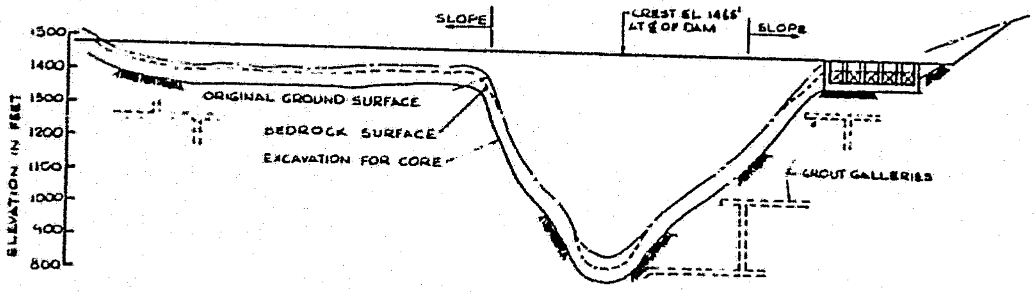
LAYOUT 4



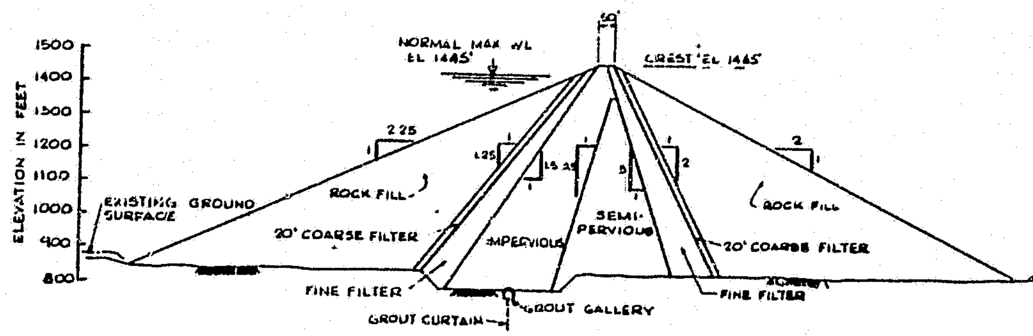
GENERAL ARRANGEMENT
SCALE A



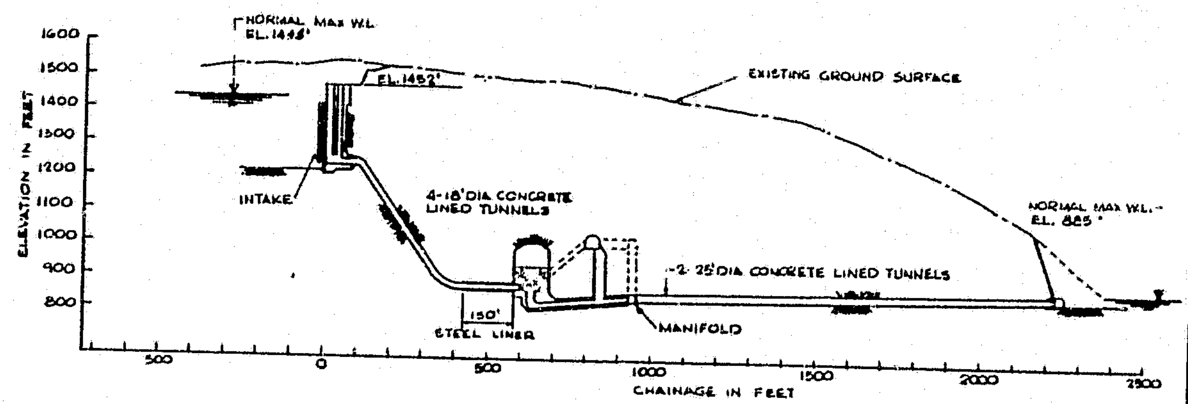
SECTION A-A
SCALE: B



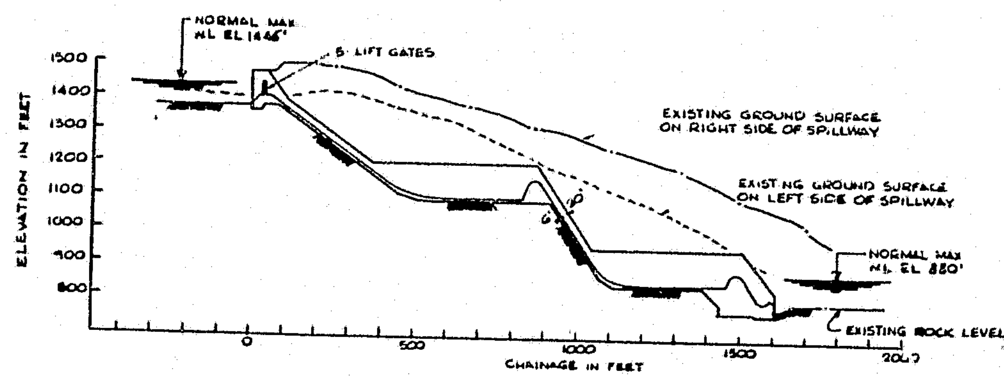
LONGITUDINAL SECTION THRU ¢ OF DAM
SCALE: B



SECTION THRU DAM
SCALE: B



POWER FACILITIES PROFILE
SCALE: B



SPILLWAY PROFILE
SCALE: B

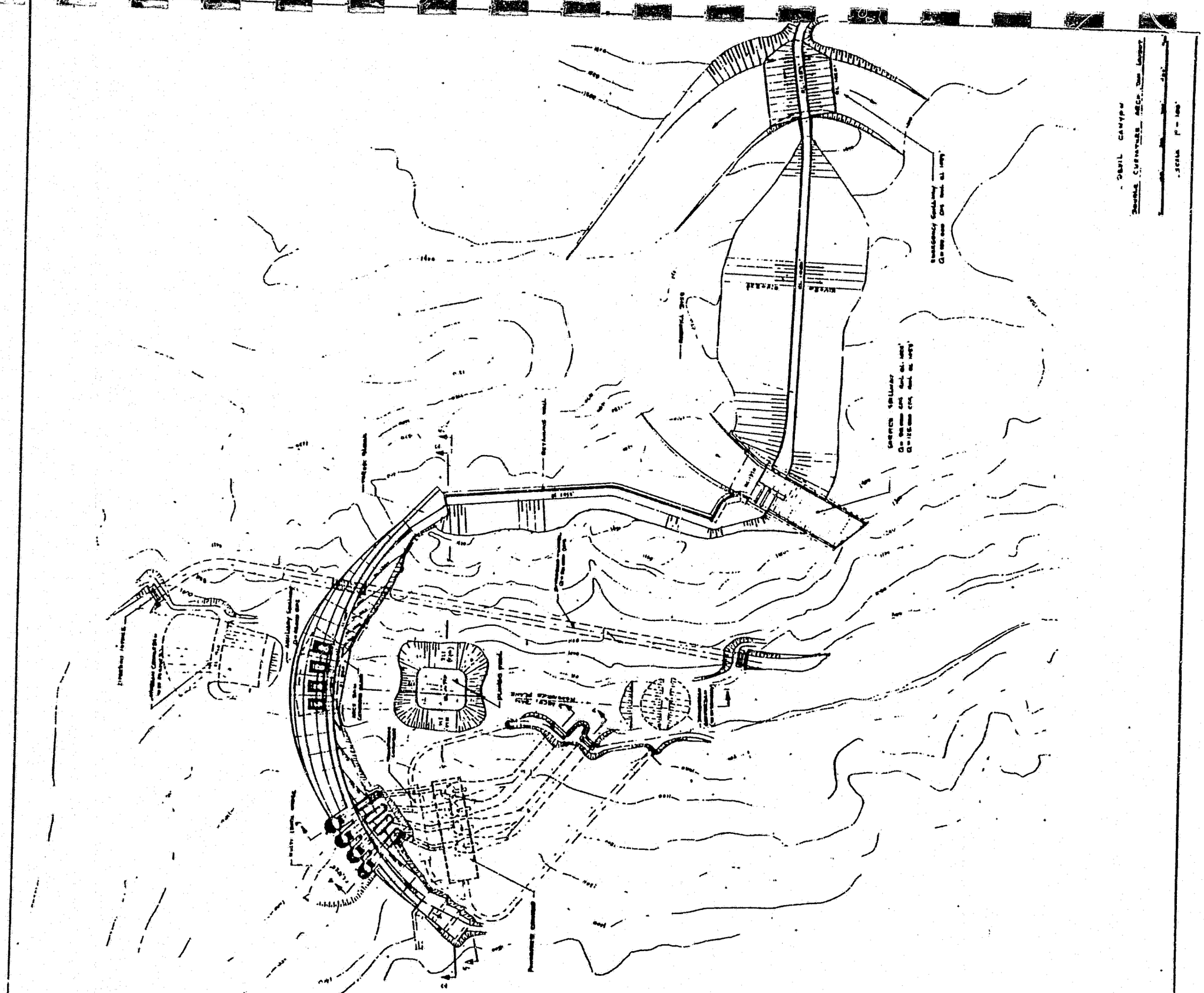
SCALE A 0 400 800
SCALE B 0 200 400

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

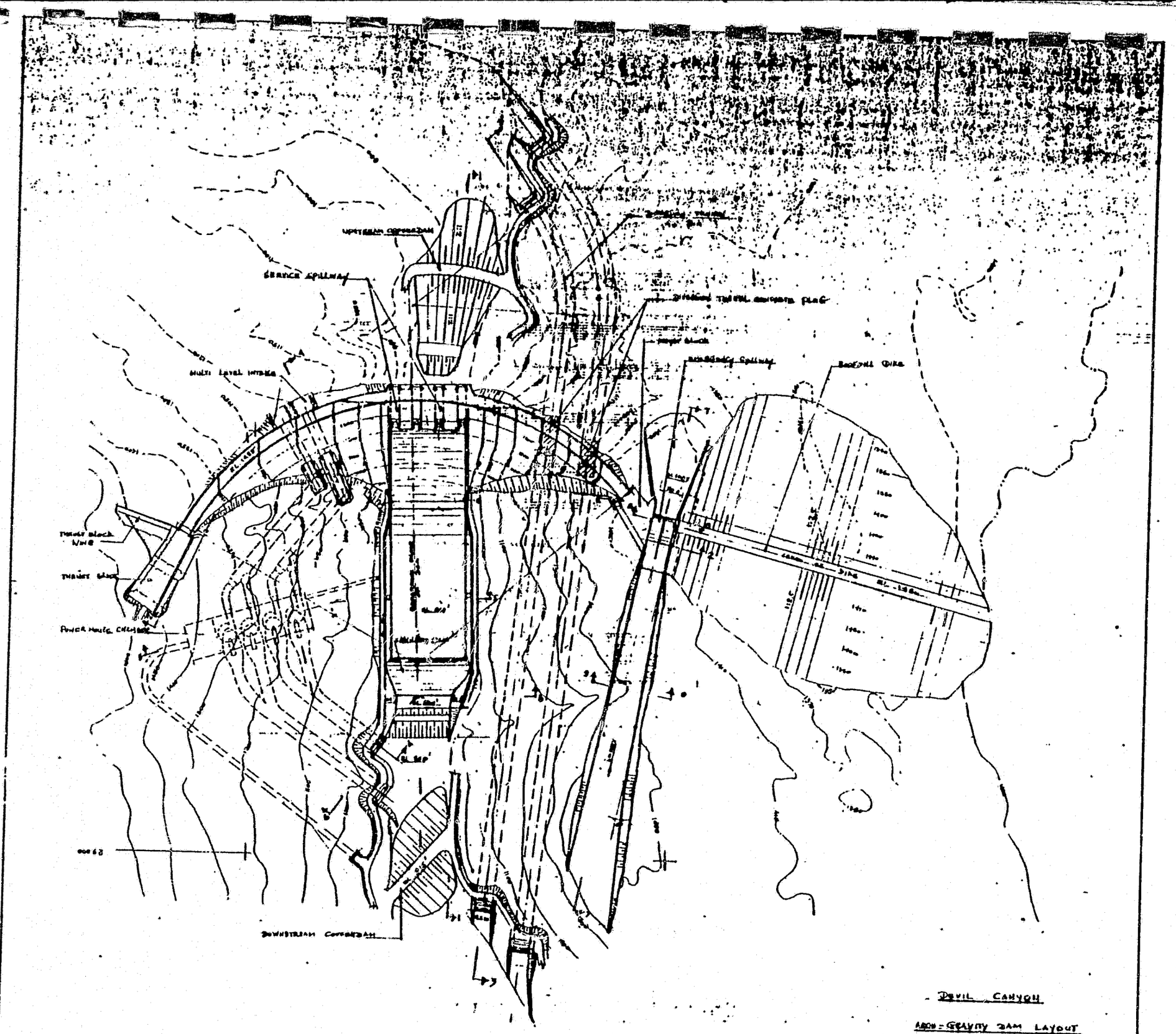
DEVIL CANYON (ROCKFILL) CREST EL 1465'
HYDRO DEVELOPMENT
PLAN AND SECTIONS

SCALE AS NOTED

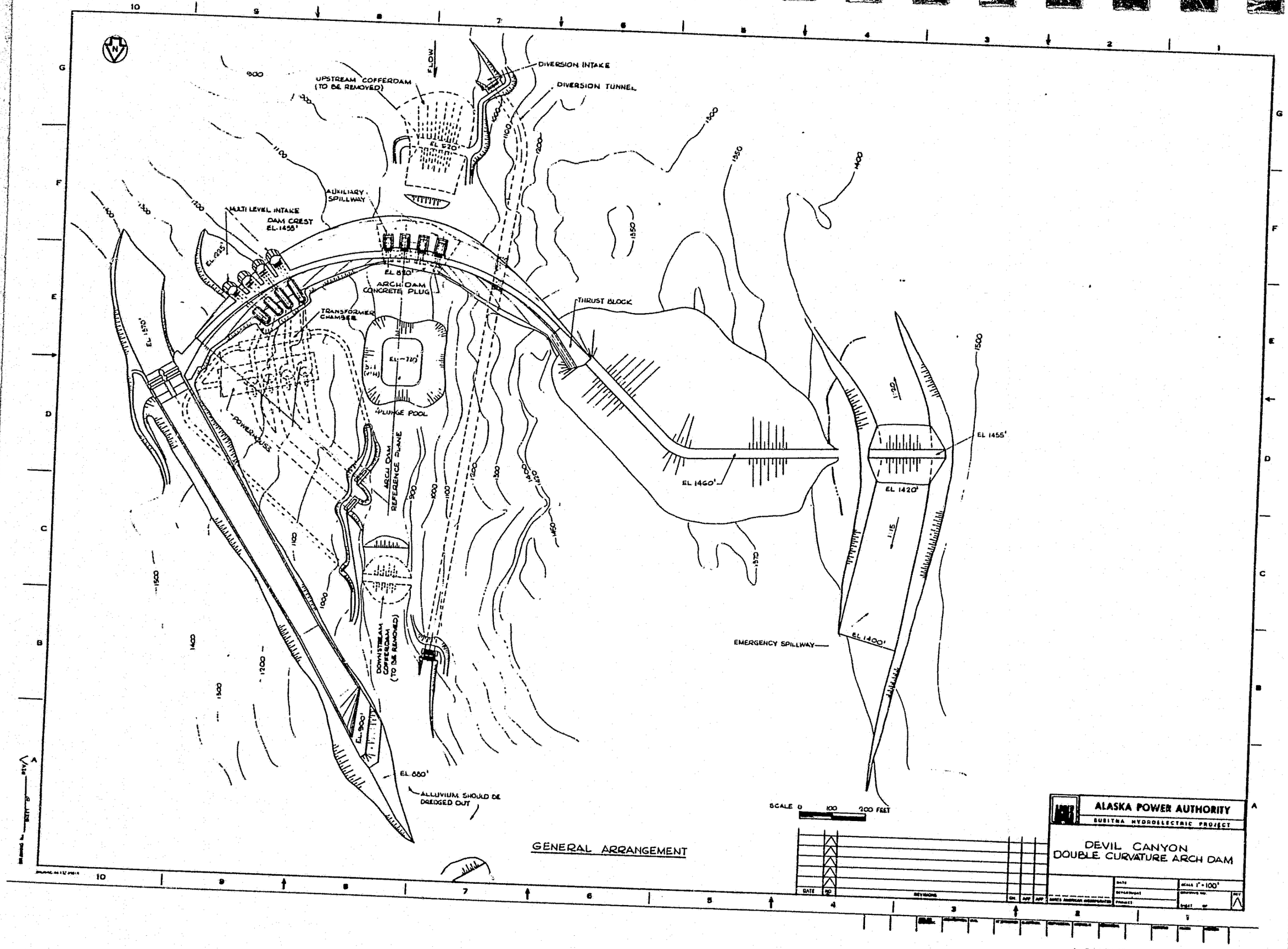
DATE | NO | REVISIONS | CH | APP | APP | ACRES AMERICAN INCORPORATED



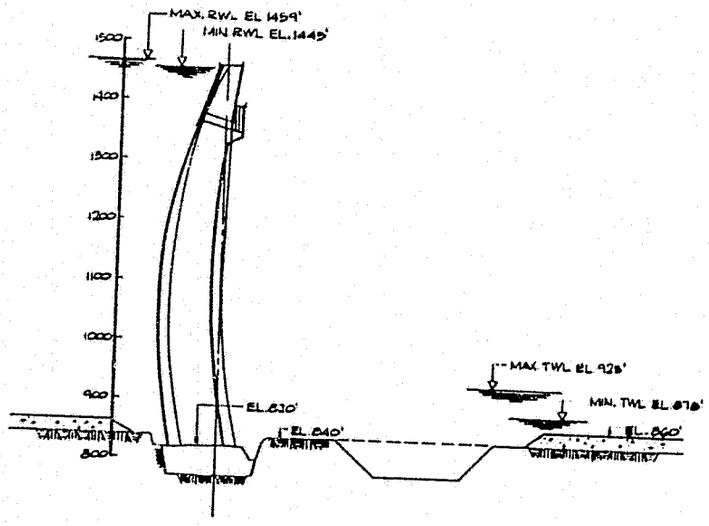
LAYOUT 1


UPSTREAM COFFERDAM
SERVICE SPILLWAY
MULTI LEVEL INTAKE
EL. 1480'
TRASH BLOCK
TRASH BLOCK
POWER HOUSE CHANNEL
DOWNSTREAM COFFERDAM
EMERGENCY SPILLWAY
EARTHFILL DIKE
CANAL AND DIKE EL. 1380'
DEVIL CANYON
ARCH - GRAVITY DAM LAYOUT
SCALE - 1" = 100'

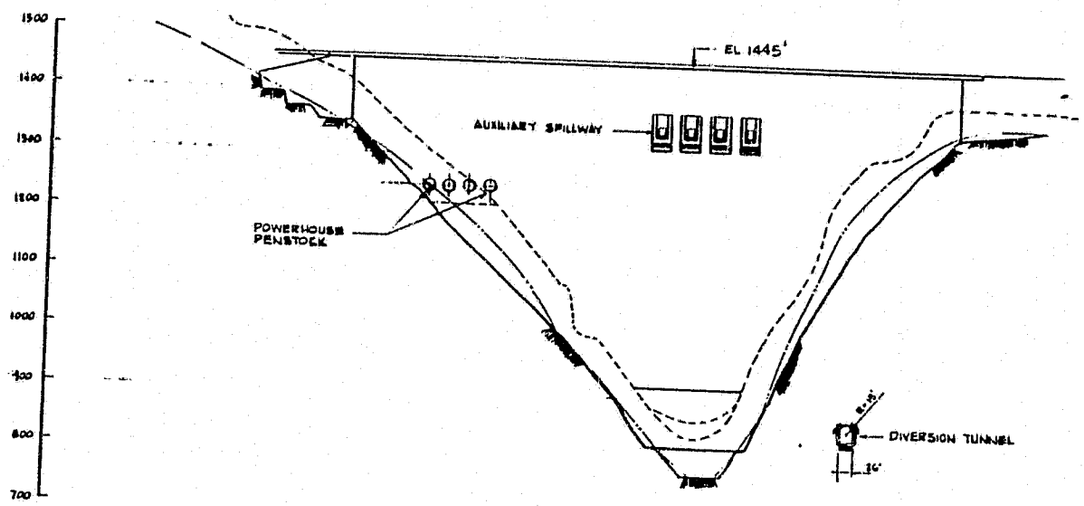
LAYOUT 2


DIVERSION INTAKE
DIVERSION TUNNEL
UPSTREAM COFFERDAM (TO BE REMOVED)
FLOW
AUXILIARY SPILLWAY
MULTI LEVEL INTAKE
DAM CREST EL. 1455'
EL 820'
ARCH DAM CONCRETE PLUG
TRANSFORMER CHAMBER
THRUST BLOCK
PLUNGE POOL
POWERHOUSE
ARCH DAM REFERENCE PLANE
DOWNSTREAM COFFERDAM (TO BE REMOVED)
EL. 900'
EL. 660'
ALLUVIUM SHOULD BE DREDGED OUT
EL 1460'
EL 1455'
EL 1420'
EL 1400'
1:1.5
EMERGENCY SPILLWAY
SCALE 0 100 200 FEET
GENERAL ARRANGEMENT
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
DEVIL CANYON
DOUBLE CURVATURE ARCH DAM

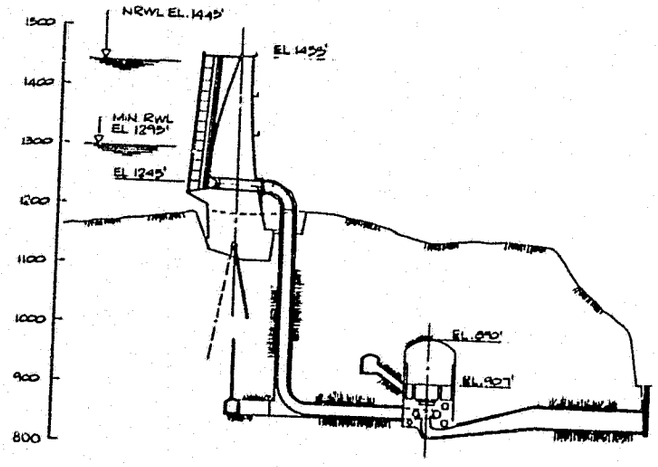
LAYOUT 3



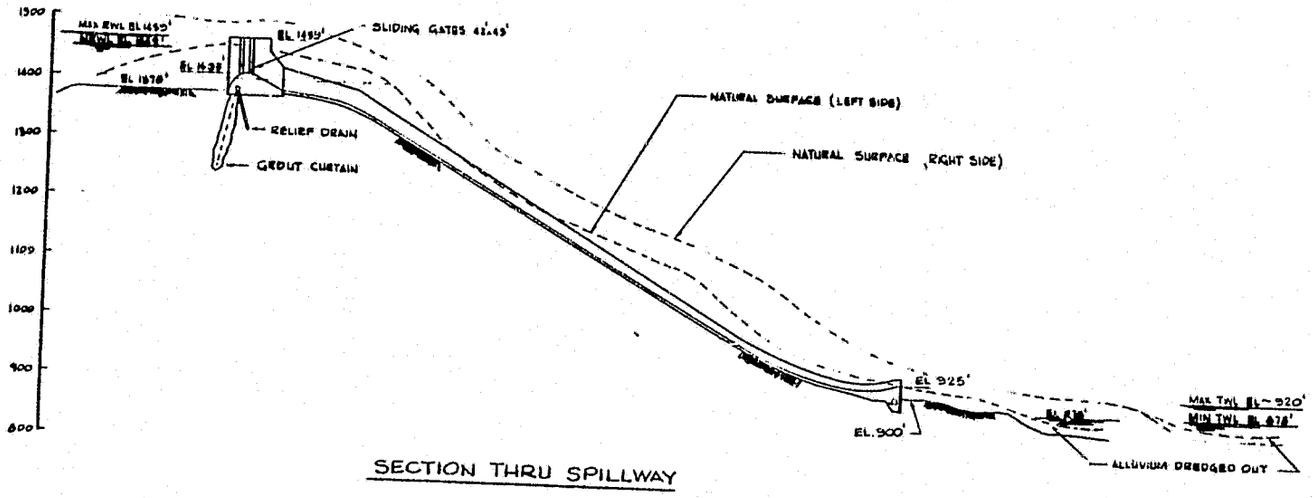
CROWN SECTION



DAM PROFILE



SECTION THRU POWER FACILITIES



SECTION THRU SPILLWAY

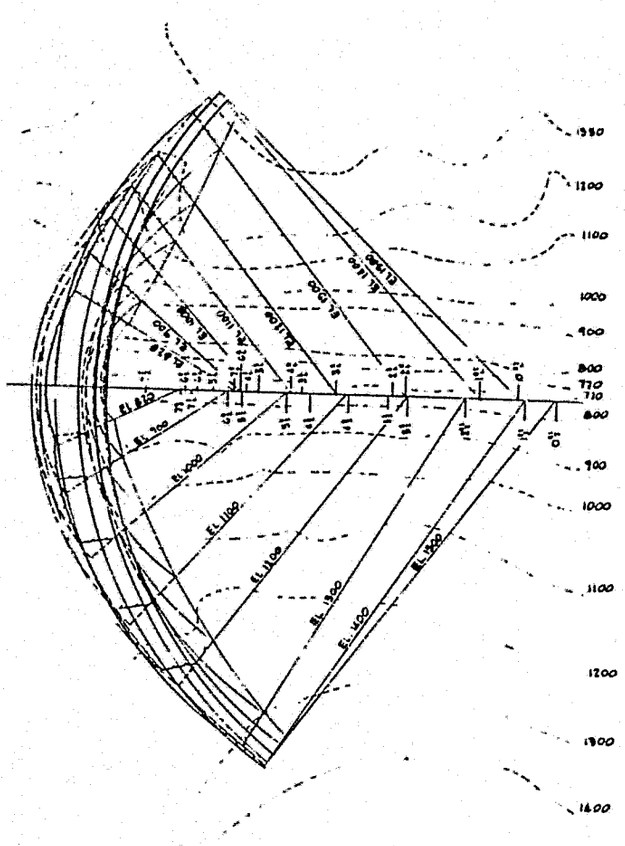
SCALE 0 100 200 FEET

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

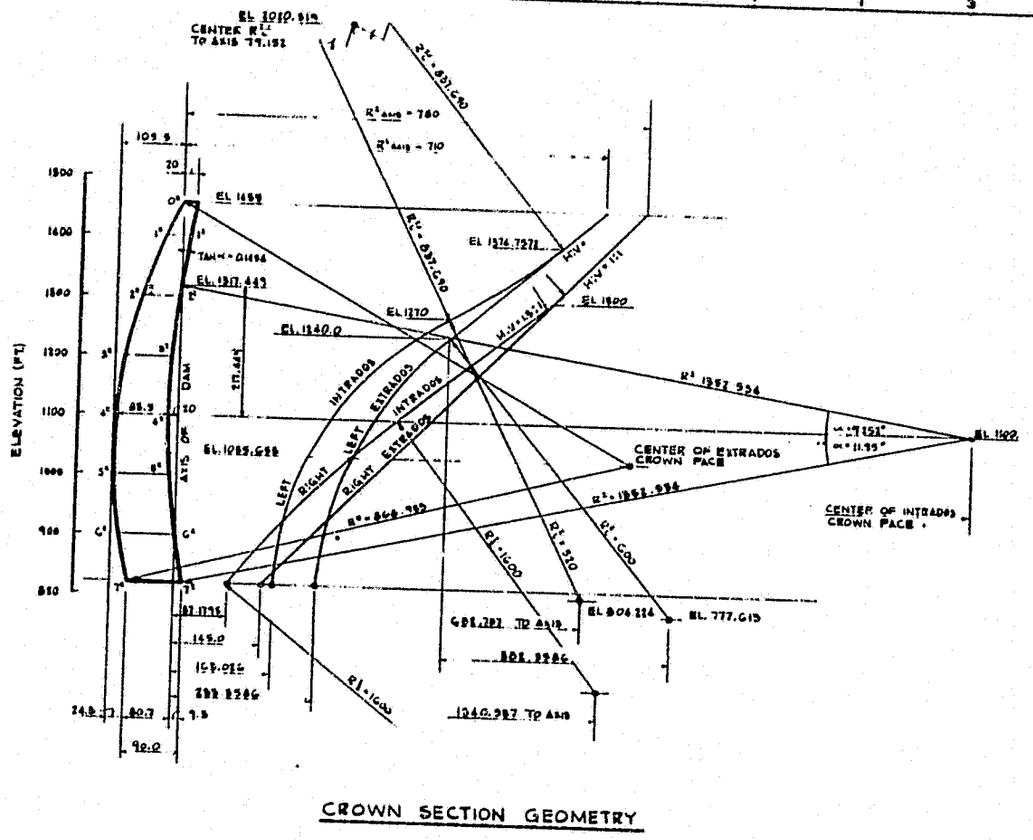
DEVIL CANYON
DOUBLE CURVATURE ARCH DAM
SECTIONS

ACRES AMERICAN INCORPORATED

SCALE 1"=100'



PLAN OF ARCH



CROWN SECTION GEOMETRY

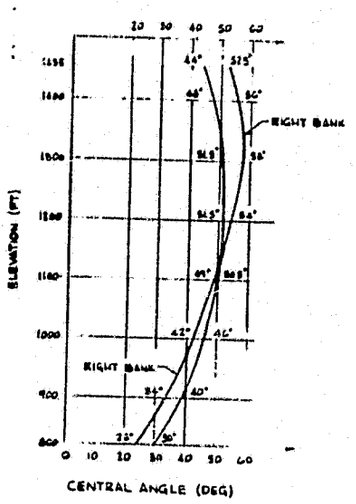


DIAGRAM OF CENTRAL ANGLES

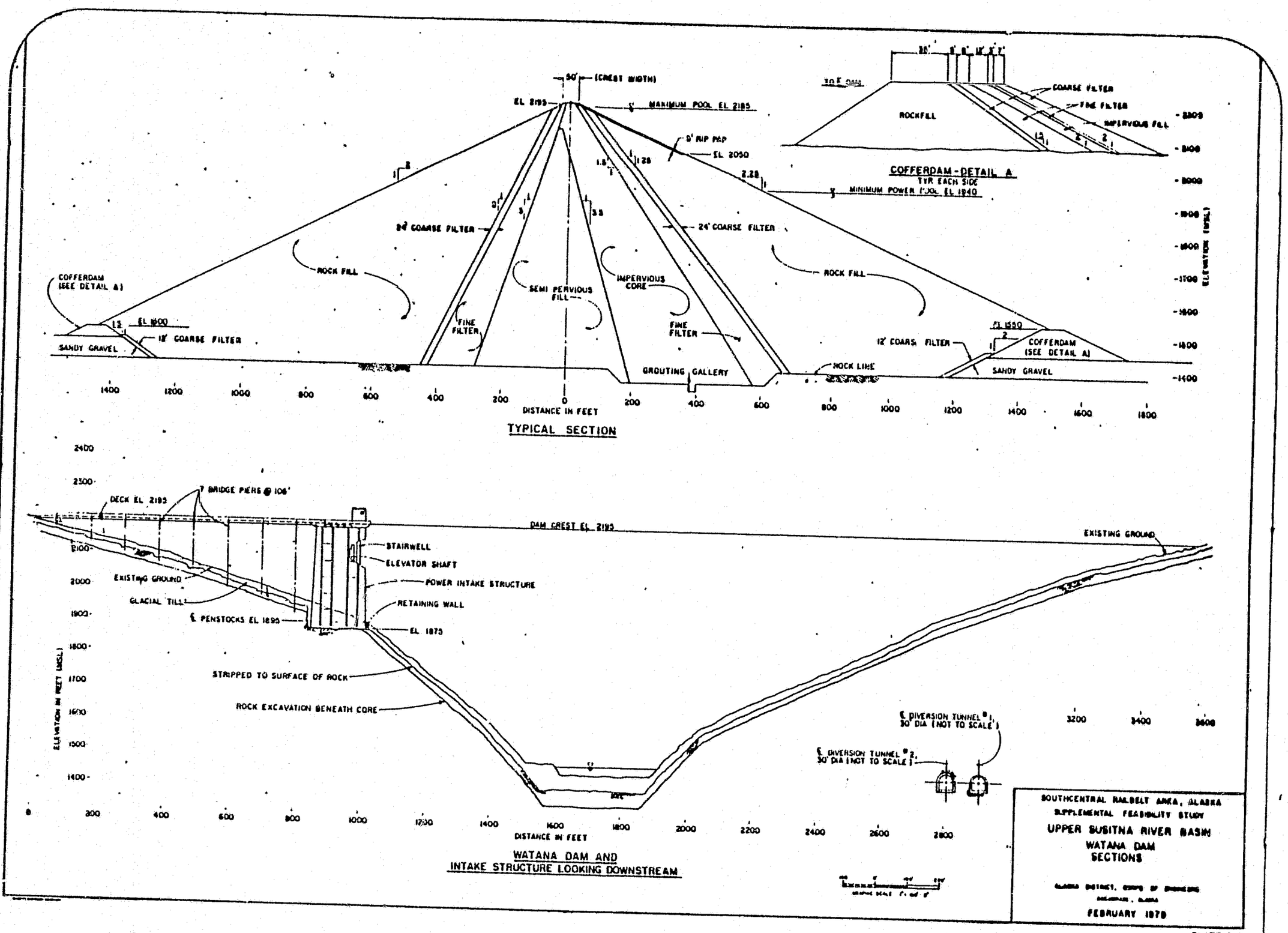
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

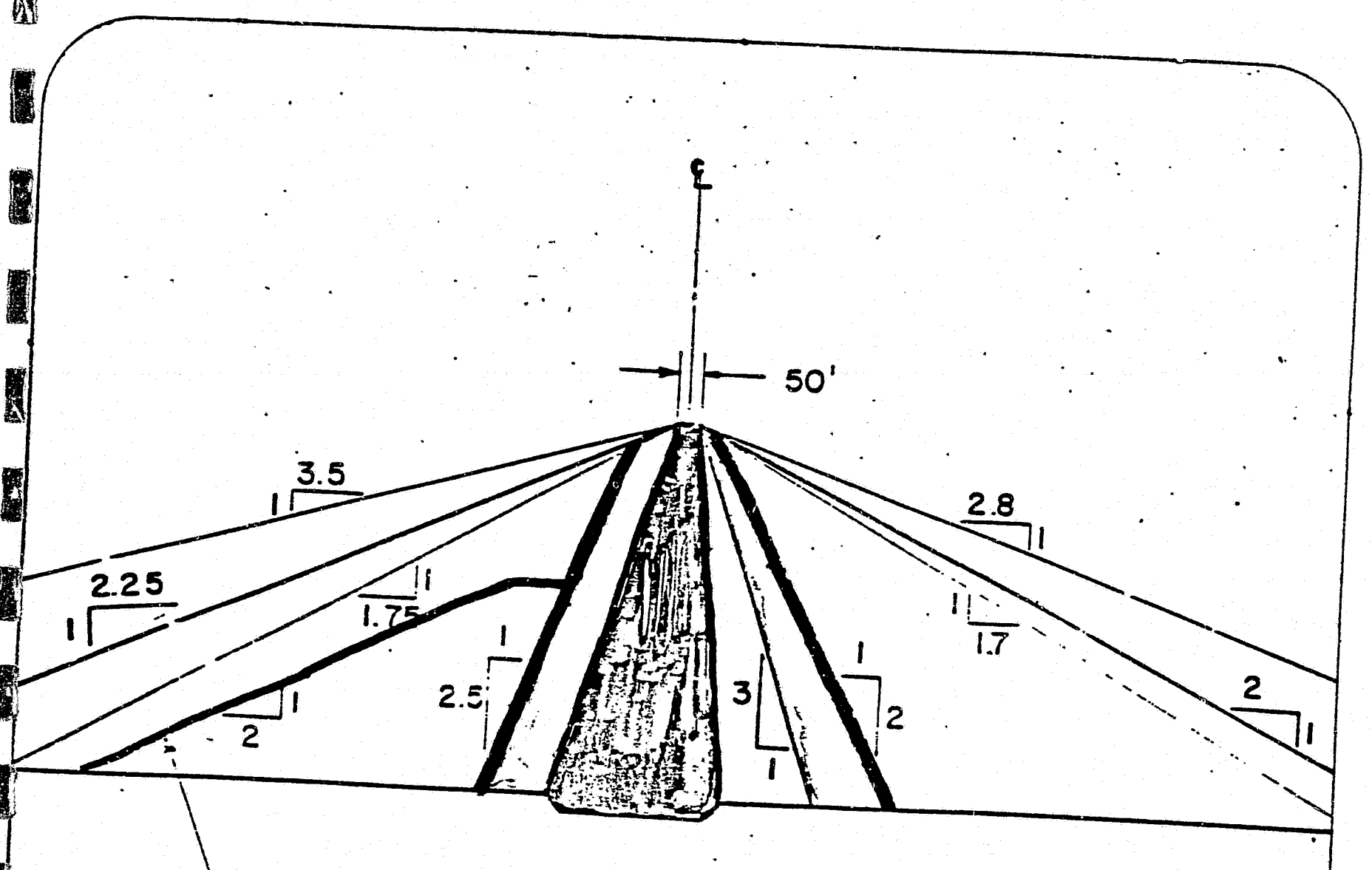
DEVIL CANYON
DOUBLE CURVATURE ARCH DAM
GEOMETRY

9. ATTACHMENT 3

WATANA DAM DESIGN

CONSIDERATIONS


50' (CREST WIDTH)
EL 2195
MAXIMUM POOL EL 2185
3' RIP RAP
EL 2050
MINIMUM POWER POOL EL 1940
24' COARSE FILTER
ROCK FILL
IMPERVIOUS CORE
SEMI PERVIOUS FILL
FINE FILTER
COFFERDAM (SEE DETAIL A)
EL 1600
12' COARSE FILTER
SANDY GRAVEL
GROUTING GALLERY
ROCK LINE
DISTANCE IN FEET
COFFERDAM - DETAIL A
TYP EACH SIDE
ROCKFILL
COARSE FILTER
FINE FILTER
IMPERVIOUS FILL
ELEVATION (MSL)
TYPICAL SECTION
DECK EL 2195
7 BRIDGE PIERS @ 108'
DAM CREST EL 2195
EXISTING GROUND
STAIRWELL
ELEVATOR SHAFT
POWER INTAKE STRUCTURE
RETAINING WALL
EL 1873
GLACIAL TILL
℄ PENSTOCKS EL 1895
STRIPPED TO SURFACE OF ROCK
ROCK EXCAVATION BENEATH CORE
ELEVATION IN FEET (MSL)
℄ DIVERSION TUNNEL #1, 50' DIA (NOT TO SCALE)
℄ DIVERSION TUNNEL #2, 50' DIA (NOT TO SCALE)
WATANA DAM AND
INTAKE STRUCTURE LOOKING DOWNSTREAM
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAM
SECTIONS
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
FEBRUARY 1979
PLATE B-3



POSSIBLE LIMIT FOR PLACEMENT
OF ROUNDED COBBLES

WATANA DAM

CONCEPTUAL DESIGN

* BASED ON A STUDY OF 28 MAJOR DAMS – FROM SEISMICALLY ACTIVE AREAS – WORLD WIDE
HEIGHT RANGE: 197 TO 800 FEET.

WATANA DAM DESIGN

FOUNDATION CONSIDERATIONS:

- ROCK FOUNDATION IS ADEQUATE TO SUPPORT THE DAM.
- ROCK IS RELATIVELY TIGHT FOR SEEPAGE CONSIDERATIONS, HOWEVER A GROUT CURTAIN WILL BE INCORPORATED.
- PROVISIONS FOR DRAINAGE GALLERIES AND DRAINAGE CURTAIN IN ABUTMENTS

-RIVER ALLUVIUM VARY IN DEPTH FROM 40 TO 80 FEET.

- UNDER A LARGE MAGNITUDE EARTHQUAKE, THEIR STABILITY (BOTH LIQUEFACTION & LOSS OF STRENGTH) IS QUESTIONABLE
- CURRENT THINKING IS-EXCAVATE UNDER THE ENTIRE DAM: OPTIONAL TO LEAVE IN PLACE UNDER THE SHELL IF PROVEN STABLE

EXCAVATION OF ROCK DOWN TO UNWEATHERED ROCK ( ). UNDER THE CORE AND THE FILTERS AND REMOVAL OF LOOSE ROCK UNDER THE SHELL

TREATMENT OF LOCAL ANOMALOUS-FEATURES AS CONSIDERED NECESSARY

EMBANKMENT DESIGN:

- ZONED ROCKFILL DAM WITH IMPERVIOUS CORE & U/S - D/S FILTERS

CONSTRUCTION MATERIAL REQUIREMENTS LARGE AND FINE GRAINED SOILS VERY SENSITIVE TO WATER CONTENT WITH RELATIVELY LOW OPTIMUM WATER CONTENT.

PHILOSOPHY IN DESIGN

- SAFETY OF STRUCTURE IS PRIME OBJECTIVE
- OPTIMUM USE OF AVAILABLE MATERIAL INCL. REQUIRED EXCAVATION
- MATERIAL PERFORMANCE UNDER STATIC LOADS, EARTHQUAKE AND POST EARTHQUAKE CONDITIONS AND FROST SUSCEPTIBILITY
- DESIGN SAFEGUARD FEATURES AGAINST SEEPAGE, PIPING, CRACKING AND STRESS CONCENTRATION

- CONSIDERATIONS OF CONSTRUCTION PROCEDURES AND ENVIRONMENTAL CONSTRAINTS ON DESIGN ASSUMPTIONS
- DEVELOPMENT LEVEL & SEQUENCE I.E. FULL DEVELOPMENT, STAGED DEVELOPMENT, ETC.

DESIGN APPROACH:

- DESIGN A DAM CROSS SECTION BASED OF JUDGMENT AND CONVENTIONAL PROCEDURES
- PERFORM SLOPE STABILITY ANALYSIS FOR STATIC LOADING CONDITIONS
- PERFORM PSEUDOSTATIC ANALYSIS TO EVALUATE THE OVERALL STABILITY INDEX AGAINST LARGE SLIDING
- PERFORM NEWMARK TYPE DEFORMATION ANALYSIS TO AID IN DETERMINING THE FREEBOARD REQUIREMENTS
- PROVIDE DEFENSIVE MEASURES AGAINST EARTHQUAKE EFFECTS SUCH AS AMPLE FREEBOARD, WIDE TRANSITION AND FILTER ZONES, WIDER CORE CONTACT WITH ABUTMENTS

(A FURTHER REFINEMENT OF SEISMIC STABILITY ANALYSIS MAY BE DONE BY STUDYING PORE PRESSURE GENERATION & DISSIPATION WITHIN CRITICAL ZONES)

OROVILLE DAM GOLZE & SEED, 1967

VII. OTHER EARTHQUAKE RESISTANT DESIGN FEATURES

INHERENT IN THE CONVENTIONAL EMBANKMENT DESIGN WERE THESE ADDITIONAL EARTHQUAKE RESISTANT FEATURES:

1. THE DAM EMBANKMENT WILL BE FOUNDED DIRECTLY ON BEDROCK OR ON A MINOR AMOUNT OF SAND AND GRAVEL WITH DENSITY GREATER THAN THAT OF THE EMBANKMENT, THUS ELIMINATING ANY POSSIBILITY OF FOUNDATION LIQUEFACTION.
2. THE EMBANKMENT ZONING SCHEME PROVIDES WIDE TRANSITION ZONES OF WELL GRADED SAND AND GRAVEL BETWEEN THE SHELLS AND THE CORE. THE TRANSITION WILL BE DENSE AND ALSO RELATIVELY IMPERVIOUS.
3. FREEBORAD IN EXCESS OF WAVE REQUIREMENTS ABOVE NORMAL WATER SURFACE AMOUNTS TO APPROXIMATELY 17 FEET (5 METRES) WHICH IS MORE THAN THAT REQUIRED FOR ANY POSSIBLE CREST SLUMPING. THIS FREEBOARD IS AS A RESULT OF SPILLWAY HYDRAULIC REQUIREMENTS.
4. THE CORE MATERIAL IS A DENSE, PLASTIC, EXTREMELY IMPERVIOUS MATERIAL WITH A WIDE RANGE OF PARTICLE SIZES. ALL MATERIAL PLACED AT CONTACTS WITH BEDROCK OR CONCRETE STRUCTURES WILL HAVE AN INITIAL WATER CONTENT FROM 1 TO 3 PERCENT ABOVE OPTIMUM TO ENSURE A PLASTIC ZONE IN CONTACT WITH THESE MORE RIDGE ELEMENTS. THE SLOPING CORE WILL BE PLACED AT OR SLIGHTLY WET OF OPTIMUM SO AS TO PROVIDE PROTECTION AGAINST POTENTIAL CRACKING.

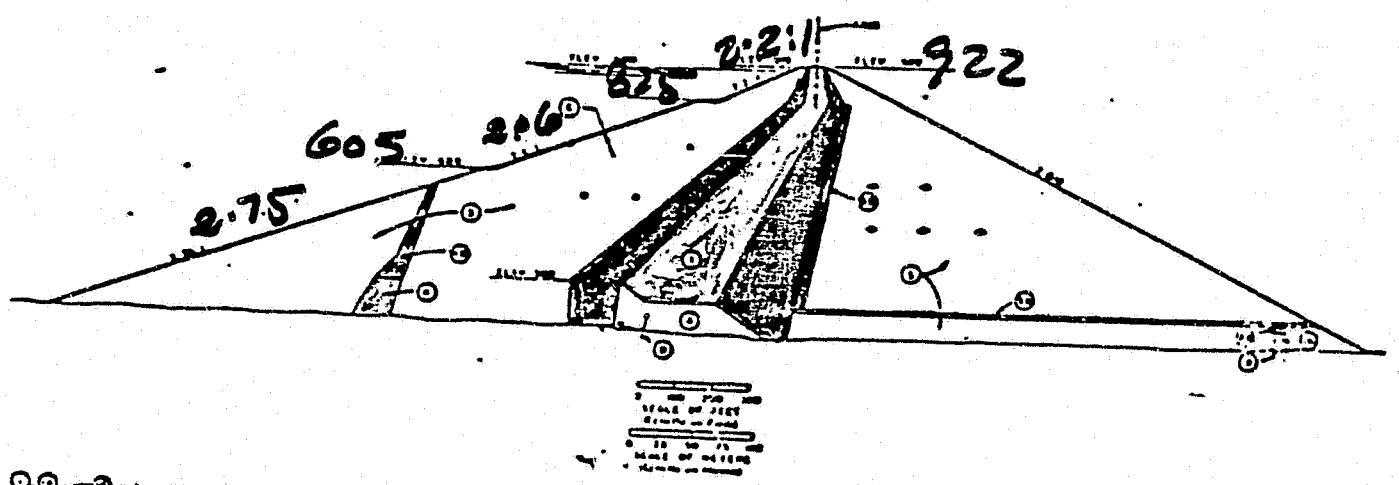


Fig. 1
Maximum Embankment Section — Oroville Dam.
Barrage d'Oroville — Coupe du massif.

TABLE 1

POSSIBLE WAYS IN WHICH AN EARTHQUAKE MAY CAUSE FAILURE OF AN EARTH DAM

1. DISRUPTION OF DAM BY MAJOR FAULT MOVEMENT IN FOUNDATION.
2. LOSS OF FREEBOARD DUE TO DIFFERENTIAL TECTONIC GROUND MOVEMENTS.
3. SLOPE FAILURES INDUCED BY GROUND MOTIONS.
4. LOSS OF FREEBOARD DUE TO SLOPE FAILURES OR SOIL COMPACTION.
5. SLIDING OF DAM ON WEAK FOUNDATION MATERIALS.
6. PIPING FAILURE THROUGH CRACKS INDUCED BY GROUND MOTIONS.
7. OVERTOPPING OF DAM DUE TO SEICHES IN RESERVOIR.
8. OVERTOPPING OF DAM DUE TO SLIDES OR ROCKFALLS INTO RESERVOIR.
9. FAILURE OF SPILLWAY OR OUTLET WORKS.

(REF. "CONSIDERATIONS IN THE EARTHQUAKE-RESISTANT DESIGN OF EARTH AND ROCKFILL DAMS" BY H. BOLTON SEED, 1979)

Table 5

Probable Upper Bound Displacements for Embankment Dams Subjected to Magnitude 8¼ Earthquakes (little or no strength loss)

	Crest Accn.	k_m	F.S = 1.15 for k = 0.1 15% strength loss k_y = 0.10	F.S = 1.15 for k = 0.15 15% strength loss k_y = 0.15	F.S = 1.15 for k = 0.15 No strength loss k_y = 0.20
Probable upper bound of accelns. for most earth dams	1.0g	≈0.4	≈17 ft	≈7 ft	≈3 ft
	0.75g	≈0.3	≈10 ft	≈3 ft	≈8 inches
	0.5g	≈0.2	≈3 ft	≈4 inches	0
	0.25g	≈0.1	0	0	0

Acceptable performance

REF. Seed (1979)

In short, many of the potentially harmful effects of earthquakes on earth and rockfill dams can be eliminated by adopting defensive measures which render the effects non-harmful. A list of such defensive measures would include the following:

1. Allow ample freeboard to allow for settlement, slumping or fault movements.
2. Use wide transition zones of material not vulnerable to cracking.
3. Use chimney drains near the central portion of embankment.
4. Provide ample drainage zones to allow for possible flow of water through cracks.
5. Use wide core zones of plastic materials not vulnerable to cracking.
6. Use a well-graded filter zone upstream of the core to serve as a crack-stopper.
7. Provide crest details which will prevent erosion in the event of overtopping.
8. Flare the embankment core at abutment contacts.
9. Locate the core to minimize the degree of saturation of materials.
10. Stabilize slopes around the reservoir rim to prevent slides into the reservoir.
11. Provide special details if danger of fault movement in foundation.

This list should not by any means be considered all-inclusive.

(REF. SEED, 1979).

"ALSO, BECAUSE OF THE POSSIBILITY OF EARTHQUAKES, AMPLE CREST WIDTH AND FREEBOARD WILL BE PROVIDED AND A COMPARATIVELY THICK CORE FOR THE PERMEABILITY OF THE MATERIAL WILL BE ADOPTED. IN ADDITION, SINCE THE VIBRATION CAUSED BY EARTHQUAKE AT THE DAM CREST WILL BE GREATER THAN AT THE BASE, THE OUTSIDE SLOPES (EVEN AT THE UPPER PORTIONS) WILL NOT BE STEEPENED, WITH BOTH UPSTREAM AND DOWNSTREAM FACES HAVING UNIFORM GRADES OF 1:2.5 AND 1:1.8 RESPECTIVELY."

(REF. FROM A DESCRIPTION OF THE AYRACIK DAM - TURKEY - "WATER POWER & DAM CONSTRUCTION" DEC., 1975)

10. REPORT BY SPECIALIST

CONSULTANTS

21 February 1981

Mr. John Lawrence
Project Manager
Acres American Incorporated
900 Liberty Bank Building
Buffalo NY 94202

Subject: Susitna Project
Second Specialist Consultants Panel Meeting
February 17 and 18, 1981

Dear Mr. Lawrence:

Introduction

The members of the Panel visited the office of Acres American in Buffalo on February 17 and 18, 1981. Information regarding progress on the Susitna Project since the First Panel Meeting was provided to each Panel Member prior to this visit.

Dr. L. R. Sykes participated in the discussions on February 17, but because of other commitments was unable to remain in Buffalo on February 18 and therefore did not assist in preparing this report.

This report presents our consensus of the information obtained and suggestions regarding future investigations on the project.

General Geology and Seismology

The comments on geology and seismology in the Panel letter of 25 October 1980 remain the view of the Panel and are neither repeated nor changed as of the date of this report. Since October of 1980 WCC have indicated that the maximum ground acceleration at both Devil Canyon and Watana Dam sites from a magnitude 8.5 earthquake on the Benioff zone would be on the order of 0.40 g. In addition, an earthquake of magnitude 8.5 on the Denali

Fault would produce about 0.20 g at each site. These values seem reasonable to the Panel. Comments on this subject are also given in the report by Dr. Sykes dated 4 February 1981.

The main items of work that remain to be resolved are the investigation of features and hypothesized features that pass near or through the dam sites. Such features for Watana Dam are:

(1) The Talkeetna Overthrust (see letter of October 25).

(2) KD3-7, a linear drawn on the basis of air and satellite photography through the Watana dam site parallel to the Susitna River.

(3) The Susitna feature, another linear which has been drawn to the northwest of Watana dam site.

As stated previously, geologic field work needs to be done to substantiate if there is a feature; if there is, how continuous it is and what is its date of last movement. Of all the items listed above, the Talkeetna Overthrust is the only well defined tectonic feature, and the effort is definitely justified to gather evidence on the date of last significant movement. Up to the present, no other feature mentioned above has been substantiated by direct field evidence.

Sykes (February 1981) states that the 1912 and 1943 earthquakes indicate that a floating earthquake of magnitude 6.5 should be considered in the Talkeetna terrain. On this premise, the need to investigate some of the shorter linears dissappears unless they are in the immediate area of the dam sites and could result in the offsetting of the proposed structures. In this connection, it is suggested that the recurrence interval be computed for a floating earthquake of magnitude 6.5 occurring within a distance of 10 km of the Watana Site, taking into account the area of the Talkeetna terrain, the period of observation, and the 1912 and 1943 observations. It is suggested that both WCC and Dr. Sykes independently assess the probability of occurrence of this floating earthquake closer than 10 km to the site.

The foregoing comments lead us to the following suggestions and conclusions concerning the preliminary budget layout for 1981 activities being considered for the WCC effort.

We believe that the main effort should be devoted to Activity (1), field mapping and Quaternary geology, particularly to develop the geological structure near the Watana site, to reach conclusions regarding the nature of the linears or other features close to the site (KD3-3, KD3-7), and to obtain whatever pertinent data can be assembled regarding the time since any nearby proven faults were active (whether post-Pleistocene, Tertiary, etc., without reference to an arbitrary age such as 100,000 years). To the extent that trenching at critical points may aid the mapping and dating, we consider it to be a desirable adjunct, not a primary effort directed toward determining an age older or younger than 100,000 years.

In view of the possibility that the application for license may include the two-dam project, we favor a similar effort for the Devil Canyon site (Activity 2).

We do not endorse the proposed calibration effort to test out the efficacy of dating procedures. We question whether remote sensing will provide further useful information, and we consider that geophysical and seismic refraction surveys should be utilized primarily to extend the limits of knowledge of buried channels or other low-velocity zones already discovered, and especially to explore the depths and areal extent of the buried channels close to the dam sites, where they may influence the layouts of the projects with respect to diversion, spillways, power plants and water passages, and foundation conditions. In short, we believe the expenditures for these vital purposes should be primary objectives, and that inferences drawn therefrom regarding seismicity should be considered as useful by-products.

We believe the funds proposed for Activities (3), (8), (9), and (15) could better be spent as an increased effort under Activities (1) and (2). Modest expenditures under Activities (4), (5), possibly (6), (11), and (17) appear appropriate. Activity (10), installation and operation of a seismic network in 1981, would be desirable for developing background information prior to reservoir filling, but in view of the likelihood of a period of nearly 10 years before filling, the item could be deferred. The network could possibly then be established under the aegis of a permanent agency.

Engineering Geology and Rock Engineering

All comments from the October 25, 1980, report apply unchanged. It is felt that at least two borings are necessary in the area of the underground powerhouse at Watana Dam. Although exploratory adits will yield the best information on the feasibility of the underground powerhouse, it would be preferable not to spend the money on the adits at this time. It is suggested that a layout be considered for evaluation which includes a surface powerhouse, in order that the relative economics of the surface and underground layouts can be compared before large sums are expended to investigate the underground powerhouse further.

Since it has been found that the andesites immediately downstream of Watana Dam are extrusive, it is again emphasized that the base of the andesites and the underlying weathered surface on the diorite should be more extensively investigated to evaluate the possibility that tunnels may intersect this unconformity. This feature could affect tailrace tunnels from an underground powerhouse or power tunnels to a surface powerhouse. Borings to investigate the nature of this contact should be given a higher priority than Boring B-11 presently proposed for the "fins" area of Watana.

Additional borings supplemented by seismic exploration would be desirable to delineate an approximate width of the buried channel just upstream on the right bank of WATANA Dam site. Eventually percolation tests and pumping tests to determine the permeability of the channel should be conducted. Piezometers should also be placed at several locations in the buried channel between the Susitna River and Tsusena Creek to learn about any possible existing hydraulic gradients in the present condition of the channel.

At the Devil Canyon site, two angle borings have been proposed on the left river bank, one dipping beneath the river and the other into the canyon wall. The boring dipping beneath the river is intended to check the possibility of a shear zone beneath the river. Both borings are intended to explore the geologic structure as well. Inasmuch as the most prominent jointing, and some observable shears seem to be oriented perpendicular to the axis of the river, such borings may not disclose them. On the other hand, one or both borings might fortuitously be located entirely in one of the shears characteristic of metamorphic rocks and might give an erroneous conception of the rock mass. We suggest that the need for these borings be reviewed and that, if they are deemed necessary, they be oriented to cross the geologic structure.

Watana Dam Layout

Several preliminary layouts were presented and discussed for an embankment dam at Watana. We concur that an external cross

section similar to that at Oroville represents a satisfactory and conservative starting point. A dam with these slopes requires a long diversion tunnel, whereas the length of the tunnel is constrained by the configuration of the river and the quality of the rock near the portals. The position of the cofferdams, similarly constrained, may in part determine the amount of riverbed alluvium that can be excavated beneath the dam. The depth of alluvium will also be a significant factor in this determination. Hence, determination of the configuration of the river bottom and of the depth and character of the alluvium are considered matters of high priority for 1981. A Becker drill, perhaps of large diameter, may prove useful in riverbed exploration.

We concur that an ample allowance for blanket and curtain grouting, for foundation treatment, and for drainage of foundation and abutments should be made in the preliminary estimates. A decision regarding the adoption of drainage or grouting galleries can and should be deferred until more is known regarding the character of the rock.

An embankment dam has been investigated in some detail for the Watana site. To provide a reasonable evaluation of alternative design possibilities, a thin double curvature arch dam design should be prepared and studied. The geological and topographical conditions at the Watana site appear to be satisfactory for a structure of this type.

Devil Canyon Dam Design

An acceptable arch dam design has been prepared for the Devil Canyon site. Stress analyses were made for normal full reservoir and maximum drawdown with appropriate concrete temperatures. The stresses computed for these conditions are satisfactory.

Some minor changes in the design can be made with minimal effort and should improve the structural behavior while reducing the concrete volume required for the dam.

An analysis indicating the effects on the design of earthquake should be made when appropriate ground accelerations are determined. Response spectra analyses are satisfactory for this stage of development.

Yours sincerely,

Merlin D. Copen

Alfred J. Hendron Jr.

Ralph B. Peck

RBP/ajj

Lamont-Doherty Geological Observatory
of Columbia University
Palisades, New York 10964
5 March 1981

Mr. Ralph B. Peck
1101 Warm Sands Drive, S.E.
Albuquerque, New Mexico 87123

Dear Ralph,

I have looked over the report you sent me about our meeting at Acres American in Buffalo on February 17-18, 1981. I have but one suggested change or comment to make. On page 2 starting in the middle of the page I am quoted as indicating that a floating earthquake of magnitude 6.5 should be considered in the Talkeetna terrain. My main concern is that the magnitude of that event not be "cast in concrete" too quickly.

In the report that I wrote for Acres I mentioned that work needs to be done by Woodward-Clyde to obtain better locations for earthquakes of about magnitude 7in 1912 and 1943. We need to know if those events actually occurred within the Talkeetna terrain and whether they occurred at shallow depths or along the Benioff zone. If they cannot be shown to have occurred along the boundaries of the Talkeetna terrain or along the Benioff zone, it may be necessary to consider an event of comparable size within the terrain itself. If they can be assigned to another feature, the size of the floating earthquake could be smaller than 7. In any case, however, the occurrence of other events within the terrain (such as the shock of 1929) indicates that the size of the floating earthquake will probably be at least 6 1/2.

My expectation is that the work that Woodward-Clyde has been asked to do this year should help to resolve these problems.

Sincerely yours,

Lynn R. Sykes

LRS/lz

cc: Mr. John Lawrence