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SUSITNA HYDROELECTRIC PROJECT

FIRST SPECIALIST CONSULTANTS PANEL MEETING

OCTOBER 21 THROUGH 23, 1980

ANCHORAGE, ALASKA

REPORT ON MEETINGS

ACRES

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REPORT ON MEETINGS

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I. OBJECTIVES

The objectives of this series of meetings are to familiarize the Specialist Consultants Panel with the Susitna Hydroelectric Project feasibility studies currently being undertaken by Acres, to review with the panel the available geological, geotechnical and seismic information, to discuss the ongoing planned geotechnical and seismic investigations and the preliminary design studies for the Devil Canyon dam, currently proposed as an arch, and the Watana rockfill dam. Particular items of concern which will be reviewed are:

- the upcoming decision on whether or not to adopt an arch dam alternative for the Devil Canyon site.
- the scope of geotechnical exploration activities at Devil Canyon and Watana sites in the winter of 1980-81 and summer of 1982.
- the method of screening identified seismic features for further examination and the scope of seismic exploration activities in 1981.
- the upcoming decision on whether or not to adopt a tunnel alternative development in lieu of the Devil Canyon Dam.

II. GENERAL INFORMATION

In Attendance:

Acres	APA	R&M	WCC	Specialist Panel
J. Lawrence	E. Yould	G. Smith	Dr. W. Savage	Dr. R. W. Peck
Dr. J. Hayden	R. Mohn	J. Brown	Dr. J. Lovegreen	Dr. A. J. Hendron
J. Gill	D. Wozniak			M. A. Copen
A. Tawil				
V. Singh				
J. Henschel				
M. Bruen				

Date	Time & Location	Activity
10/20...........	....	Travel to Anchorage, AK
10/21...........	8:30 A.M., Acres Anchorage Office (all day)	Presentation of Geotechnical, Seismic and Civil design information
10/22...........	8:00 A.M. (tentative, weather permitting - all day)	Field visit, Fly Watana camp, inspect Watana site, fly Devil Canyon, inspect Devil Canyon site. Return to Anchorage via Talkeetna to inspect drill cores.

Date	Time & Location	Activity
10/23	8:30 A.M. - Anchorage office (all day)	Panel review and discussions
10/24	....	Return travel

III. OCTOBER 21, 1980 ACTIVITIES

Presentation of geological, geotechnical & seismic information

Moderator: John D. Lawrence

Agenda:

Time	Topic	Speaker
8:30 A.M.	Background to Susitna	E. Yould
8:45 A.M.	Introduction to Acres Plan of Study	J.D. Lawrence/J.W. Hayde
9:15 A.M.	Introduction to geotechnical	J.D. Gill
9:30 A.M.	Geologic Information/ Previous Work	M. Bruen

a. Regional Geology

1. Bedrock Geology - Csejtey, Turner & Smith and Turner
2. Glacial Geology - Peue, Karlstrom

b. Site Specific

1. Devil Canyon
   geologic mapping - Kachadoorian, 1957
   drilling - U.S.B.R., 1957
   Seismic - Shannon & Wilson, 1978

2. Watana
   reconnaissance - U.S.B.R., 1950, 1953
   Corp of Eng., 1975
   geologic mapping - Corp of Eng., 1978
   drilling - Corp of Eng., 1975
   seismic - Dames & Moore, 1975
   - Shannon & Wilson, 1978

3. Watana Reservoir
   geologic mapping - Corp of Eng., 1978
   brief description of lithology, structure, joints-fractures-faults, surficial material permafrost

10:00 A.M. Geotechnical Information - V. Singh

1. Lab testing
2. Instrumentation
3. Geotechnical Evaluation of Previous Work

Time	Topic	Speaker
10:15 A.M.	Break	
10:30 A.M.	1980 Geologic Mapping Program	J. Gill/M. Bruen

Objectives

A. Confirm previous work

B. Expand area of geologic mapping

C. Provide geologic information necessary for optimization of type and location of dams

D. Identify potential problems needing further study in 1981

A & B (above)

1. Watana dam site
2. Devil Canyon dam site
3. Watana Reservoir
4. Devil Canyon Reservoir/Tunnel Routes

- lithology, structures (joints, fractures, shears), surficial materials, permafrost

C & D (above)

- Problem areas, areas of concern

Time	Topic	Speaker
1:00 P.M.	1980 Geotechnical Exploration	J. Gill/R. Henschel
11:30 A.M.	Air Photo Interpretation Discussion	J. Brown
12:00 Noon	Lunch	
1:30 P.M.	Planned Geotechnical Investigations	V. Singh/R. Henschel
2:30 P.M.	Break	
2:45 P.M.	Seismic Information & 1980 Program	W. Savage/J. Lovegreen
3:45 P.M.	1981 Seismic Program	
4:15 P.M.	Discussions	....
4:55 P.M.	Review of Field Reconnaissance Trip/ October 22	J. D. Gill
5:00 P.M.	Meeting Adjourns	....

SUSITNA HYDROELECTRIC PROJECT P5700.13.40
FIRST SPECIALIST CONSULTANTS PANEL MEETING
October 21, 1980

SUMMARY NOTES (by J. Lawrence)

In Attendance:

Consultants Panel

Dr. R. B. Peck
Mr. M. D. Copen
Dr. A. J. Hendron Jr.

Alaska Power Authority

E. P. Yould
R. J. Mohn
T. McGuire
D. Wozniak

Acres American Inc.

J. D. Lawrence
Dr. J. W. Hayden
J. D. Gill
B. Brownfield
A. Tawil
V. Singh
M. Bruen
R. Henschel

Woodward-Clyde

W. Savage
J. Lovegreen

R&M

G. Smith
R. Brown

IV. OCTOBER 22, 1980 ACTIVITIES

Field reconnaissance (weather permitting)

Organizer & Team Leader: - Panel Members
- Other Participants to be Selected

V. OCTOBER 23, 1980 ACTIVITIES

Moderator: J. W. Hayden

Agenda:

Time	Topic	Speaker
8:00 A.M.	Project Design Considerations - Introduction	J.D. Lawrence/J.W. Hayden
8:30 A.M.	Watana Dam Design	V. Singh
9:00 A.M.	Discussion	
10:00 A.M.	Break	
10:15 A.M.	Devil Canyon Dam	J. D. Lawrence
11:00 A.M.	Discussion	
12:00 Noon	Lunch	
1:00 P.M.	Tunnel Alternatives	J. W. Hayden
1:30 P.M.	Discussion	
2:00 P.M.	Panel Review & Report	

OCTOBER 24, 1980 ACTIVITIES: Travel

1. Introduction by J. Lawrence

2. Background to Susitna by E. Yould

3. Summary of participating subcontractors, Acres project group structure and Perspective of POS by J. Lawrence

4. Summary of Acres POS by J. Hayden

5. Geotechnical field activities (by J. Gill):
   - Introductions to Anchorage staff
   - Schedule of work (POS slide)
   - List of Task 4 Sub-tasks
   - List of Task 5 Sub-tasks
     5.01 complete - data available from USBR/C of E
     5.02 Photointerpretation by R&M in hand
     5.03 Complete - review of previous work
     5.04 1980 Program complete, evaluation in hand
     5.05 In hand (1981 program design)
   - Exploratory program scope - in terms of $ expenditures by activity, excluding design office support and logistical support (see Section VIII page 25)
   - Test pits in borrow areas partly replaced by reversed circulation drilling because of boulder problems
   - 35mm Slides
     •BLM permits, etc.
     •24 hour-day diamond drilling
     •Helicopter support
   - <u>Watana Site</u>:
     •Fins and fingerbuster features - diorite - Watana
     •Spillway to left of buried valley
   - <u>Devil Canyon Site</u>:
     •Left abutment lineament
     •3 drillholes and USBR data available
     •Difficult access conditions
     •Denali fault slides
     •Southerly abutments - 50 to 100 feet deep permafrost

6. Presentation of Geologic Mapping Program (by M. Bruen) - (including existing data available from previous work)
   - Regional geology - Talkeetna Mts. and Susitna area
     •Slide of geologic mapping (regional)
     •Denali fault 43 miles north
     •Castle Mountain fault 75 miles south
     •Susitna fault - questionable?
   - Devil Canyon geology (Kachadoorian/USBR/Shannon & Wilson)
     •Slide showing DC geology
     •Phillite (Kachadoorian) i.e. metamorphosed argillite and graywacke (brittle)

- Numerous shears, mainly left abutment, up to 2 feet gouge
- Thin overburden (tills), 85' thick in buried channel - drilling/ geophysical)
- Permafrost not found by USBR

- Watana geology (USBR, old/C of E, recent)
  - Drilling by C of E 1978 and seismic lines
  - OMB criticised C of E for insufficient drilling ($3,000,000 in 1978 including logistics)
  - Slides showing Watana geology
  - Diorite - Andesite Porphyry Dikes (downstream of dam)
  - 40 - 80' thick overburden, generally less than 20' on abutments
- Buried channel postulated by others as a buried fault (WCC).
- Reservoir geology map - C of E - slide

7. <u>Presentation of Geotechnical Investigations by others (by V. Singh)</u>
   - Watana:
     - Slide showing previous Watana exploration
     - 57 million cubic yards of material needed
     - Materials exploration/testing by C of E (slide)
     - Potential problems identified:
       - Buried channel - previous zones?
       - left abutment permafrost
       - artesian pressures
       - Susitna fault?
       - Talkeetna thrust
     - Recommended exploration:
       - general river channel/Fog Lakes area
       - right abutment slide block and overburden
       - left abutment - permafrost
       - borrow areas
       - Susitna fault
       - Buried river channel
     - Impervious core material - well graded
     - Slide of fill quantities required (57.8 million c.y. total)
   - <u>Devil Canyon</u>:
     - Slide showing previous USBR exploration
     - Earthquakes 8.5 @ 40 mi., 7.0 @ 10 mi. (i.e. 0.68 peak acceleration at site)
     - Appears to be no rationale for floating earthquake assumption
     - Potential problems identified (see Section VIII page 66)
     - Recommended exploration:
       - Pilot tunnels
       - Detailed foundation/abutment exploration
       - Curtain/consolidation grouting probably required.

8. <u>Presentation of 1980 Mapping Program</u> (by M. Bruen)
   - Objectives (slide)
   - DC geology (slide)
     - No bedding plane strips observed on south side

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8. Presentation of 1980 Mapping Program (by M. Bruen)
   - Objectives (slide)
   - DC geology (slide)
     - •No bedding plane strips observed on south side

- Access problems in area (Chicaloon)
- Wind rose diagrams (see Section VIII, pages 31-33)
- Slides of rock faces, etc.
- Open joints 80' to 90' back from edge of cliff in left abutment
- Example slide of rock slides (in DC reservoir)
- Concerns will be predominantly in rock faces, not overburden

- Watana geology - (slide)
  - Wind rose diagrams (See Section IX, pages 37-39)
  - Slide of "fins"
  - Tsusena Creek - oxidized exposures - (Gouge?) - 2 slides
  - Borrow area H for till identified if another source needed, 35' thick at exposure (See Section VIII, page 53)
  - Edge of Borrow area D - some outwash (slide)
  - Borrow area E - west of Tsusena Creek, evidence of buried channel- (not same as spillway buried channel)
  - Numerous mud flows in Watana Creek area (slide)
  - Major ice (permafrost) exposures found <u>above</u> DC/Watana reservoir areas

  <u>Potential Problems</u> - (see slide, Section VIII, page 40)
  - Note that reservoir beaching/mudslides not as great a concern as rock slopes
  - Reservoir fluctuation 100' per year
  - Reservoir fill schedule 2 to 2½ years (C of E)

9. <u>Presentation of Air Photo Interpretation</u> (by J. Brown, R&M)
   - Land form analysis by color aerial photography
   - Terrain unit method (special purpose term to define land forms to depth of 20 to 25')
     - Buried channels
     - Permafrost
     - Erodible materials
   - Approach - look at field units and check in field
   - Chart existing different terrain units
   - No attempt yet to describe bed-rock areas other than "hard/soft"
   - Probably not useful for cone material identification
   - Attempted to note fine/coarse borrow characteristics
   - Buried channel orientation different from others at Watana

<u>Lunch</u>

10. <u>Presentation of 1980 Geotechnical Exploration Results</u>
    - J. Gill
      - Program designed before completion of air-photo interpretation and design concept still being finalized
      - Introduction to scope of exploration at D.C./Watana
      - 50% of total diamond drilling done in 1980
      - Less than 50% of total augur drilling done in 1980
    - R. Henschel

      Watana program, developed with C of E recommendations in mind:
      - 3 boreholes completed
      - Longyear 34 rig used
      - All holes water pressure tested, pressures 20/30 psi, max. 200 psi at depth (½ psi per foot of depth.)

- Slides of borehole logs (prelim.)
- BH - 6 no major shear zones found, some small shears identified
- BH - 2, Finger burster location - identified as a major shear zone
- No test data available -- difficulty with caving even with grouting (Water loss significant - couldn't get packers down.)
- BH - 8, left abutment (powerhouse) - no shear zone found at contact between andesite/diortie.
- A. Hendron suggested we attempt to intersect possible channels in the diorite near the andesite contact which may cause problems with tunnel excavation
- Geophysical logging done - results not available yet.
  - Borehole photography unsuccussful
  - No instruments in at Watana yet
  - Equipment awaited (Piezometers, thermister string)
- Mixed success in reading old C of E instruments
- Seismic lines completed, indicating buried channel, layers of till, outwash, alluvium
- Quarry source B not investigated but considered doubtful.
- Diorite exposures in Deadman Creek
- Borrow Area D - outwash? Need more test data to reliably determine extent usable as core material.
- Borrow Area E - boulder problem restricted boring. High water table (8' depth) will restrict exploitation. More exploration needed up Tsusena Creek.
- R. Peck suggested consideration of Area E material for dam shells. "There are few dams this high made of rockfill, which haven't had longitudinal cracks - there are many made with gravels which have not".

- <u>Devil Canyon Program</u>
  3 drill holes completed
  - BH2 - intersected granodiorite at 63' depth
  - BH4 - no shear found - argillites/phillites, some slippage observed along bedding planes
  - BH1 - argillites/phillites (el. 1450)
  - Difficult access
  - Geophysical logging not yet available
  - Borehole camera unsuccessful
  - Instrumentation done (piezometers, thermister strings)
  - Permafrost cement used for grouting
  - Borrow area - access restricted but not material shortages noted.
  - Seismic lines completed

11. <u>Proposed 1981 Program</u>
  - No question about removing Watana riverbed materials, therefore extensive exploration unwarranted.
    - 10:1 ratio dam:spillway cost at Watana
    - PMF 200,000 cfs (approx.), 100,000 cfs spillway capacity for 100 year flood
  - Revets circulation drilling to be done in buried channel and borrow areas in 1981 (winter)

- Fins at Watana need study
- Left bank at D. C. needs study
- Consider excavating with bulldozers in borrow area E to obtain better samples etc.

12. Presentation of Seismic Program
- J. Lovegreen
  - 100 km radius adopted for features
  - Castle Mountain to South, Denali to North are known to be "Faults with recent displacements"
  - LANDSAT imagery - 215 features screened on basis of length and distance more than 10 km from sites.
  - DC - 2 features with moderate to high likelihood of displacement (yellow, "indeterminate A" concern for seismic and potential for surface rupture
  - Watana "indeterminate A"
    - "Susitna Fault" (?)
    - "Talkeetna Thrust"
    - Buried channel/"Fin structure"
    - "KD3 - 7" (blue) - WCC think this is a figment, but it will be evaluated
  - Ranking on basis of likelihood of recent displacement (need to decide level of risk)
  - Much more evidence for "Talkeetna Thrust" than there is for "Susitna Fault" for which no evidence has been found to date
  - Low sun angle photograph, to be done next Spring, will allow refinement but probably not change conclusions.
- W. Savage
  - Message not coming through - approach was most conservative - nothing was left out which could be a seismic source
  - A. H. Hendron commented that he could not see how the remaining questions can be satisfactorily dealt with in one more year of field work
  - 10 seismographs installed (including DC/Watana sites)
  - Peak ground motion acceleration of 0.75 has come out of very preliminary calculations and cannot be eliminated at this time.
- R. Peck commented that from a deterministic standpoint, a fault is "dead" or it isn't. One cannot evaluate it in terms of probability. The structure must be designed for an appropriate ground motion.
  - A Talkeetna Fault Report was written by the academic community in May 79, on the Brockson Gulf/Denali intersect (publication due in one year) Differential movement of about 2 cm (3-1) is postulated as being taken up by the "Talkeetna Fault". If discounted, Talkeetna Fault magnitude reduces to about 7.4.
  - Recurrence interval should not be a consideration for features which may severely impact project structures. It is more important to investigate critical "yellow" features to determine whether or not they exist.

VII. SUSITNA HYDROELECTRIC PROJECT
FIRST SPECIALIST CONSULTANTS PANEL MEETING
October 23, 1980

SUMMARY NOTES (by R. Henschel)

In attendance:

Consultants Panel

Dr. R. B. Peck
Mr. M. D. Copen
Dr. A. J. Hendron Jr.

Alaska Power Authority

D. Wozniak

Acres American Inc.

J. D. Lawrence
Dr. J. W. Hayden
J. D. Gill
B. Brownfield
A. Tawil
V. Singh
M. Bruen
R. Henschel

1. Presentation by J. Hayden
   - Brief review of design consideration in site selection and proposed schemes - i.e. combinations of dams, etc. (Subtasks 6.01, 6.02, 6.03, 6.04)

2. Presentation by V. Singh
   - Watana Dam Design -
     Reviewed Corps design and sections (2 viewgraphs)
     J. Lawrence raised the question of the need for a cut-off under the coffer dams. General agreement that they would probably be necessary.
     Present Acres thinking about design based on data available (See Section VIII)
     - Foundation exploration work
     - Embankment design
     - Design approach
     - Liquifaction of foundation materials during earthquake.

3. Presentation by A. Tawil
   - Proposed cross section of Watana Dam presented
   - Need to incorporate features to defend against earthquakes
   - Exploration has indicated:
     a) Foundation has up to 80' alluvial material pervious, inadequate shear resistance
     b) Bedrock - Excellent shear strength, moderately high permeability (10^{-4} - 10^{-6}), probable local zones higher than 10^{-4}, weathering of no major consequence, 2 or more shear zones on right abutment
     c) Construction materials - All required materials are available around the site. Core material is the most serious question, season is very short
   - Extent of design considerations:
     a) Design is for about 750 feet of head
     b) Extent of excavation of overburden materials to be determined.
     c) Water tightness of coffer dams (100' + high structure) will require upstream till blanket and/or positive cut off plus dewatering of excavation
   - Important questions on which panel input is solicited:
     a) Amount of overburden excavation to be performed:
        - 1:1 slope - under most of dam
        - 1:1.5 - remove all of materials
     b) Treatment of bedrock foundation under core and filter zones:
        - removal of weathered bedrock under core? (not necessary - other means of treatment, e.g. cleaning, slush grouting and consolidation grouting)
        - trimming and shaping of abutments required, right abutment in particular
     c) Geometry of Core:
        - Slightly sloping upstream?
        - Width of core should be generous, about 60% of head.
          - Material is of good gradation, no plasticity, minimal adequate permeability.
          - Possibility of flaring core at abutments

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   - Brief review of design consideration in site selection and proposed schemes - i.e. combinations of dams, etc. (Subtasks 6.01, 6.02, 6.03, 6.04)

2. <u>Presentation by V. Singh</u>
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     Reviewed Corps design and sections (2 viewgraphs)
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     Present Acres thinking about design based on data available (See Section VIII)
     - Foundation exploration work
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   - Proposed cross section of Watana Dam presented
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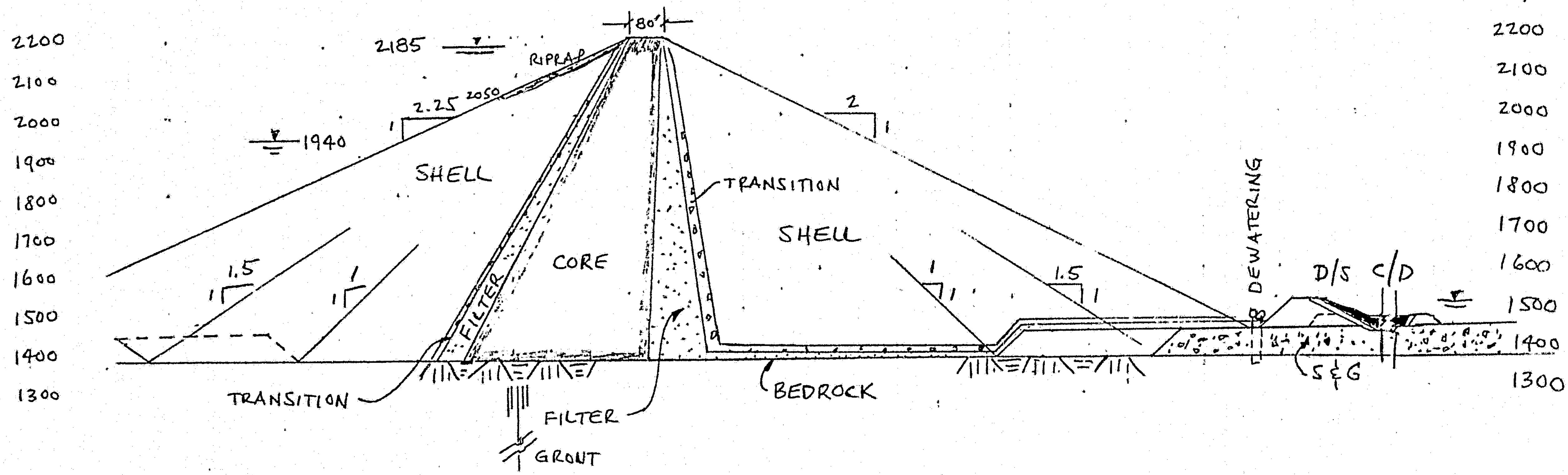

WATANA MAX SECTION

SCALE:
1" = 400' H & V

PRELIMINARY CROSS-SECTION
WATANA DAM - ROCKFILL
SUSITNA HEP
FEASIBILITY STUDY
OCTOBER, 1980

d) Water content of core materials:
Need some flexibility - place core somewhat above optimum - Design for settlement
e) Width of filters - 100 feet upstream, 150' downstream
f) Filter gradation important - to guard core
g) Transition zone - bridge gradation gap between rockfill and filter
h) Outside slope on shells - 1:2.25 upstream, 1:2 downstream
i) Materials for shells - what to use?
   - rockfill from excavation
   - Sands and gravels
   - ease of placement (rockfill placed in winter easier than sand/gravel)
j) Width of crest (C of E 10 feet, probably 2.5 feet necessary)
k) Freeboard requirements
l) Pressure relief requirements:
   - combination of grouting and relief holes will be required
   - work to be performed independently of fill placement

4. <u>Responses by Panel</u>
- A. Hendron - Question, Why downstream boundary of core is inclined slightly upstream.
- A. Tawil - There is a tendency towards tension in lower core if inclined downstream.
- R. Peck - Width and configuration of zones will be dependent on material properties.
- A. Hendron - With downstream slope on core - if shell settles it will tend to compress core, rather than place it in tension/
- R. Peck - Dependent on which settles most.
- J. Lawrence - Is there a need for grouting and drainage galleries? General agreement that they will be required.
- R. Peck - It is correct to assume (at this stage) that the material in the river channel should be removed.
  •Materials in dam should be selected for both static and dynamic behavior and then select where to use them in the dam.
  •It may be desirable to make at least half of the upstream shell of gravel rounded rather than rockfill - dilitant materials are needed under modest strains. (Rockfill is not dilatant) Use it in downstream shell also, but this is not as important. Heights of dam will justify type of material to be used. It should be primarily a gravel dam, with rockfill in some places, rather than the reverse.
  •Spillway location and design - Tsusena Creek totally inadequate - the rock excavation may not be as great as everyone is currently thinking
  •Spillway may be much closer to dam, with little rock excavation.
  •We should identify construction materials and then develop a section for the dam - concentrate on exploration of river channel as a source of construction materials, and not with intent of defining liquifaction potential for leaving in place.
  •Upstream use cobble fill (dilatant material) in high stress areas
  •Downstream - make sure rockfill does not get wet - still better to use cobble fill as much as possible

- V. Singh - Reviewed material properties (C of E data)
  Need to compare Acres laboratory test data with C of E data
  Question of internal instability of material (Sherard) - Potential piping problem?
- R. Peck - No evidence for this in western tills - should not be a problem:
  - These problems developed in materials which were not tills! - were outwash materials, gap graded, where piping could develop.
  - However, we should assume that it could happen and design for it.
  - The gradation curve for Area D is about as good a core material as you could hope to find
  - May require processing of material
  - Plasticity characteristics of material<200 sieve - (Area D) - has some plasticity. Need to determine how thick it is and over what area it can be excavated and transported without exposure to rain. A good thickness is essential so that the face of the excavation in the pit can be small.
  - Exploration should establish depth and a real extent of steep slopes.
  - Need to look for older tills, which would be nearer optimum M.C., and avoid ablation tills and outwash
  - Regarding placement moisture content, there should not be a problem placing at slightly above optimum, but at or slightly below optimum is preferable. For dam configuration shown, strength of core is immaterial to overall stability of embankment.
  - Regarding use of more plastic materials - at abutments, it is desirable to use material which is the same as the core, but more plastic phases of that material.
  - Regarding crest details, it is too early at this stage to be specific.
  - A fairly wide crest is required. It is beneficial to keep the slope to the crest. The core should be protected from freezing/frost.
  - Regarding analysis of data for earthquake, not much emphasis required at this early stage. Concentrate on proper foundation treatment and zoning aspects initially.

5. <u>Presentation on Tunnel Alternatives</u> (by John Hayden)
   - Reviewed present activities, etc. (see viewgraphs, Section VIII)
   - A. Hendron expressed concern about a possible channel filled with andesite along the tunnel alignment.
   - M. Bruen indicated diorite intrusives of tertiary age and older volcanic which may exist, should be elevated and exposed!
   - Most viable alternative schemes appear to comprise a 200' high regulation dam just upstream of Devil Creek with tunnel to just below Portage Creek.
   - Very preliminary comparisons indicate this to be a reasonable alternative to Devil Canyon Dam, but needs considerably more study.
   - No geological explanation is currently available as to why the river gradient is so steep in this section. J. Brown suggested from air photos it might be due to a change from a lake basin area into a bedrock area. J. Lovegreen suggested that in glacial times a

blockage may have prevented flow through D.C. and a change in river course created. Development of a steep gradient occurred to get back down to the required level. This would not be related to the geology in particular. A. Hendron suggested it may be possible to look at the gradient which would have existed with drainage out through Stephan Lake. This would also aid in evaluating the "Susitna Fault" question (not clear how this would be done!)

6. Presentation on Devil Canyon Dam Design (by J. Lawrence)
   - Sub-task 6.04, Feasibility of arch dam at D. Canyon, to determine:
     Feasibility
     Economic viability
   - Evaluation Sequence (See Section VIII Viewgraphs)
   - Geotechnical Information:
     Early geologic review by Acres led to concern about adequately establishing feasibility prior to license application:
     - Linament in left abutment (lake) requires explanation
     - Acres internal review panel felt that adits would be required to confirm site prior to license application. Plan to cost out adits. (Approximately $1 to 2 x 10^6 currently indicated.)
     - Alternatives to arch dam such as a rockfill dam are also being evaluated for comparison.
   - Review of USBR and C of E Designs -
     Some concern about energy dissipation of spillway discharge. USBR/C of E designs are not considered adequate.
   - Acres has developed a concrete gravity-arch design layout for analysis (Section VIII, pages 104-106) (based on similar Karun Project studies) A long stilling basin with an "over-the-dam" spillway is currently proposed for conceptual design purposes. Series of pseudostatic stress analyses performed, using the finite element "ADAP" program.
   - Results of analyses to date and assumptions used (see Section VIII, pages 107-130)
   - Thin Arch - Stress levels, both tensile and compressive, are locally high in places but can be made acceptable with better design.
   - Comment by M. Copen - Shaping will help a lot. Temperature loading will be more severe than earthquake loading. The USBR computer program (called "HEATFLO") is available to analyze temperature gradient effects

7. Discussion on arch dam design
   - M. Copen - on the question of adits at D.C., they are not necessary at this time (although they will be later) Drill holes will provide adequate data for licensing purposes.
   - V. Singh- on geology/geotechnical considerations, the orientation and characteristics of exploration program with adits was intended to investigate controlling structural features.
   - M. Copen - stability of the abutments needs detailed work, but not necessary to excavate adits at this time.
   - R. Peck - How would you propose to go about excavating adits?
   - M. Copen - What do you have to gain at this stage from adits?

- V. Singh - Joint/shear zone conditions, filling, material, etc.
- M. Copen - I would prefer more drill holes rather than adits at this time. On the basis of available data there is nothing to prohibit arch dam construction at D.C. May not get data from adits that you want.
- A. Hendron - You should use available data for analyses and then take extreme values to check sensitivity.
- J. Lawrence - We would use analyses to assess which features cause most concern and orientate adits accordingly.
- M. Copen - Adits may provide data on continuity of features (which drill holes would not).
- A. Hendron - Adits are more appropriate at Watana if anywhere to investigate shears (e.g. fins, fingerbuster)
- R. Peck - Rock conditions at the underground powerhouse need to be evaluated further, if necessary with adits.
- A. Hendron - Rock conditions at the 2 sites are quite different.
- R. Peck - There is serious concern about the shears at Watana, and their potential impact on the underground powerhouse and permanent support of structures.
- A. Hendron - You can excavate an underground powerhouse at Devil Canyon, but maybe not at Watana! Adits are needed to prove feasibility.

8. Additional Comments

- E. Yould stated that he is prepared to contest high earthquake accelerations quoted by Kachadoorian if Acres/WCC work shows lower figures appropriate.
- E. Yould and M. Copen expressed support for thin/thick arch at D.C. M. Copen would also be prepared to consider an arch alternative at Watana. ("Thin" = $\frac{\text{top}}{\text{bottom}}$ ratio 0.2)
- J. Lawrence indicated that Acres would base its recommendations on WCC/Acres analyses for earthquakes rather than C of E Reports (0.68g)
- E. Yould advised that C of E found that a rockfill dam at D.C. was most expensive of any alternatives (no published information).

VIII. COPIES OF PRESENTATION VIEWGRAPHS

PROJECT DATA

	Watana	Devil Canyon
Drainage Area sq.mi.	5180	5810
Average Discharges cfs	8140	9230
1:50 yr Discharges cfs	82,600	94,400
PMF cfs	230,000	270,000
50 year sediment Accumulative Acft	204,000	252,000
DAM		
Type	Fill	Concrete
Height ft.	810	650
Crest Length ft.	3450	1370
Crest Elevation ft.	2200	1450
RESERVOIR		
Area - Ac	43000	7550
Storage Acft	21,000,000	1,100,000
Installed Capacity	790 mw	780 mw
Firm Energy	3.0×10^9 Kwh	3.25×10^9 Kwh

TASK 4 OBJECTIVES

- [illegible]
- PRELIMINARY EVALUATION OF SEISMIC STABILITY
- ASSESS THE POTENTIAL FOR RESERVOIR INDUCED SEISMICITY
- IDENTIFY SOILS SUSCEPTIBLE TO SEISMICALLY INDUCED FAILURE ALONG TRANSMISSION LINE AND ROAD RIGHTS-OF-WAY

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TASK 4: SEISMIC STUDIES

SUBTASK

4.01	REVIEW OF AVAILABLE DATA
4.02	SHORT-TERM SEISMOLOGIC MONITORING PROGRAM
4.03	PRELIMINARY RESERVOIR INDUCED SEISMICITY
4.04	REMOTE SENSING IMAGE ANALYSIS
4.05	SEISMIC GEOLOGY RECONNAISSANCE
4.06	EVALUATION AND REPORTING
4.07	PRELIMINARY GROUND MOTION STUDIES
4.08	PRELIMINARY ANALYSIS OF DAM STABILITY
4.09	LONG-TERM SEISMOLOGIC MONITORING PROGRAM
4.10	RESERVOIR-INDUCED SEISMICITY
4.11	SEISMIC GEOLOGY FIELD STUDIES
4.12	EVALUATION AND REPORTING
4.13	GROUND MOTION STUDIES
4.14	DAM STABILITY CONSULTING SERVICES
4.15	SOIL SUSCEPTIBILITY TO SEISMICALLY-INDUCED FAILURE

APPROACH

SEISMIC EXPOSURE

- Locate Seismic Sources (Potential)
- Estimate Recurrence Intervals
- Attenuate Motions to the Sites
- Estimate Seismic Exposure During Lifetime of Facility

SURFACE RUPTURE POTENTIAL

- Estimate [illegible]
- Estimate [illegible]
- Estimate [illegible]
- Estimate Likelihood of [illegible] Through [illegible]

POTENTIAL FOR RESERVOIR INDUCED SEISMICITY

- Estimate Likelihood of Occurrence
- Assess Impact on Seismic Exposure
- Assess Impact on Surface Rupture Potential

EVALUATION OF EARTHQUAKE SOURCES

- HISTORICAL SEISMICITY
- REGIONAL TECTONICS
- SEISMIC GEOLOGY - ACTIVE FAULTING
- MICROEARTHQUAKE STUDIES

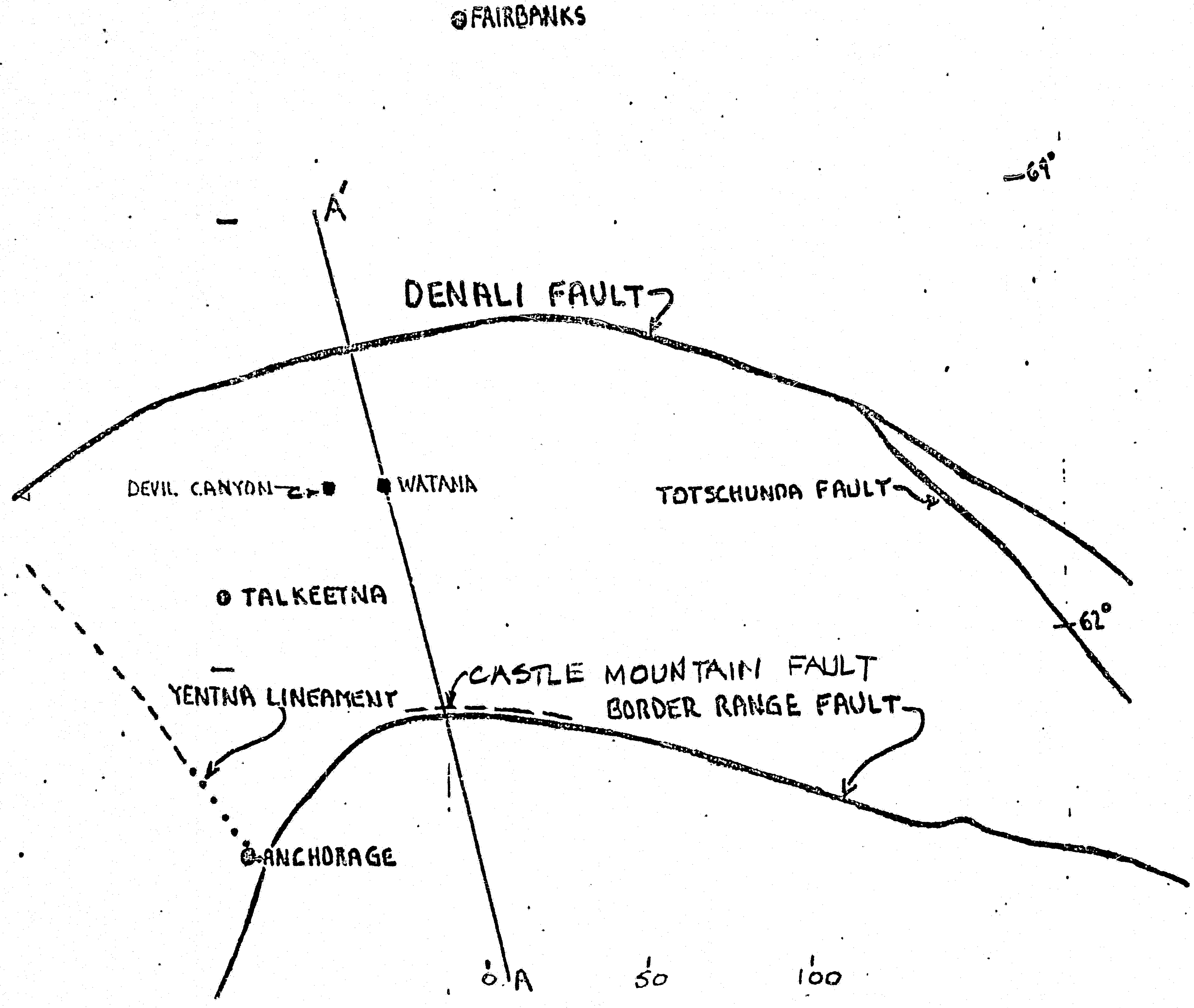
- TYPES OF EARTHQUAKES

- SHALLOW EARTHQUAKE
  N.A/PACIFIC PLATE CONTACT

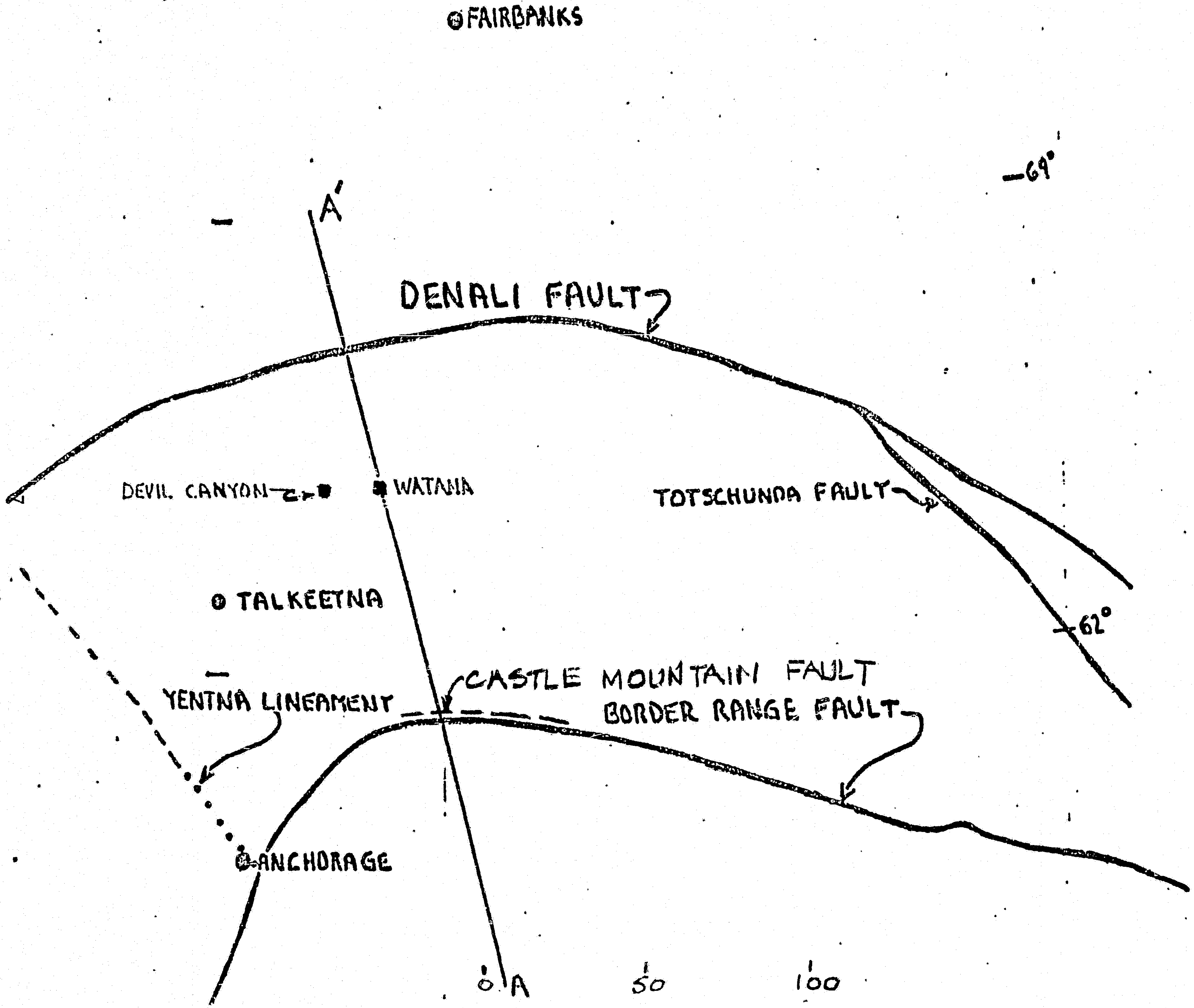
- SHALLOW WITHIN N.A.
  PLATE CRUST

- DEEP - ORIGINATING IN
  BENIOFF ZONE

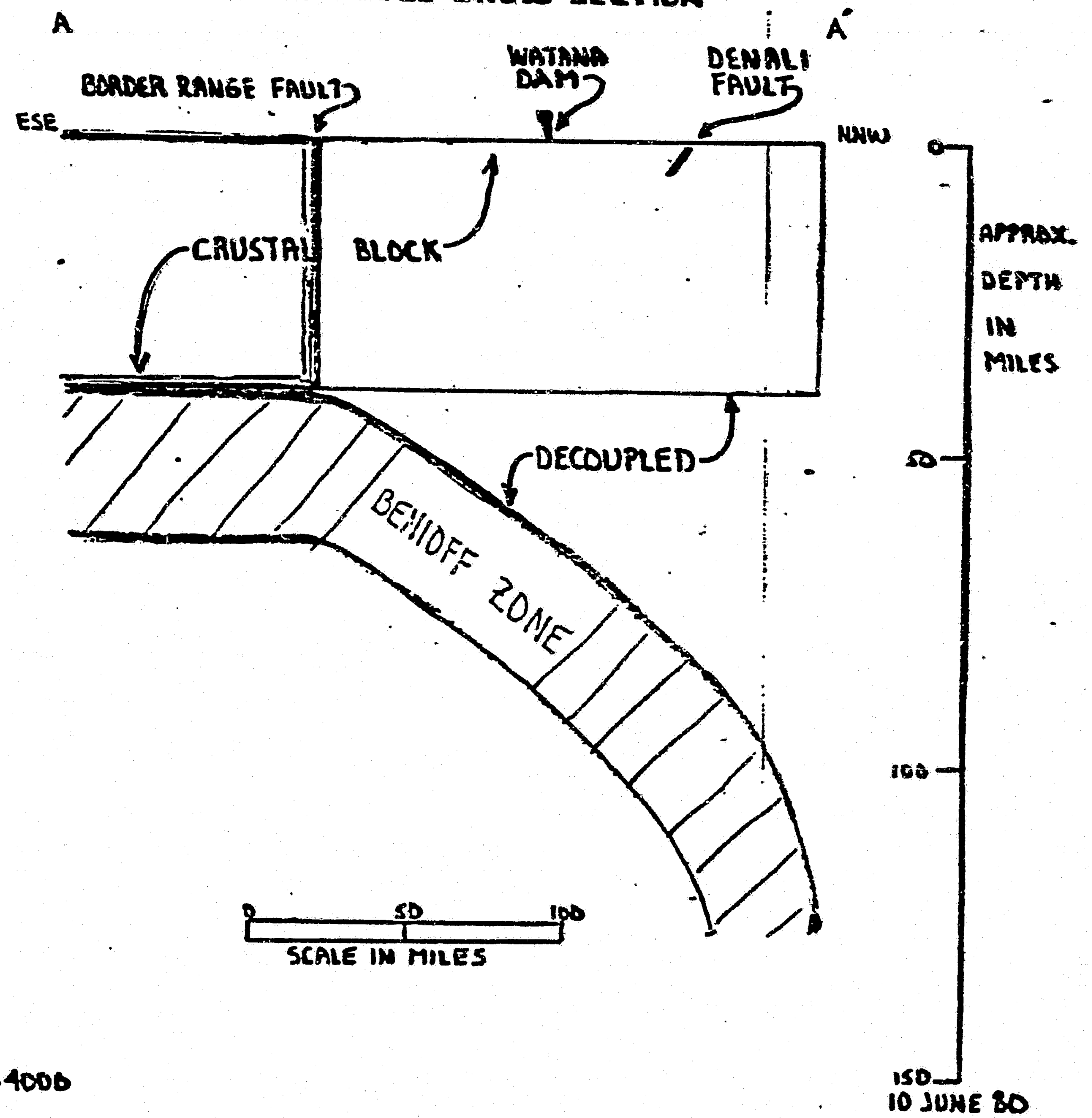
TASK 4 - TECTONIC MODEL



TASK 4 - TECTONIC MODEL



TECTONIC MODEL CROSS SECTION



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FIELD APPROACH

I. HELICOPTER & GROUND RECON. DAM SITES

II FIXED-WING RECON. REGIONAL FEATURES

III FIXED-WING RECON 15' QUADS

IV HELICOPTER & GROUND RECON. OF SELECTED FEATURES

V Q[illegible]

SEISMIC DESIGN CRITERIA

1. Acceptable Seismic Risk

2. Probable Maximum Credible Earthquake

   - near site event
   - event related to Denali fault
   - Benioff zone event

3. Design Approach

   - State-of-the-art approach

   A. Earth Structures - Watana

      - earthquake resistant features
      - critical evaluation of material properties
      - simplified approach of analysis

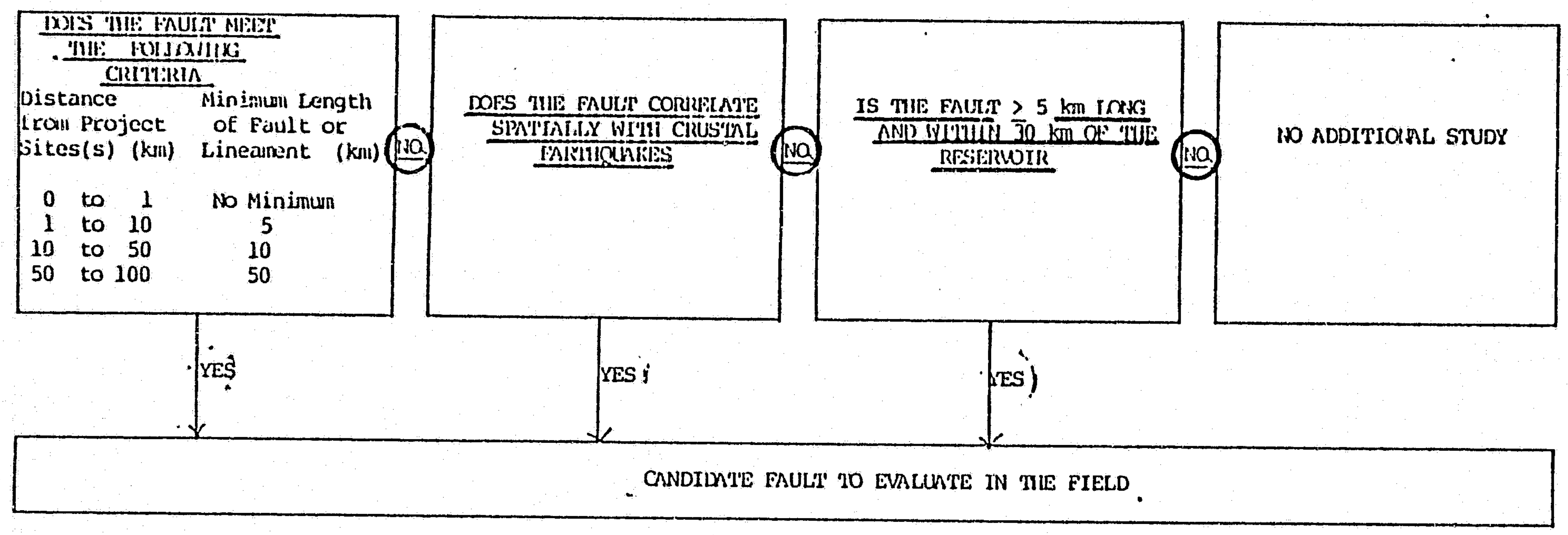
   B. Concrete Structures

      - response spectra type design
      - factor "g" design
      - modified time history analysis

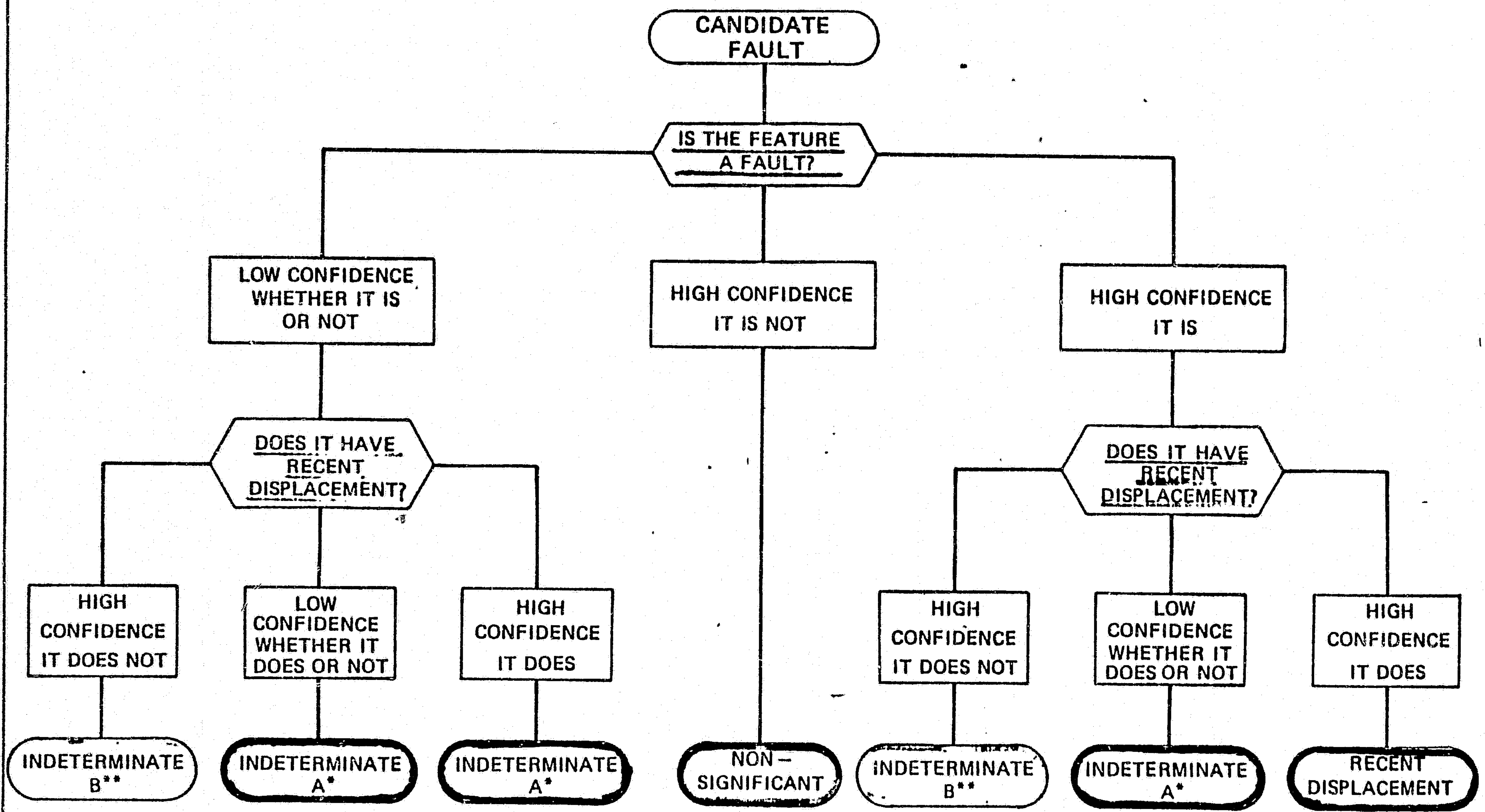
   C. For a Selected Scheme (Structure)

      - evaluate if earthquake loading governs
      - detailed analysis will be done

FAULT SCREENING CRITERIA



00234



* Indeterminate A – High to Moderate Probability of Recent Displacement

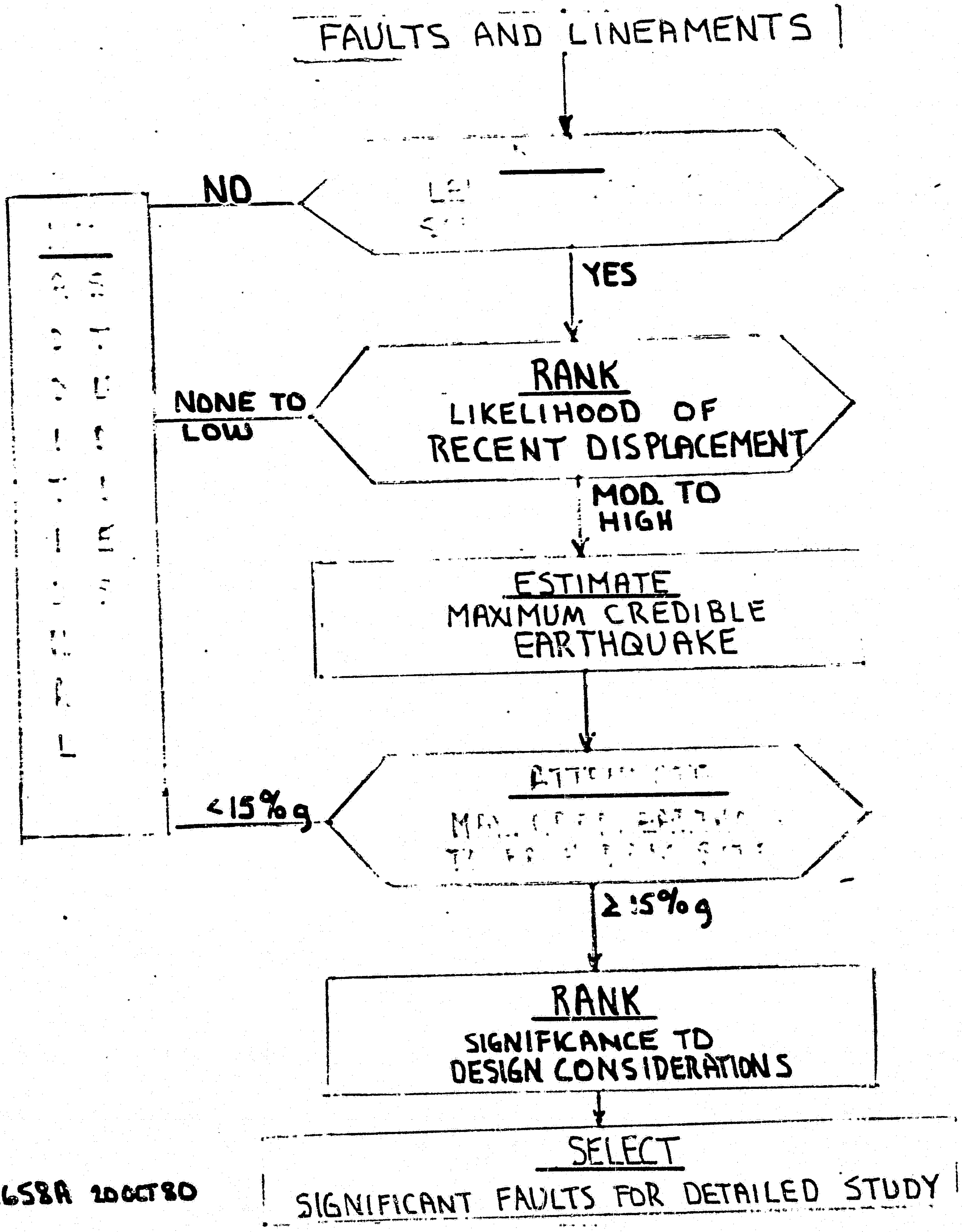
** Indeterminate B – Low Probability of Recent Displacement

Note: Table presents the criteria on which confidence levels are based.

FIELD CLASSIFICATION OF CANDIDATE FAULTS

FIGURE 22

DESIGN EARTHQUAKE EVALUATION



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MAX. CREDIBLE EQ SUMMARY

WATANA SITE

FEATURE NO.	NAME	DIST (mi.)	MAX CRED. EQ	SURFACE RUPTURE POTENTIAL
AD5-1	Castle Mtn	65	7.2	
HB4-1	McKinley Strand	40	8.4	
KC4-1	Talkeetna Thrust	4	7.5	
KD3-3	Susitna Fault	2	7.6	
KD4-2D	Lineament	1.2	5.8	?
KD4-27	Fault	0.	6.4	✓
HA4-3	Lineament	8	7.2	
KD3-2	Fault	2.5	7.0	
KD3-7	Lineament	0	7.3	✓
KD5-3	Fault	11	7.4	

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MAX. CREDIBLE EQ SUMMARY
DEVIL CANYON SITE

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AD5-1	Castle Mtn	72	7.2	
HB4-1	McKinley Strand	40	8.4	
KC4-1	Talkeetna Thrust	17	7.5	
KD5-43	Lineament	0	4.5	✓
KD5-44	Lineament	0.3	4.6	✓
KD5-2	Fault	3.5	5.6	
KD5-3	Fault	9.5	7.4	
KD5-9	Lineament	2.5	6.9	
KD5-42	Lineament	0.5	6.2	✓
KD5-44	Lineament	1.2	6.9	
KD6-4	Lineament	1.0	7.2	

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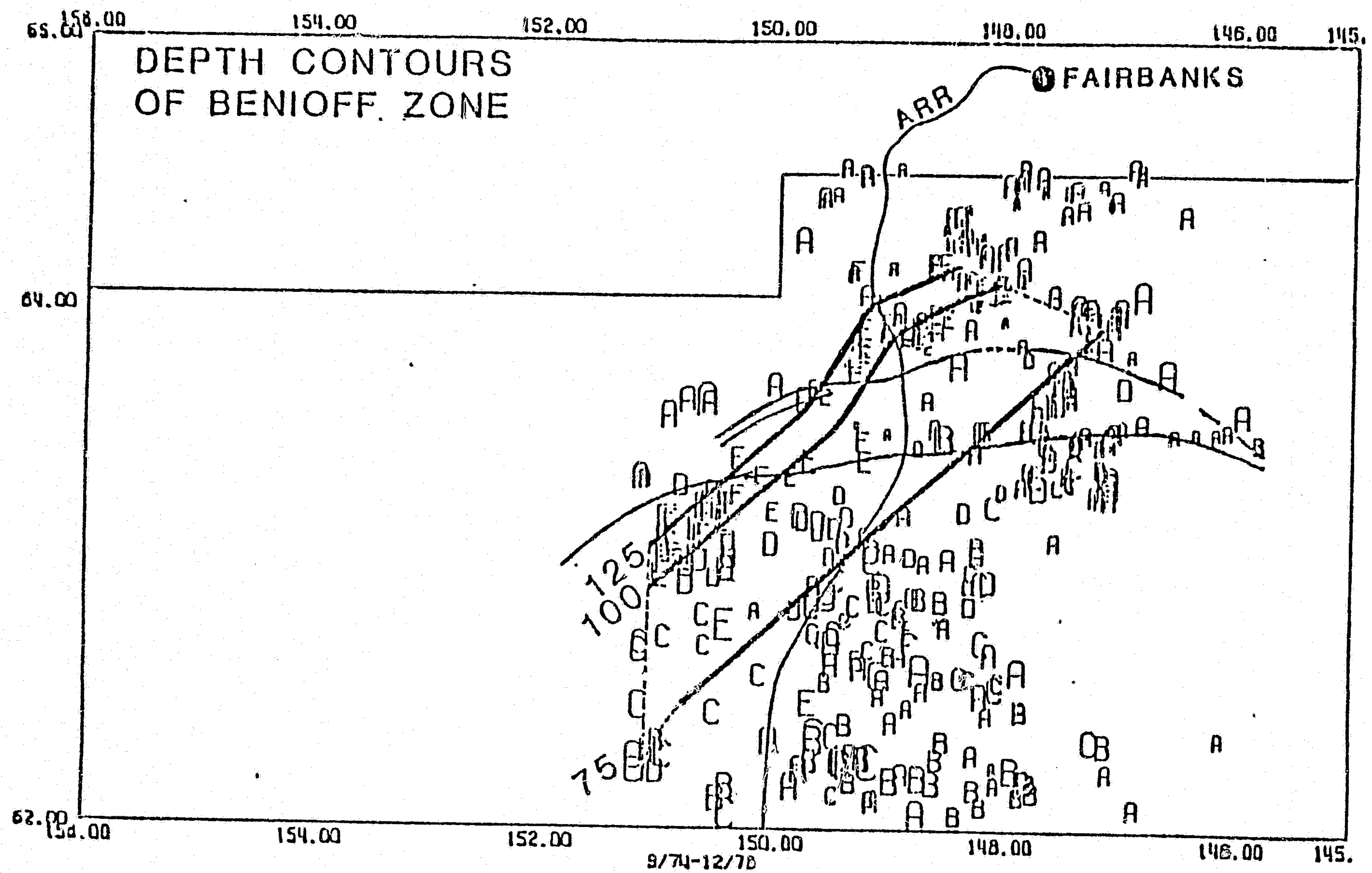
MICROEARTHQUAKE STUDY OBJECTIVES

- LOCATIONS AND FOCAL DEPTHS OF MICROEARTHQUAKES
- STYLE OF FAULTING
- STRESS ORIENTATION
- GEOLOGIC ASSOCIATIONS OF MICROEARTHQUAKES
- SOURCE AND WAVE PROPAGATION CHARACTERISTICS



⊚ DAM SITES

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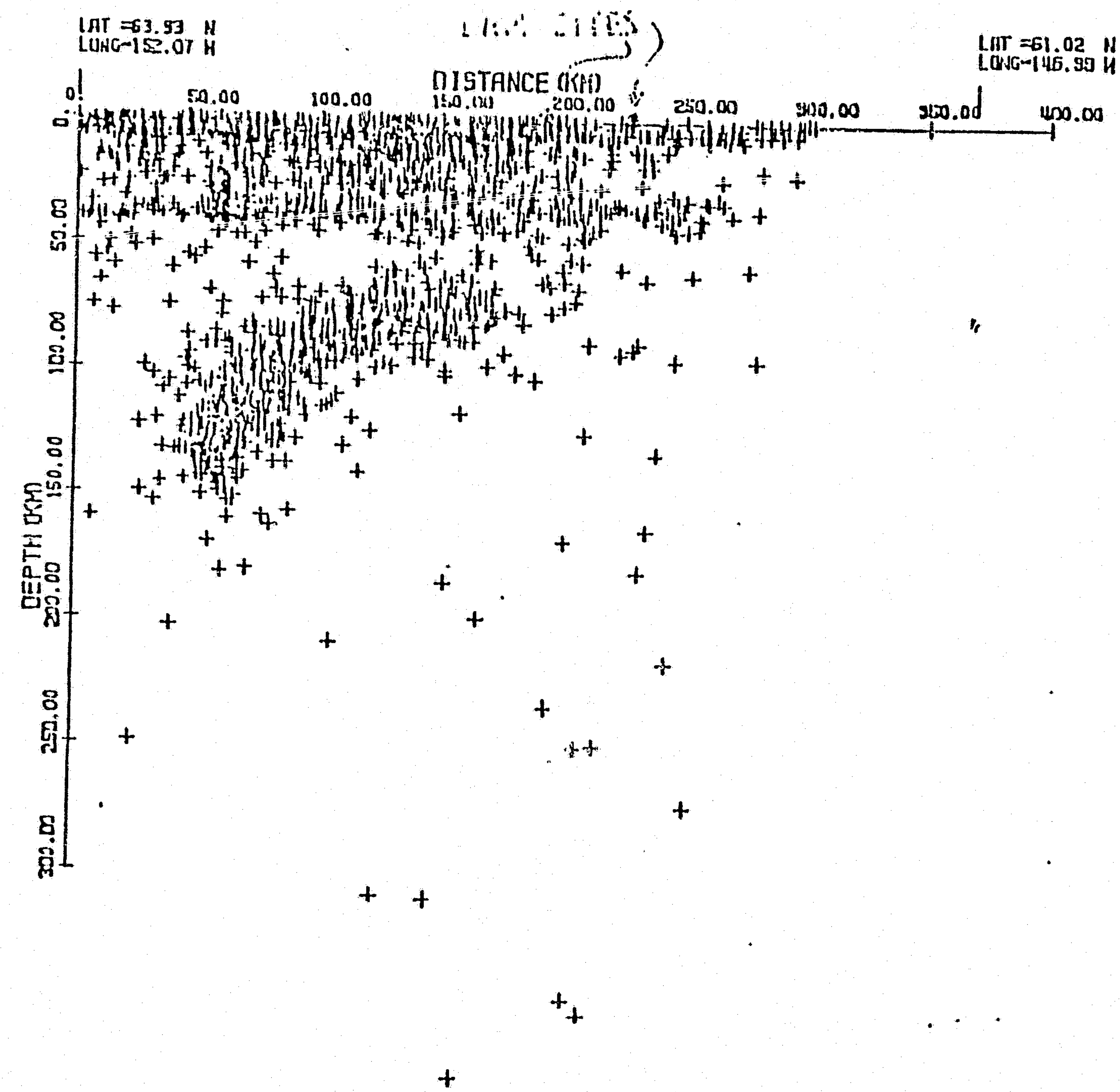

UNIVERSITY OF ALASKA GEOPHYSICAL INSTITUTE
EPICENTER DATA FOR 1974 - 1978

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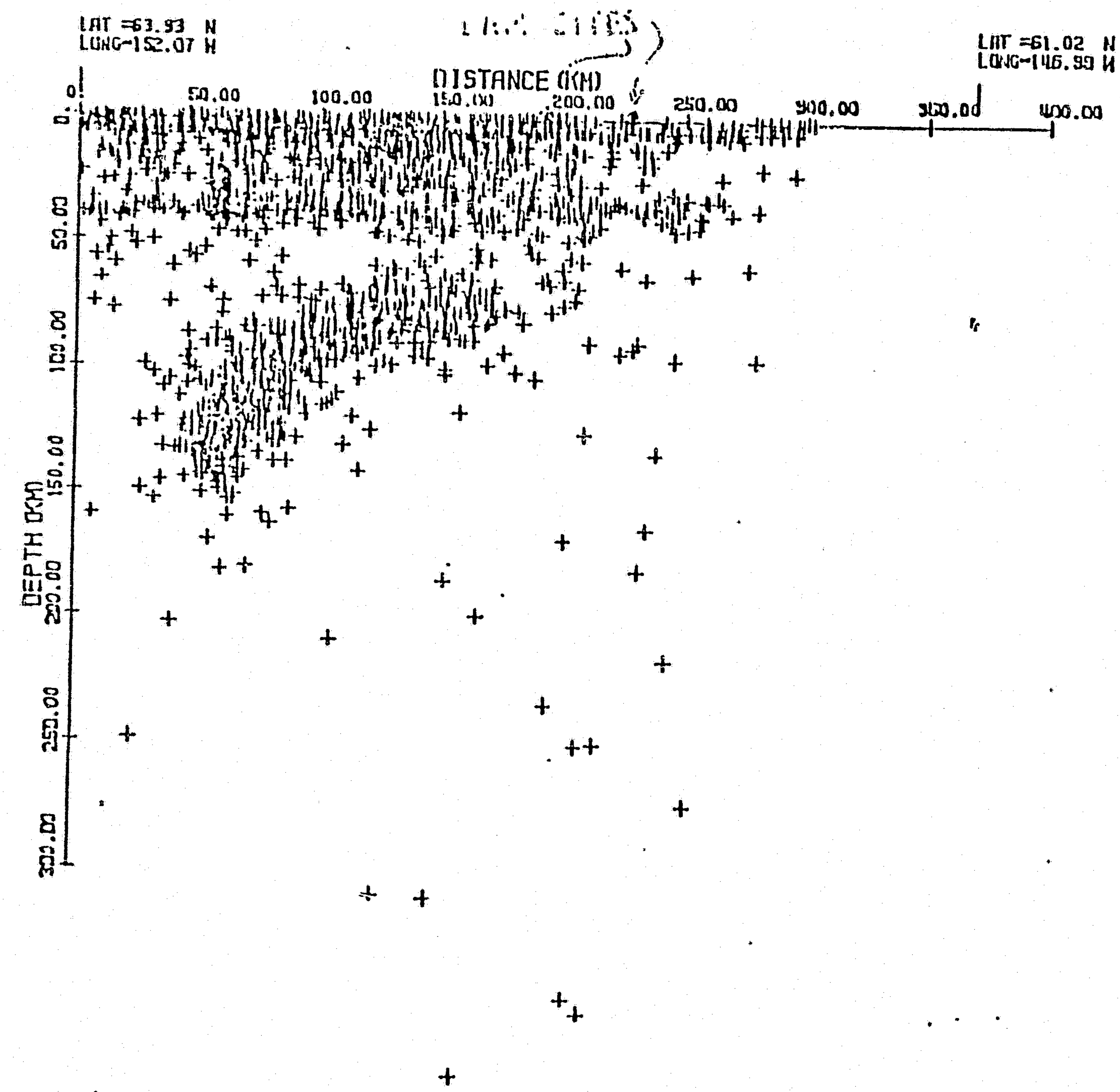
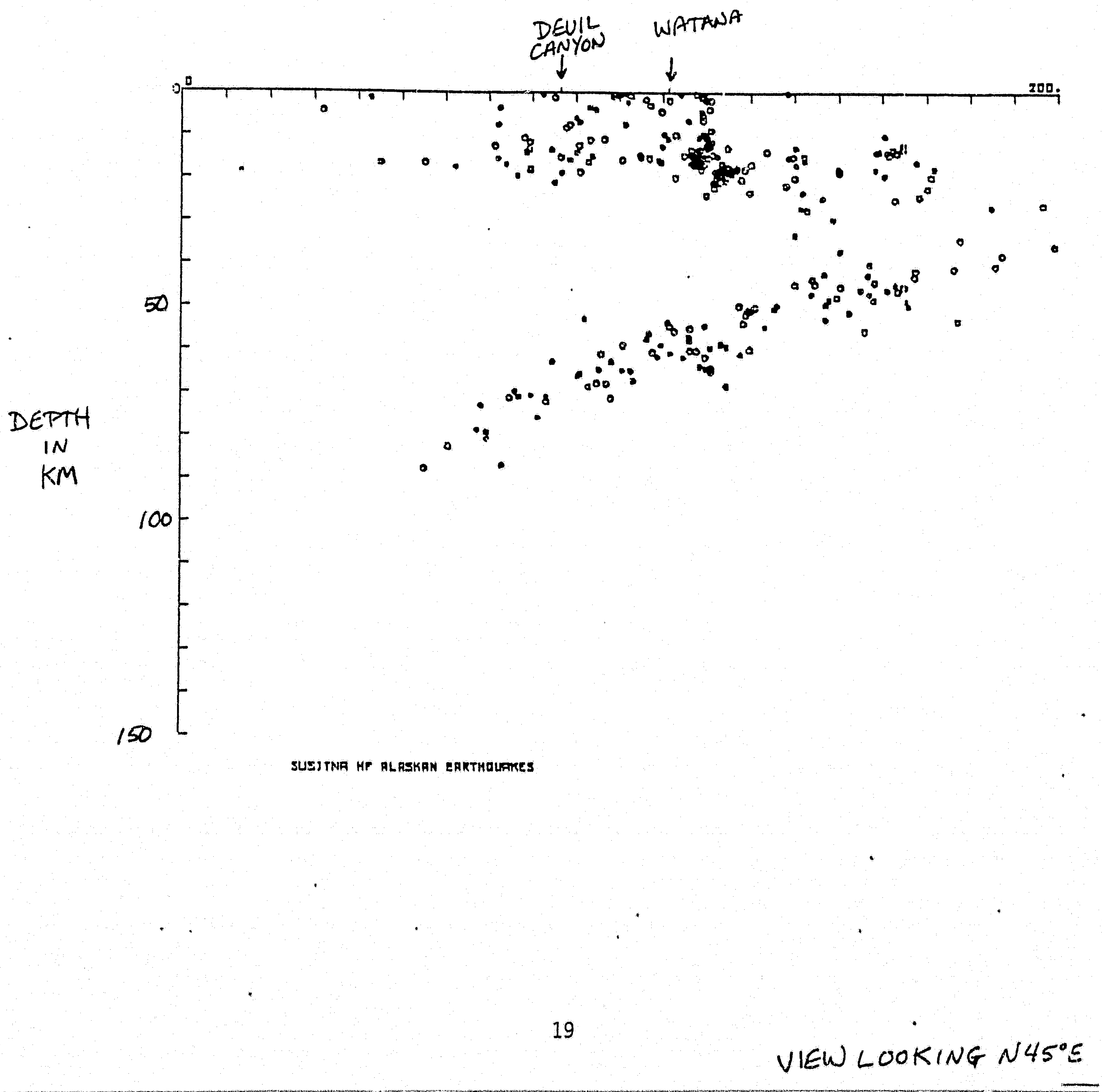


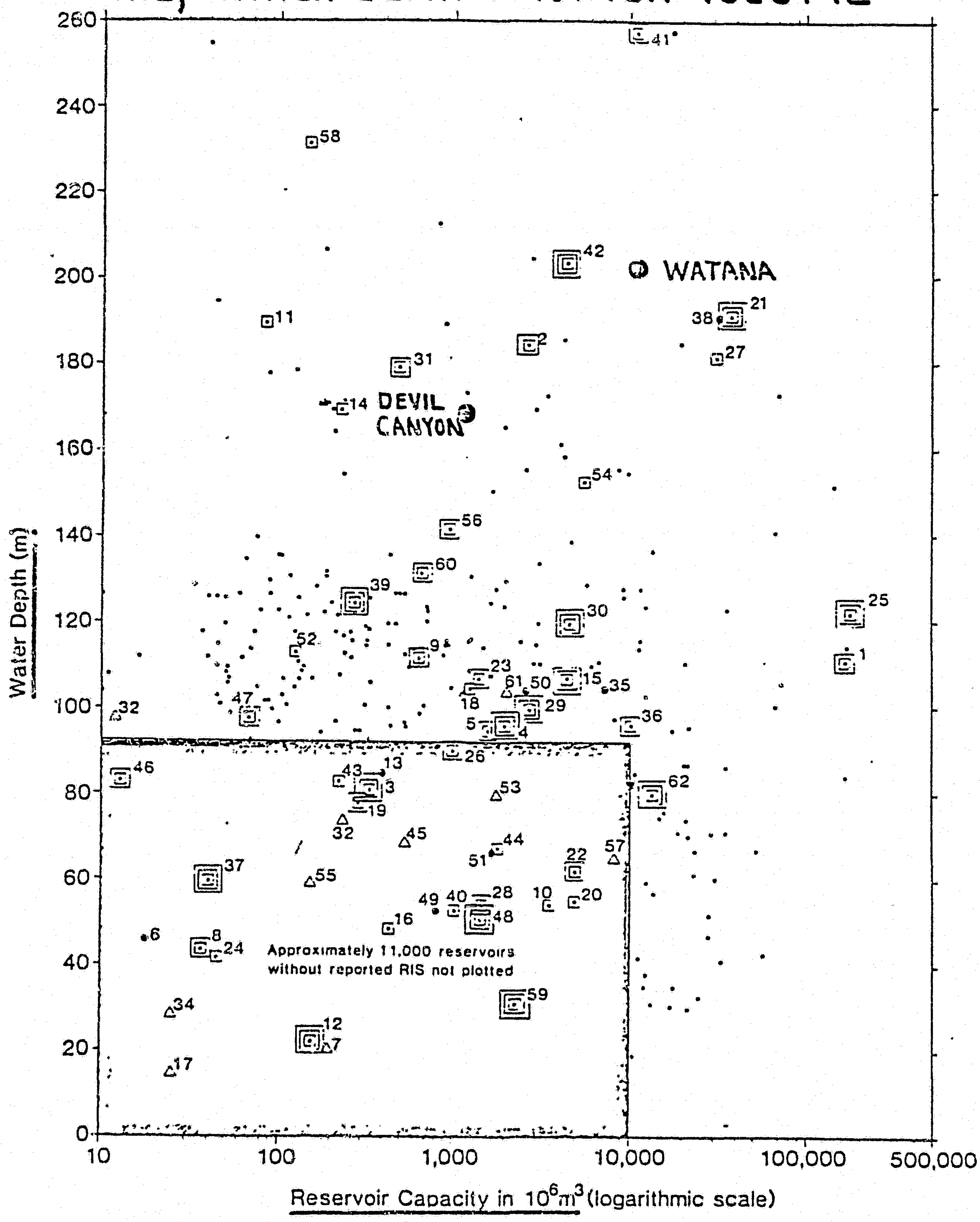
UNIVERSITY OF ALASKA GEOPHYSICAL INSTITUTE
EPICENTER DATA FOR 1974 - 1978

14658A - 4000

10 JUNE 1980


DEVIL CANYON
WATANA
0
0
200.
50
100
150
DEPTH IN KM
SUSITNA HP ALASKAN EARTHQUAKES
VIEW LOOKING N45°E

RIS, WATER DEPTH & WATER VOLUME



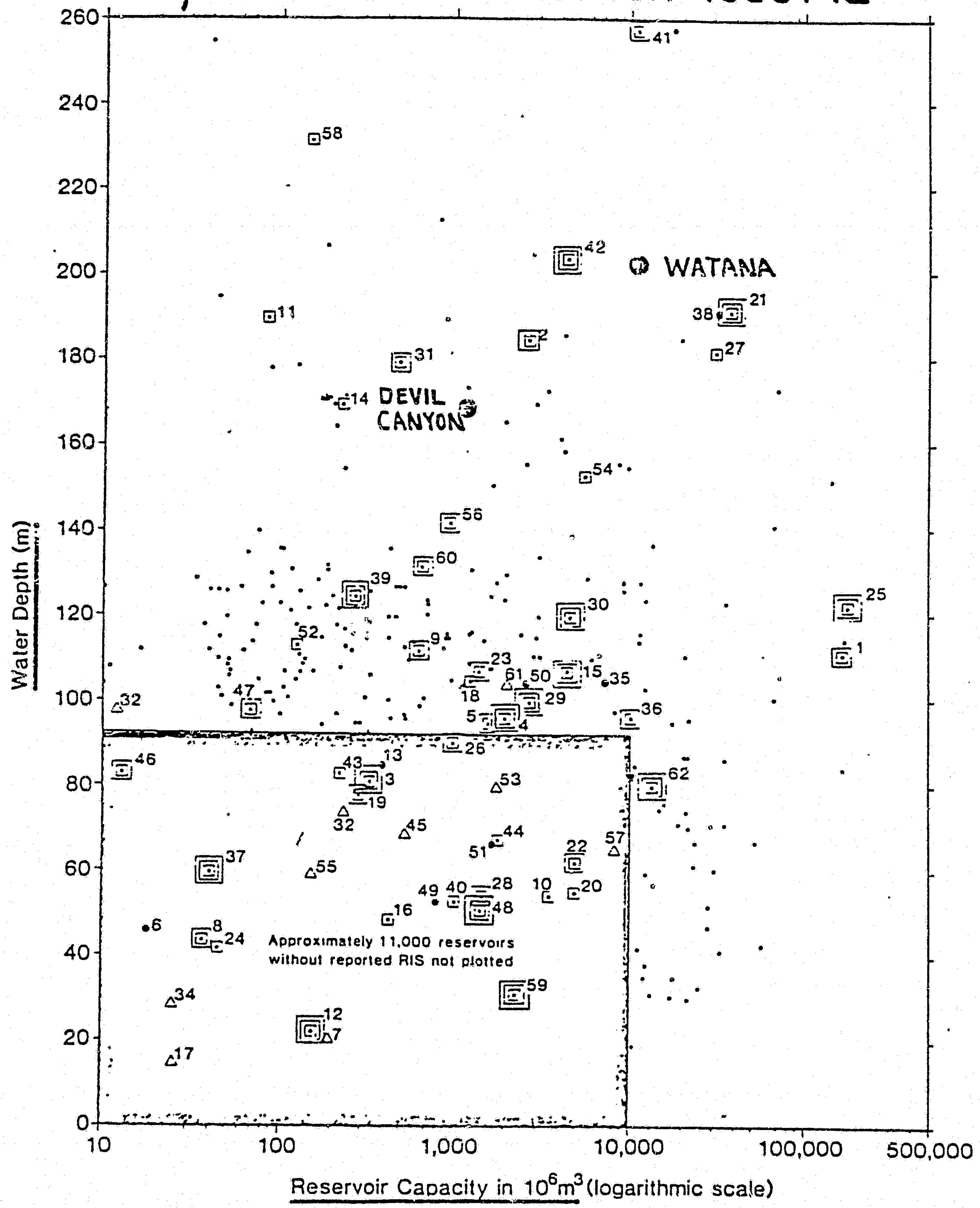
Note: The following reservoirs were not plotted because of insufficient data: Kinarsani, Sharavathi.

*41 - Nurek (USSR) depth is in excess of 285 m.

EXPLANATION:

- ◦ Deep and/or very large reservoir
- Accepted case of RIS, maximum magnitude ≥ 5
- Accepted case of RIS, maximum magnitude 3-5
- Accepted case of RIS, maximum magnitude ≤ 3
- △ Questionable case of RIS
- • Not RIS

RIS, WATER DEPTH & WATER VOLUME



Note: The following reservoirs were not plotted because of insufficient data: Kinarsani, Sharavathi.

*41 - Nurek (USSR) depth is in excess of 285 m.

EXPLANATION:

- • Deep and/or very large reservoir
- Accepted case of RIS, maximum magnitude ≥ 5
- Accepted case of RIS, maximum magnitude 3-5
- Accepted case of RIS, maximum magnitude ≤ 3
- △ Questionable case of RIS
- • Not RIS

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PRELIMINARY RESERVOIR INDUCED
SEISMICITY PROBABILITY ASSESSMENT

RESERVOIR	PROBABILITY
WATANA	0.9
DEVIL CANYON	0.5
COMBINED RESERVOIRS AS ONE RESERVOIR	0.9

TASK 5: GEOTECHNICAL EXPLORATION

SUBTASK

5.01 DATA COLLECTION AND REVIEW

5.02 PHOTOINTERPRETATION

5.03 EXPLORATORY PROGRAM DESIGN (1980)

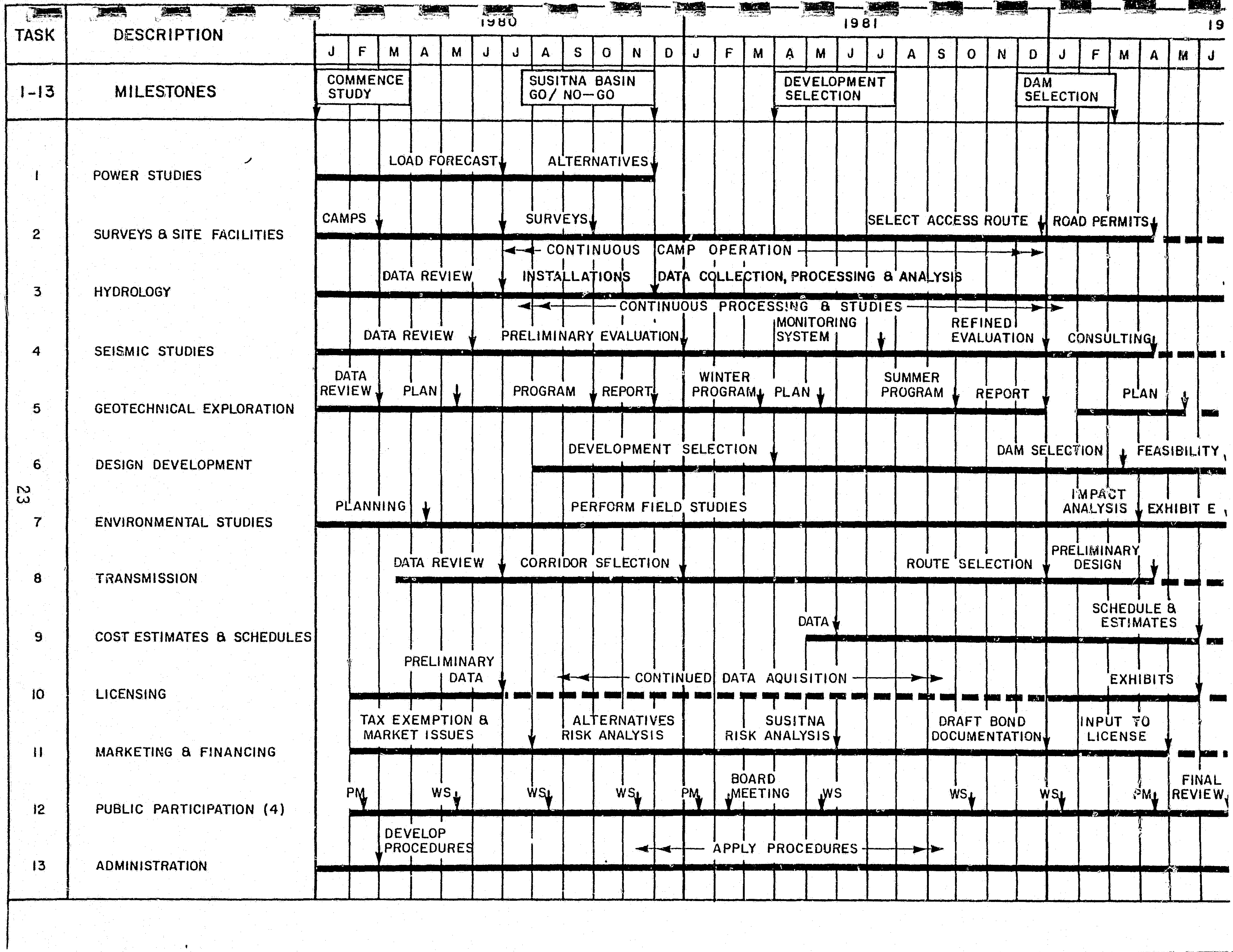
5.04 EXPLORATORY PROGRAM (1980)

5.05 EXPLORATORY PROGRAM DESIGN (1981)

5.06 EXPLORATORY PROGRAM (1981)

5.07 EXPLORATORY PROGRAM DESIGN (1982 - 1984)

5.08 DATA COMPILATION


TASK
DESCRIPTION
1980
1981
19
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J
1-13 MILESTONES
COMMENCE STUDY
SUSITNA BASIN GO/ NO-GO
DEVELOPMENT SELECTION
DAM SELECTION
1 POWER STUDIES
LOAD FORECAST
ALTERNATIVES
2 SURVEYS & SITE FACILITIES
CAMPS
SURVEYS
SELECT ACCESS ROUTE
ROAD PERMITS
CONTINUOUS CAMP OPERATION
3 HYDROLOGY
DATA REVIEW
INSTALLATIONS
DATA COLLECTION, PROCESSING & ANALYSIS
CONTINUOUS PROCESSING & STUDIES
4 SEISMIC STUDIES
DATA REVIEW
PRELIMINARY EVALUATION
MONITORING SYSTEM
REFINED EVALUATION
CONSULTING
5 GEOTECHNICAL EXPLORATION
DATA REVIEW
PLAN
PROGRAM
REPORT
WINTER PROGRAM
PLAN
SUMMER PROGRAM
REPORT
PLAN
6 DESIGN DEVELOPMENT
DEVELOPMENT SELECTION
DAM SELECTION
FEASIBILITY
7 ENVIRONMENTAL STUDIES
PLANNING
PERFORM FIELD STUDIES
IMPACT ANALYSIS
EXHIBIT E
8 TRANSMISSION
DATA REVIEW
CORRIDOR SELECTION
ROUTE SELECTION
PRELIMINARY DESIGN
9 COST ESTIMATES & SCHEDULES
DATA
SCHEDULE & ESTIMATES
10 LICENSING
PRELIMINARY DATA
CONTINUED DATA AQUISITION
EXHIBITS
11 MARKETING & FINANCING
TAX EXEMPTION & MARKET ISSUES
ALTERNATIVES RISK ANALYSIS
SUSITNA RISK ANALYSIS
DRAFT BOND DOCUMENTATION
INPUT TO LICENSE
12 PUBLIC PARTICIPATION (4)
PM
WS
WS
WS
PM
BOARD MEETING
WS
WS
WS
PM
FINAL REVIEW
13 ADMINISTRATION
DEVELOP PROCEDURES
APPLY PROCEDURES

SUSITNA HYDROELECTRIC PROJECT

EXPLORATION PROGRAM SCOPE

EXPLORATION	TOTAL	1980	1981
GEOPHYSICAL	$ 63,000	$ 39,000	$ 24,000
DIAMOND DRILLING (INCLUDING INST.)	7625 lf/$564,647	3800 lf/$282,000	3825 lf/$282,647
IN-HOLE GEOPHYSICS	$ 25,000	$ 11,000	$ 14,000
AUGER DRILLING	$ 43,800	$ 20,000	$ 23,800
TEST PITS/ R.C. DRILLING	$ 45,000	$ -	$ 45,000
LAB TESTING (Plus Manhours)	$ 15,000	$ 5,000	$ 10,000
AIRBORNE IMAGERY	$ 51,500	$ -	$ 51,500
TRANS. LINE	$ 63,000	$ -	$ 63,000
ACCESS ROAD	$ 85,000	$ -	$ 85,000
CLEARING DRILL SITES	$ 98,000	$ 49,000	$ 49,000
TOTAL BUDGET	$1,053,947	$406,000	$647,947
FUNDS AVAILABLE	$1,053,947	$445,364	$608,583

OBJECTIVES OF 1980 GEOLOGIC MAPPING PROGRAM

A. Confirm previous work

B. Expand area of geologic mapping

C. Provide geologic information necessary for optimization of type and location of dams

D. Identify potential problems needing further study in 1981

HAYDEN

REGIONAL GEOLOGY

GEOLOGIC HISTORY

Three Major Periods

Glaciation

TECTONICS

Denali, Castle Mountain, Talkeetna, Susitna (?) Faults

WATANA

PREVIOUS SITE INVESTIGATIONS:

Reconnaissance:

U.S.B.R.; 1950, 1953

Corp of Eng.; 1975

Kachadoorian & Moore; 1978

Geologic Mapping:

Corp of Eng.; 1978

Drilling, Subsurface Investigations:

Corp of Eng.; 1978

Seismic:

Dames & Moore, 1975

Shannon & Wilson, 1978

WATANA

LITHOLOGY:

Dam Site

Diorite, Quartz Diorite, Granodiorite

Andesite Porphyry

Quarry A

Andesite Porphyry

Rhyodacite

Surrounding Area

Volcanic Sediment

Basalt

Argillite

STRUCTURE:

Joints:

Major: N35^{o}W 73^{o}NE

Minor: N70^{o}W 51^{o}NE

Shears:

"Fins" to Tsusena Creek

"Fingerbuster"

SURFICIAL MATERIALS:

Susitna/Tsusena Confluence - Glaciolacustrine Sands

Borrow 'D' & 'H' - Till

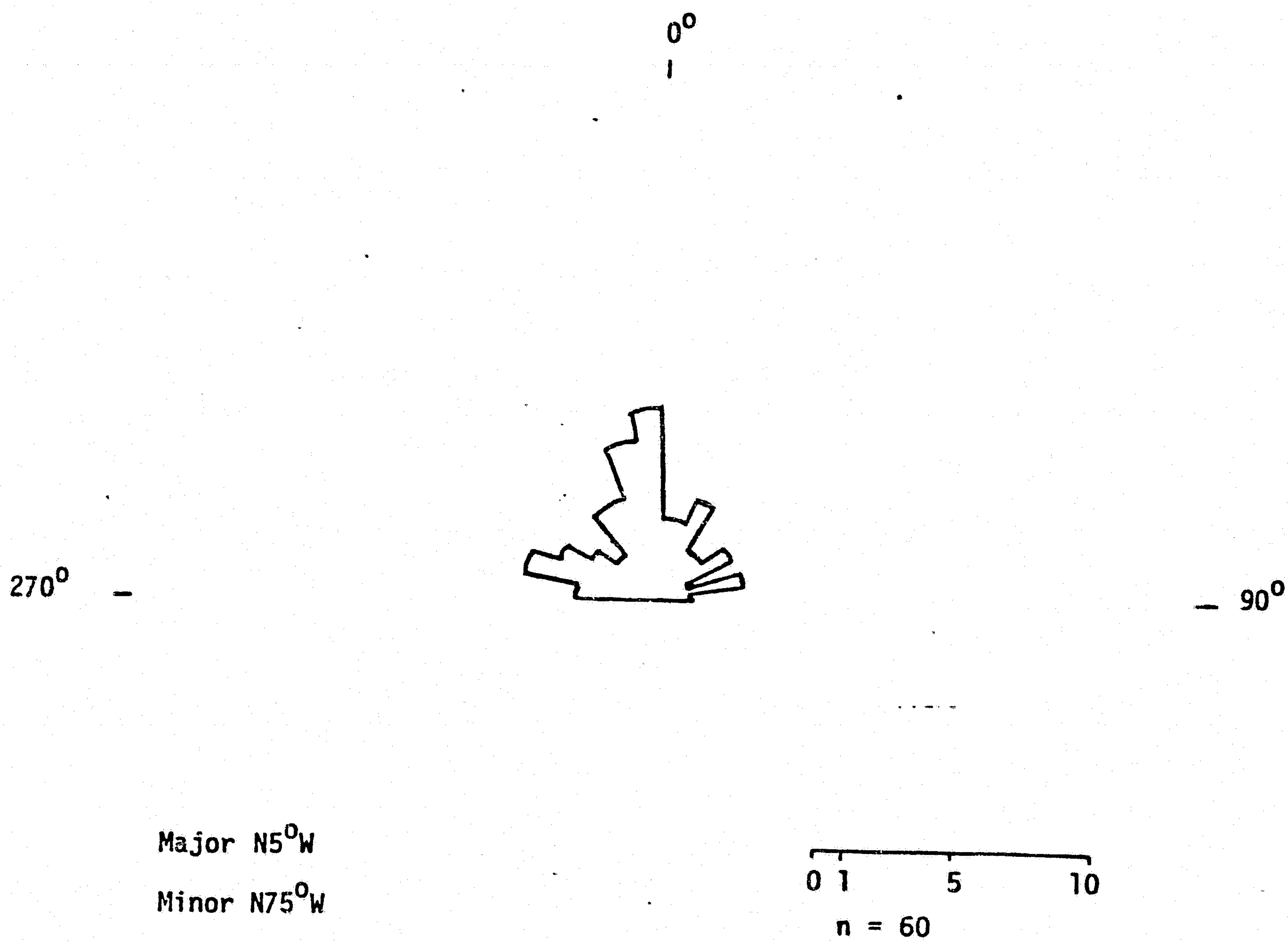
Borrow 'E', River Alluvium

RESERVOIR:

Overburden in Lower Reservoir - Till, Lacustrine Sands and Silts

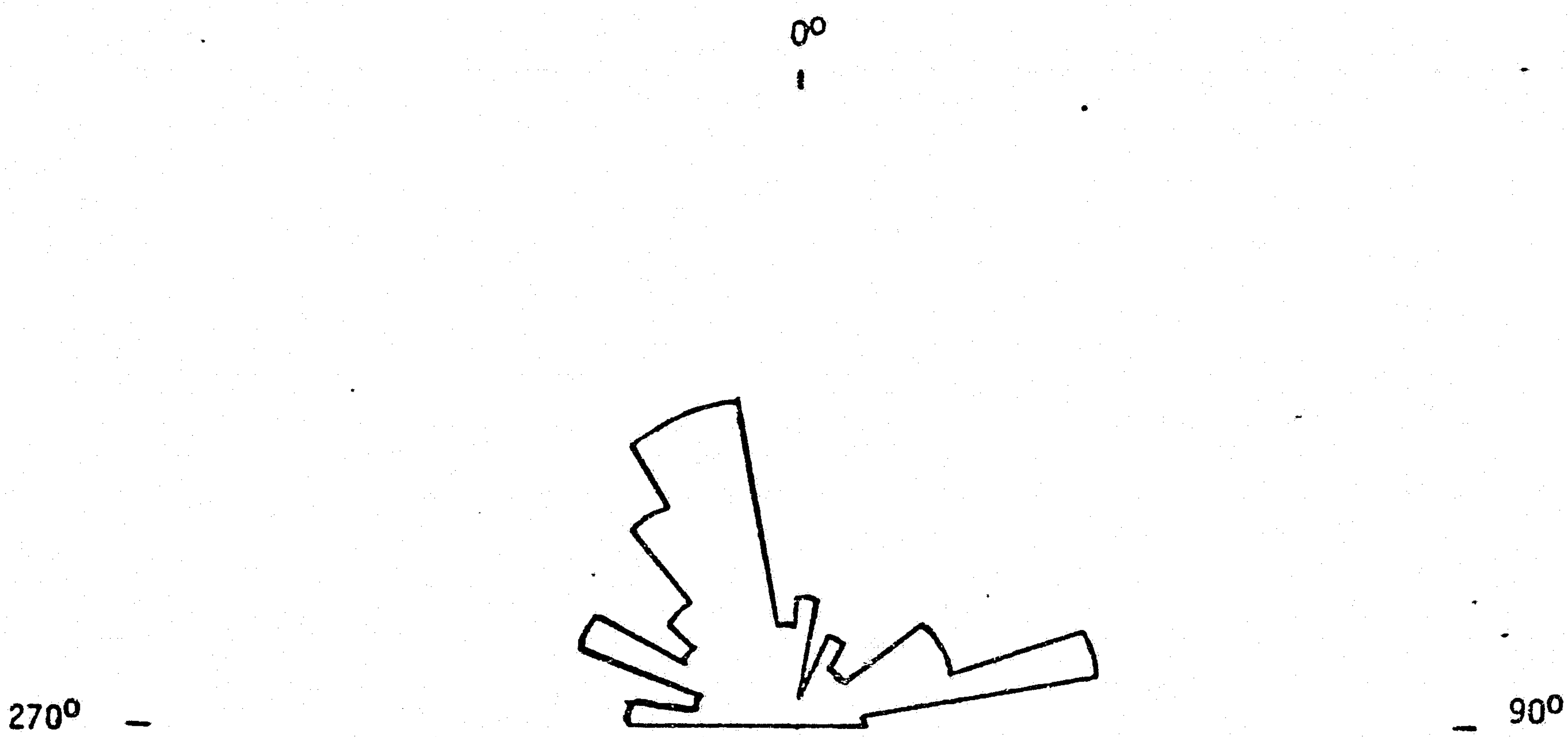
Watana Right Abutment

along center line



Watana Left Abutment

200' upstream from the fins



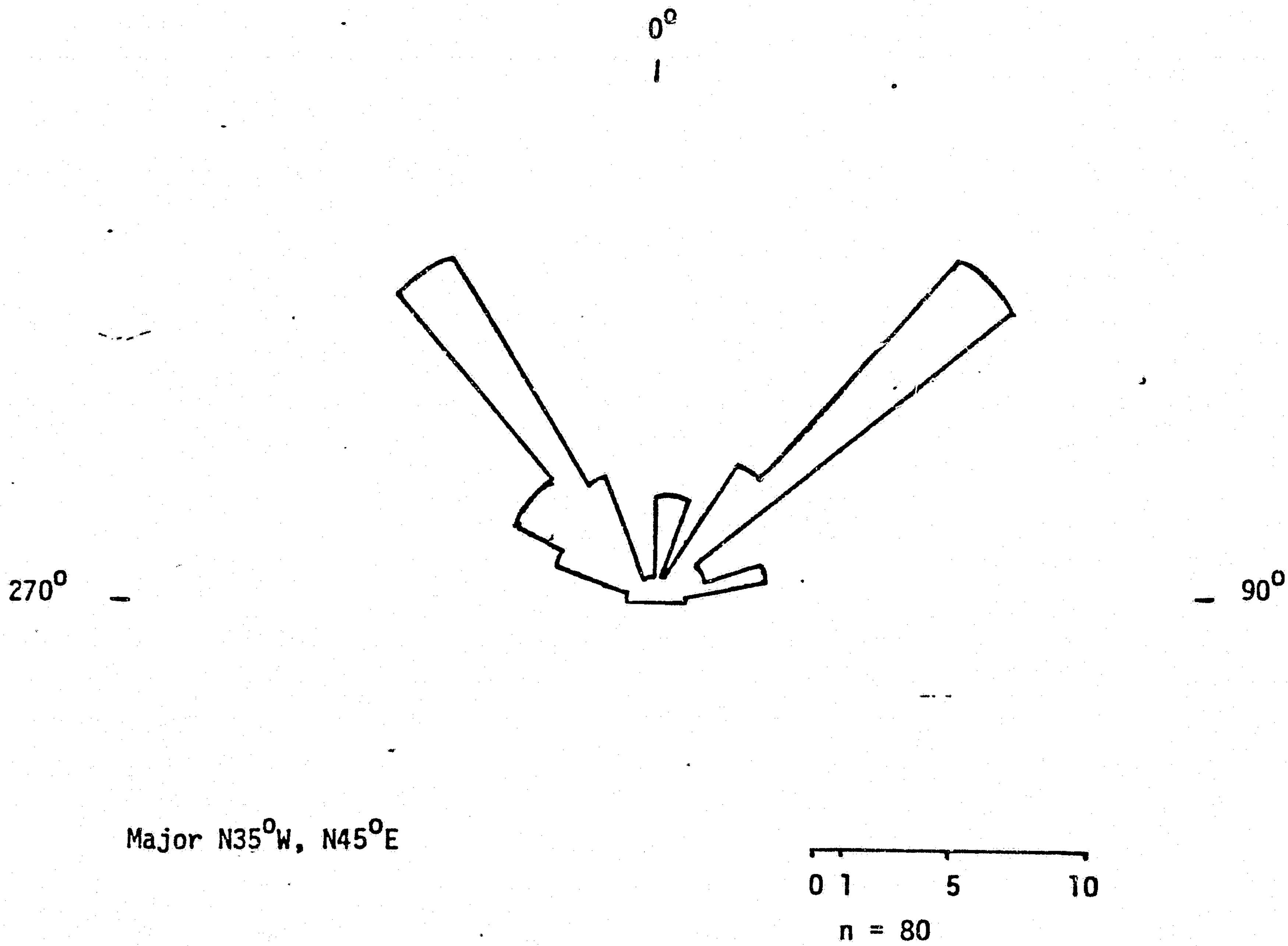
Major N20°W, N75°E

Minor N65°W

0 1 5 10

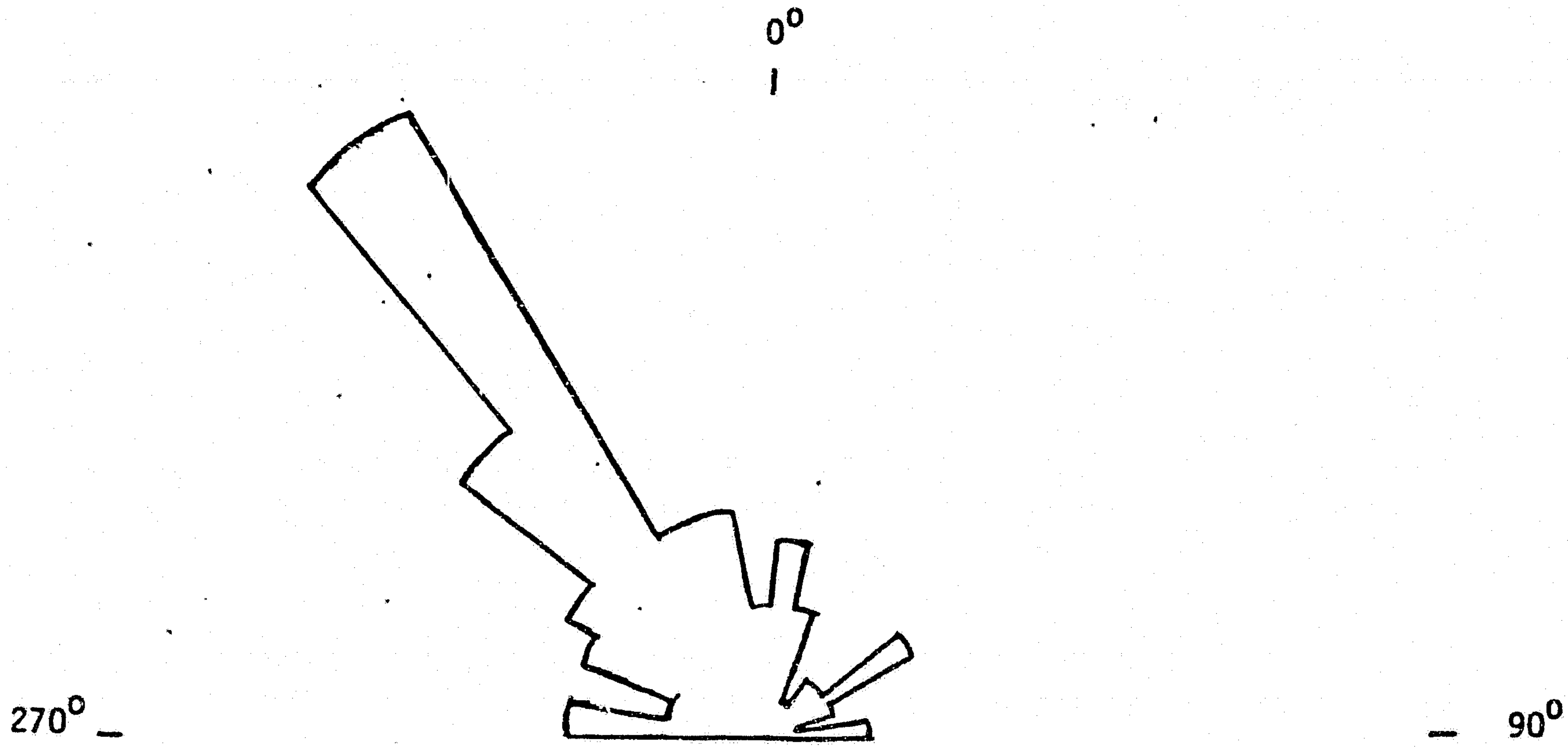
n = 86

Watana Fins

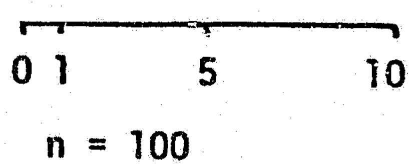


Major N35°W, N45°E

Watana - Tsusena Creek



Major N35°W



WATANA RESERVOIR

PREVIOUS SITE INVESTIGATIONS

Geologic Mapping:

Corp of Eng.; 1978

LITHOLOGY:

Diorite, Argillite

Tertiary Sediments, Basalt Flows

Metavolcanics

Schist

STRUCTURE:

Talkeetna thrust

SURFICIAL MATERIALS:

Till, Outwash, Glaciolacustrine, Sands and Silts

PERMAFROST

DEVIL CANYON

PREVIOUS SITE INVESTIGATIONS:

Geologic Mapping:

Kachadoorian, 1957

Drilling:

U.S.B.R.; 1957

Seismic:

Shannon & Wilson, 1978

DEVIL CANYON

LITHOLOGY:

Argillite and Graywacke (Phyllite)

STRUCTURE:

Joints:

Major: N25°W 80°E

Minor: Sub-parallel Bedding

N90°E Steep to north

N90°E 15°N to 15°S

Shears:

N°25°W 80°NE to Vertical

Bedding: N90°E 55°-75°S

SURFICIAL MATERIALS:

River alluvium - estimated 35'

- max. depth to rock 85'

Overburden on abutements: insignificant

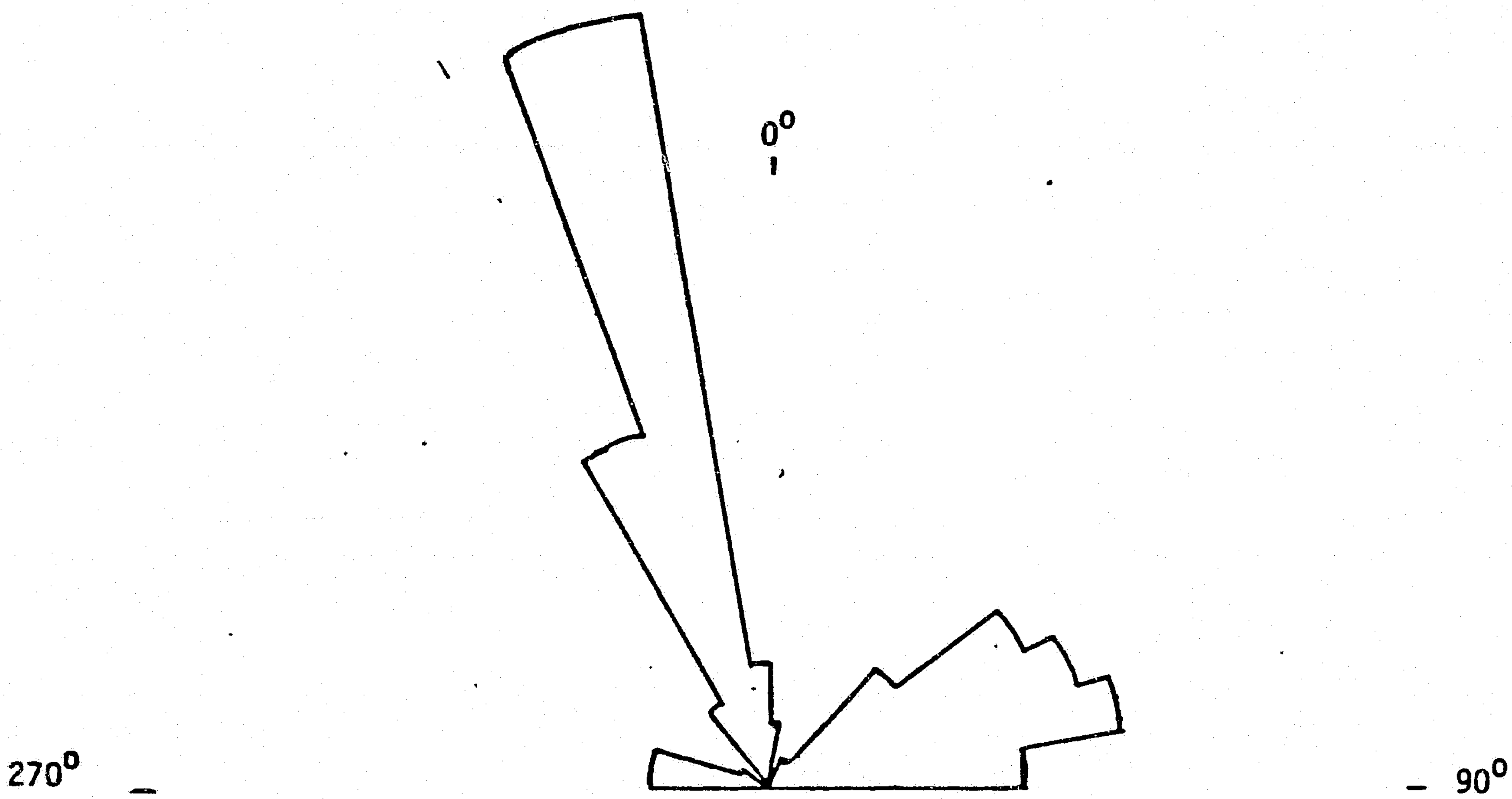
Buried Channel - up to 90 feet of overburden (1293')

Point Bar (Fan) Deposit

PERMAFROST

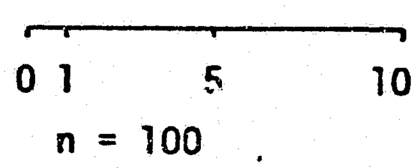
Devils Canyon

Right Abutment
above Borehole # 2



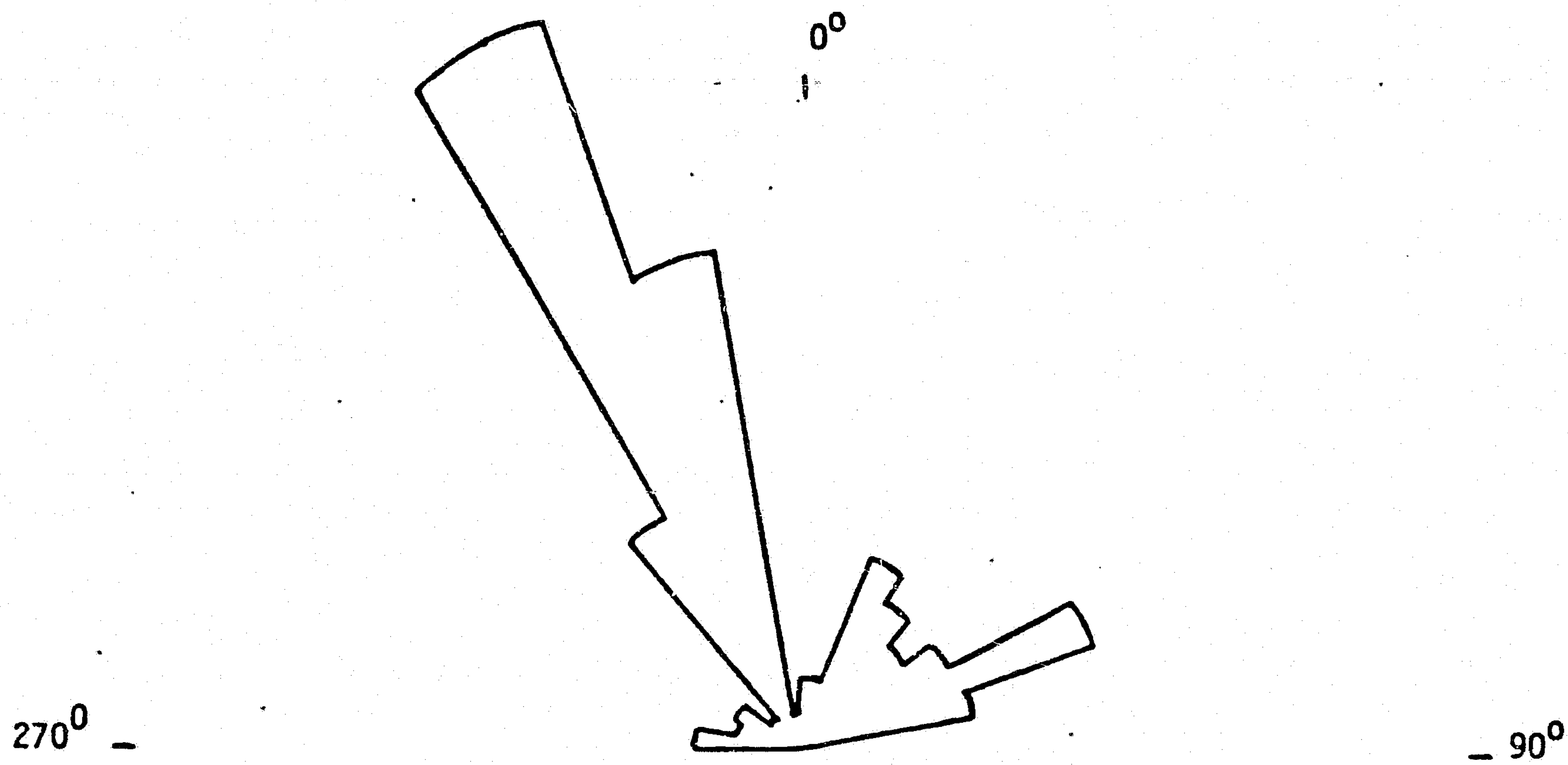
Major N15°W

Minor N75°E



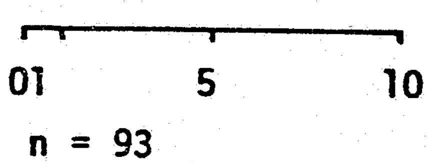
Devils Canyon

Left Abutment

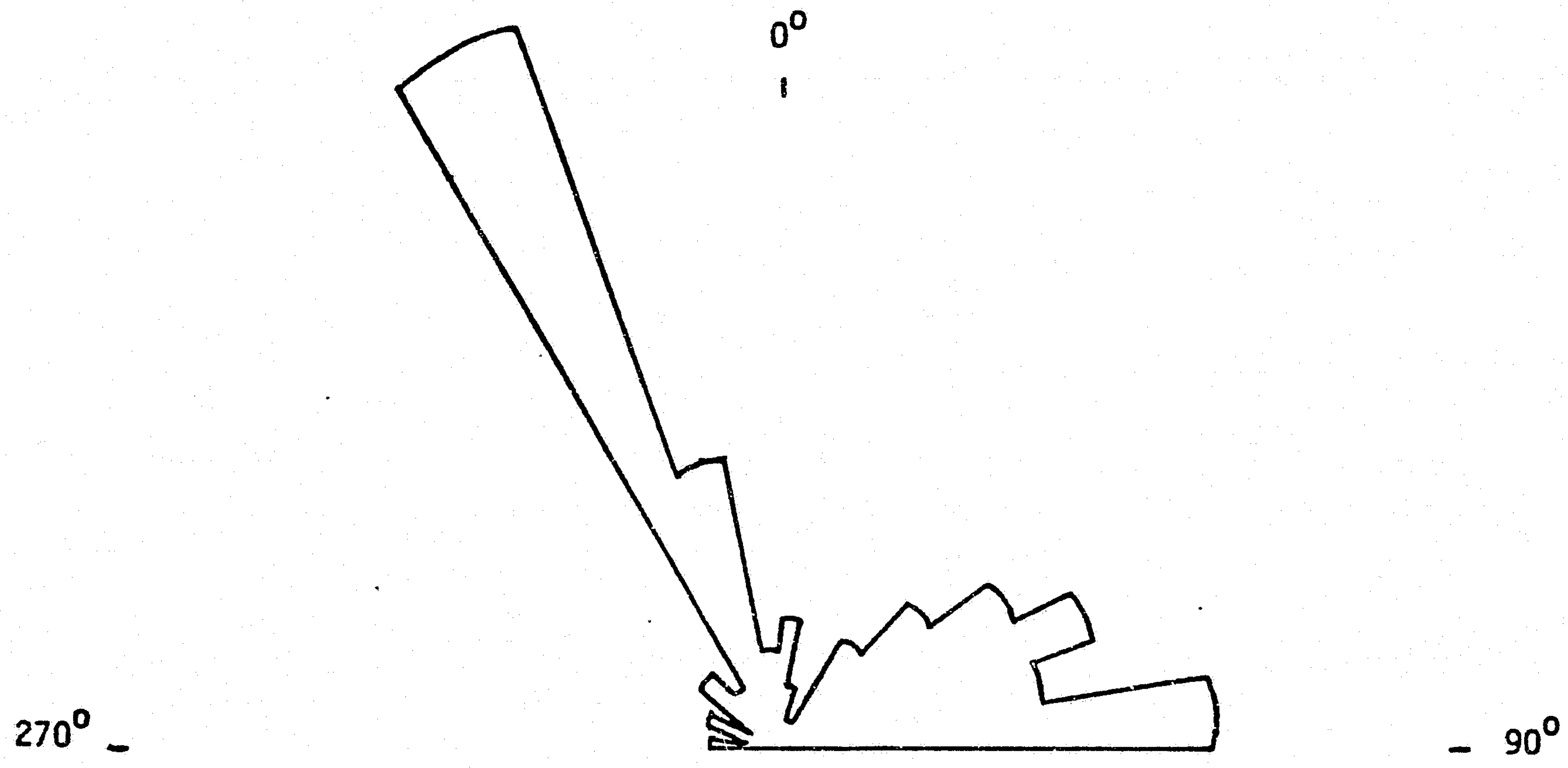


Major N25°W

Minor N65°E, N25°E

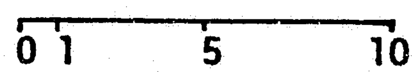


Devils Canyon
Right Abutment
on the River



Major N25°W

Minor N65°E, N85°E



n = 100

POTENTIAL PROBLEMS, AREAS OF CONCERN

DEVIL CANYON

1) Accessibility of canyon walls
2) Abrupt bend in the river, bedrock beneath point bar
3) Semi-impervious or impervious material for saddle dam

WATANA

1) Exit of buried channel on the Susitna River
2) Potential faults or shears
   "Fins" to Tsusena Creek
   "Fingerbuster"
3) Thickness of andesite at Quarry 'A'
4) Alternate source of impervious material
5) Reservoir - mudslumps/permafrost

slide block

Faulting in Fog Creek

GEOTECHNICAL DESIGN CRITERIA

1. Earth/Rock Fill Structures

   - Abutment conditions and treatment
   - Foundation conditions and treatment (Watana - Relatively deep alluvium)
   - Construction material :
     - availability
     - suitability (engineering properties)
     - workability (moisture)

2. Concrete Dam - Devil Canyon

   - Abutment conditions and treatment
   - Foundation conditions and treatment

3. Underground Structures

WATANA

STRUCTURE: 810' HIGH EARTH DAM

INVESTIGATION:

1950-'53, USBR, RECONNAISSANCE

1975, COE, RECONNAISSANCE

D&M, 22500LF SEISMIC

1978 COE 28 BOREHOLES, 30' TO 600' DEEP

27 TEST PITS

18 AUGER HOLES

S&W 47665LF SEISMIC

INSTRUMENTATION

10 PIEZOMETERS

13 TEMP. PROBES

SIGNIFICANT FEATURES

300' - 600' WIDE VALLEY 30° - 60° SLOPES

40' - 80' OVERBURDEN

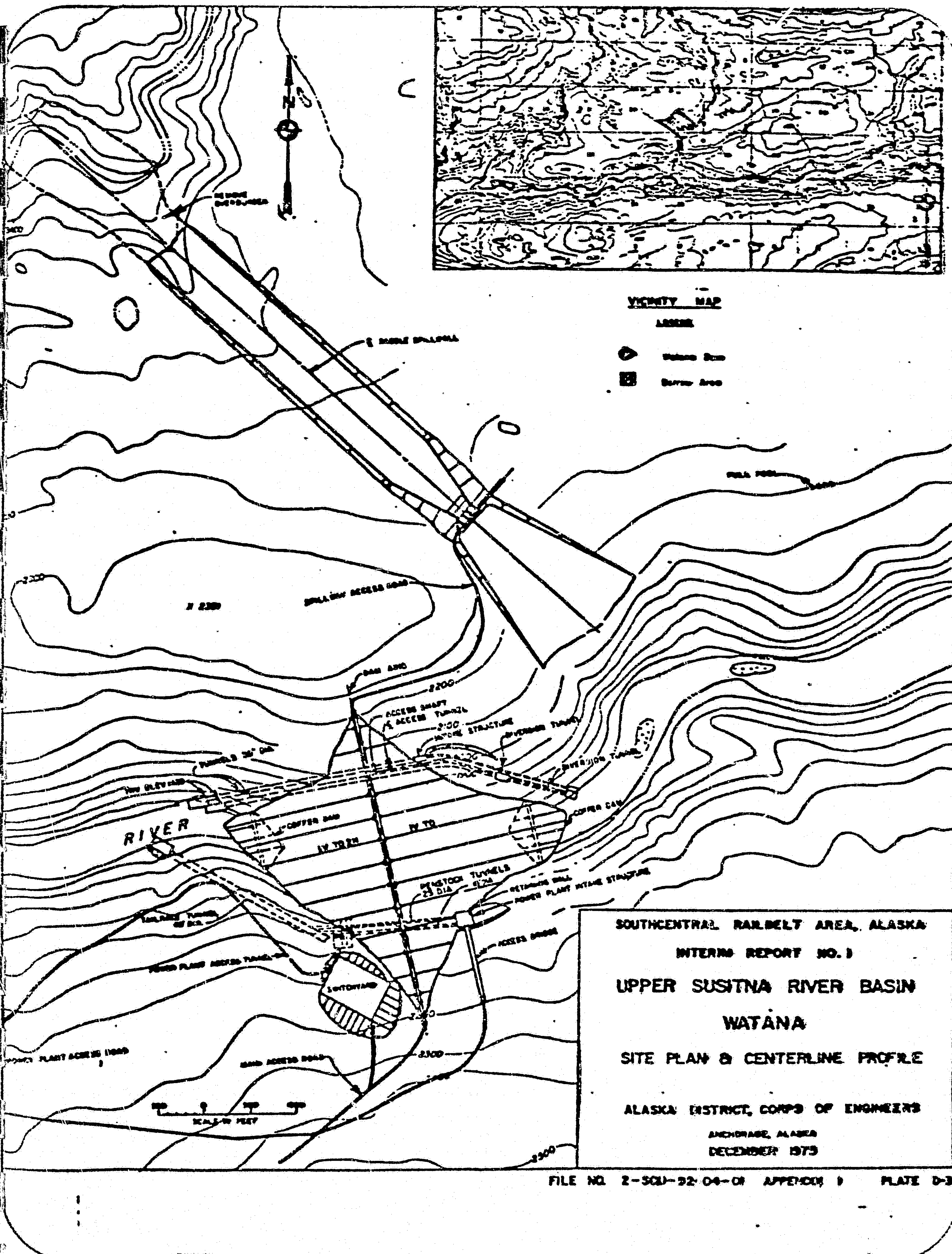
5' - 40' WEATHERED ROCK

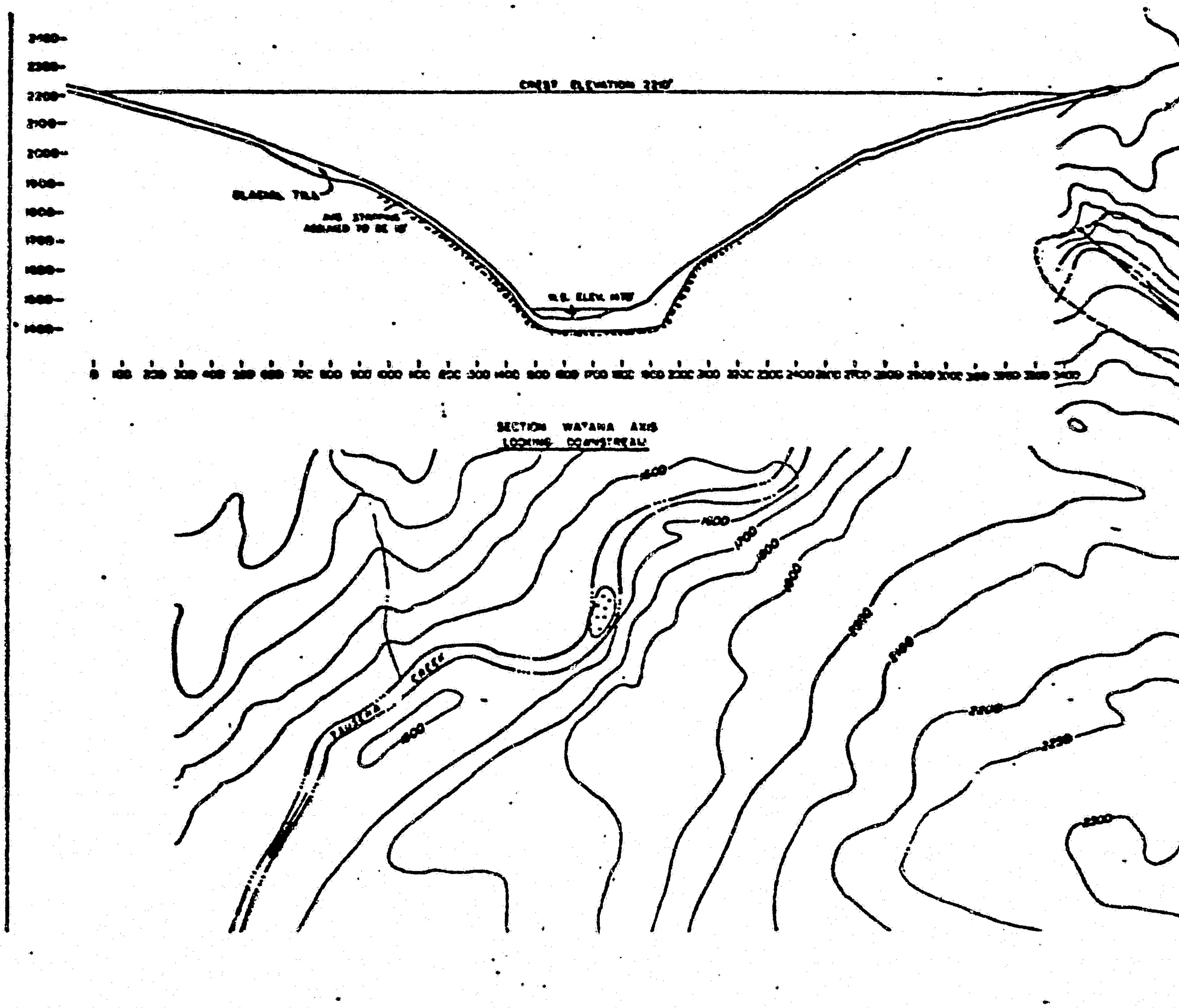
ALLUVIUM - FROZEN TO SOFT

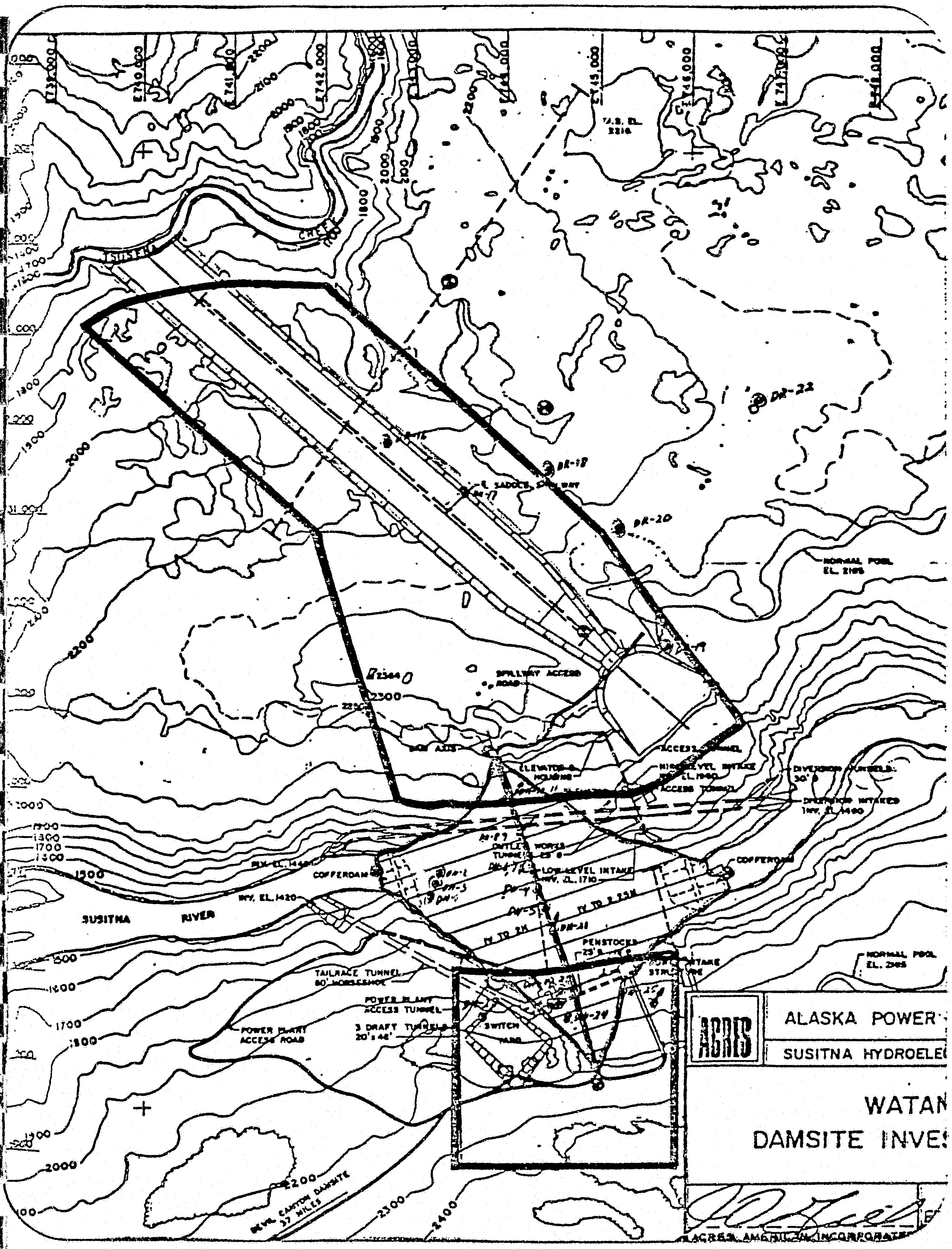
RELICT CHANNEL UP TO 454' DEEP;
FILLED WITH GLACIAL AND ALLUVIAL MTLS.

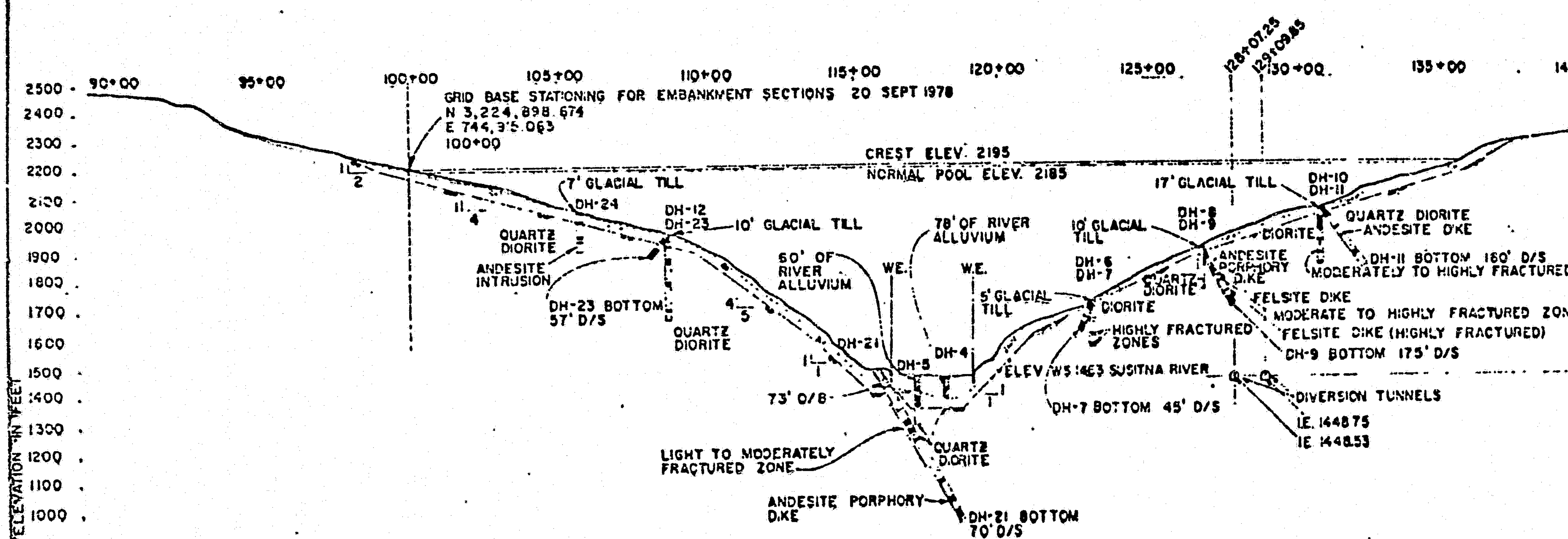
NEAR VERTICAL SHEAR ZONES

THE "FINNS" AND "FINGERBUSTER"


VICINITY MAP
SPILLWAY ACCESS ROAD
DAM AXIS
ACCESS SHAFT
ACCESS TUNNEL
INTAKE STRUCTURE
DIVERSION TUNNEL
COFFER DAM
RIVER
PENSTOCK TUNNELS
23 DIA.
RETAINING WALL
POWER PLANT INTAKE STRUCTURE
ACCESS BRIDGE
POWER PLANT ACCESS TUNNEL
SWITCHYARD
MAIN ACCESS ROAD
2200
2100
2300
SOUTHCENTRAL RAILBELT AREA, ALASKA
INTERIM REPORT NO. 1
UPPER SUSITNA RIVER BASIN
WATANA
SITE PLAN & CENTERLINE PROFILE
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
DECEMBER 1975
FILE NO. 2-SCU-32-04-01 APPENDIX 1 PLATE D-3


CREST ELEVATION 2210'
GLACIAL TILL
SECTION WATANA AXIS
LOOKING DOWNSTREAM


ALASKA POWER
SUSITNA HYDROELE
WATAN
DAMSITE INVES
SUSITNA
RIVER
COFFERDAM
COFFERDAM
TAILRACE TUNNEL
POWER PLANT ACCESS TUNNEL
POWER PLANT ACCESS ROAD
3 DRAFT TUNNELS
SPILLWAY ACCESS ROAD
ACCESS TUNNEL
ELEVATOR & HOUSING
LOW LEVEL INTAKE
PENSTOCKS
NORMAL POOL
DR-22
DR-18
DR-20
CREEK



SECTION A-A

WATANA

CORPS EXPLORATION

ACRES 1980 EXPLORATION

WATANA EMBANKMENT QUANTITIES (COE)

MATERIAL	QUANTITY (CY)	POSSIBLE SOURCE
IMPERVIOUS	7,373,000	BORROW AREA D
SEMI PERVIOUS	6 077 000	BORROW AREA D
FINE FILTER	5 621 000	BORROW AREA E
COARSE FILTER	2,201,000	QUARRY A, B OR BORROW AREA E
ROCKFILL	36 297 000	QUARRY A OR B
RIPRAP	223 000	QUARRY A OR B
TOTAL	57 792 000	

ACRES 1980 EXPLORATION

WATANA EMBANKMENT QUANTITIES (COE)

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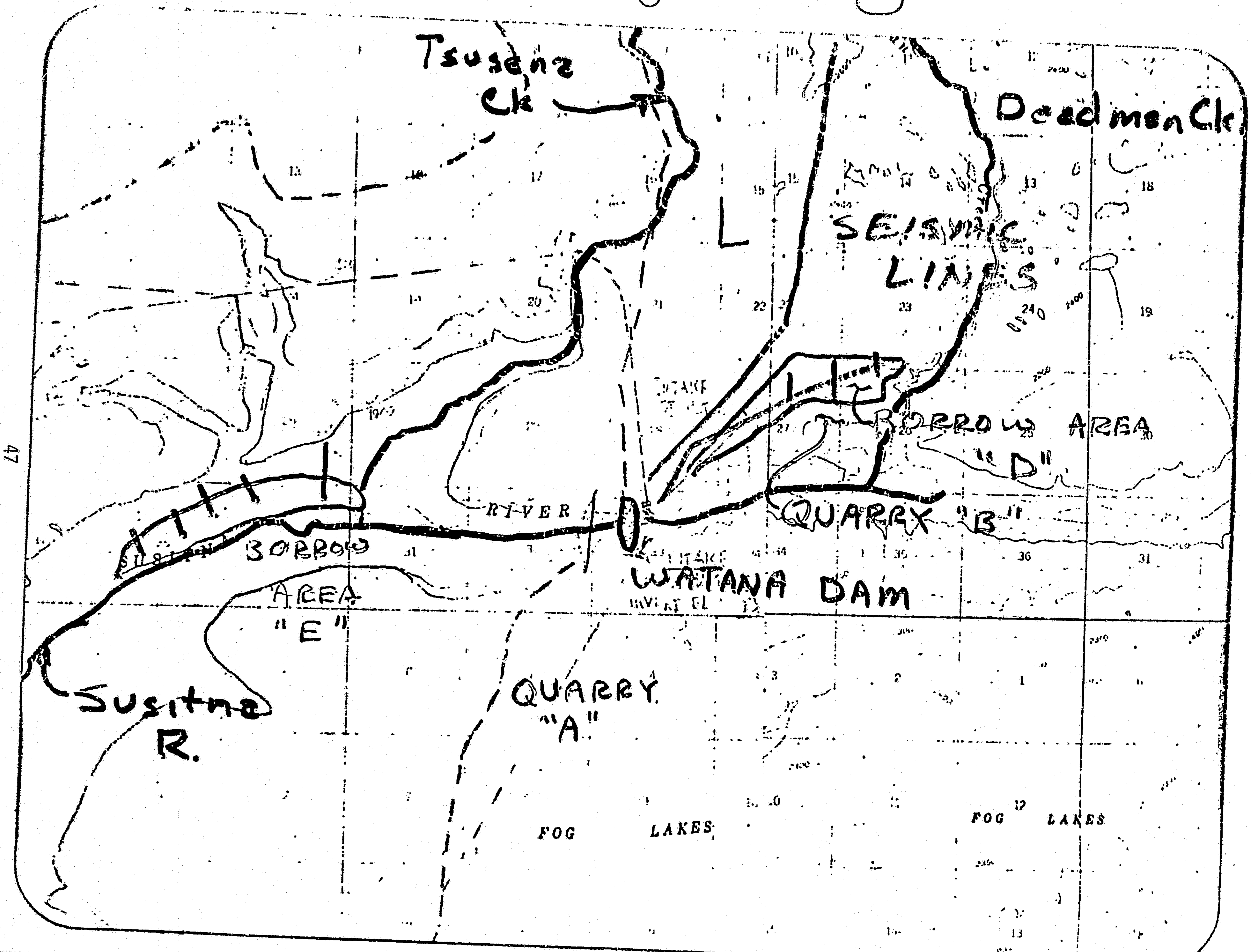
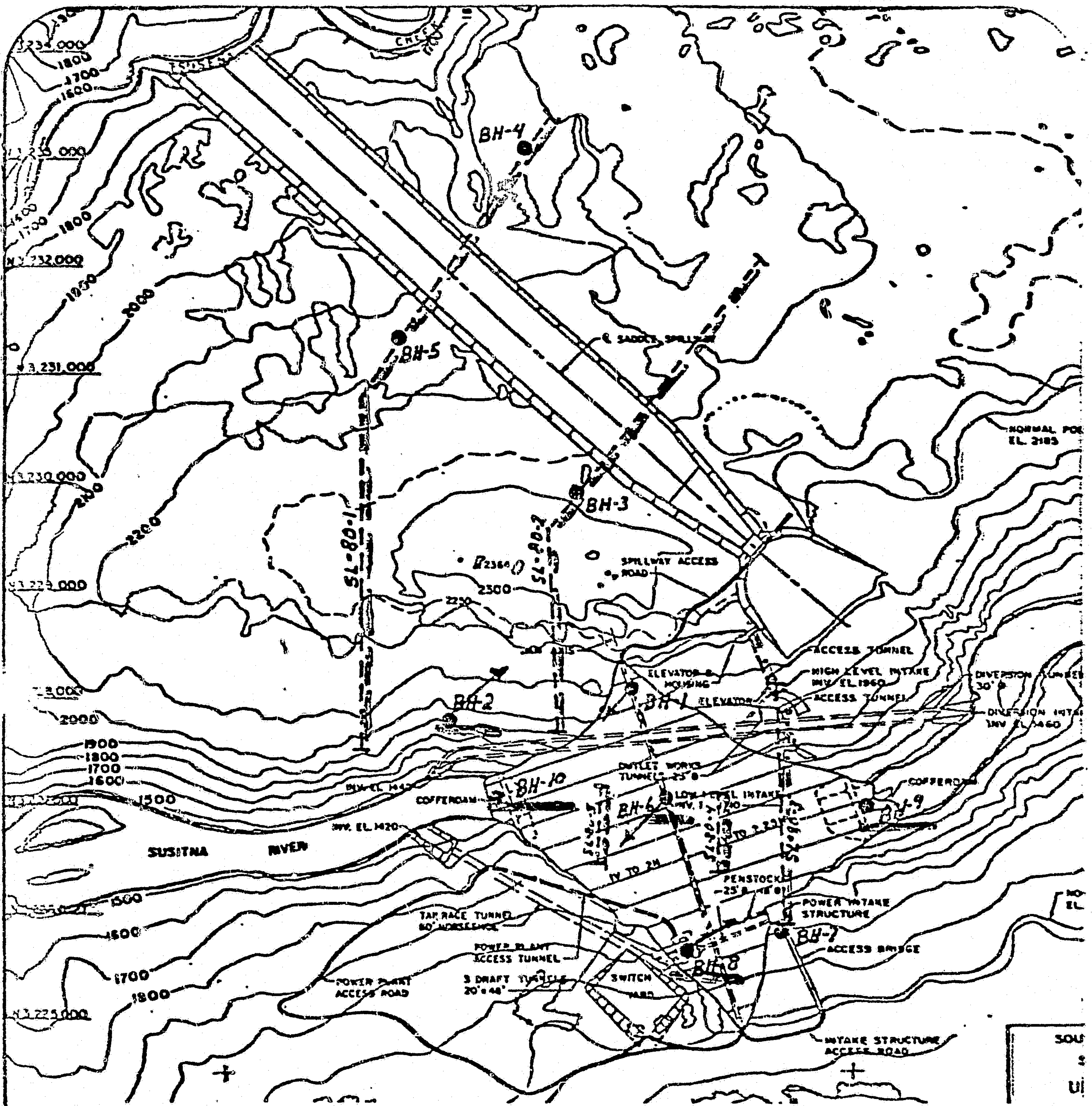
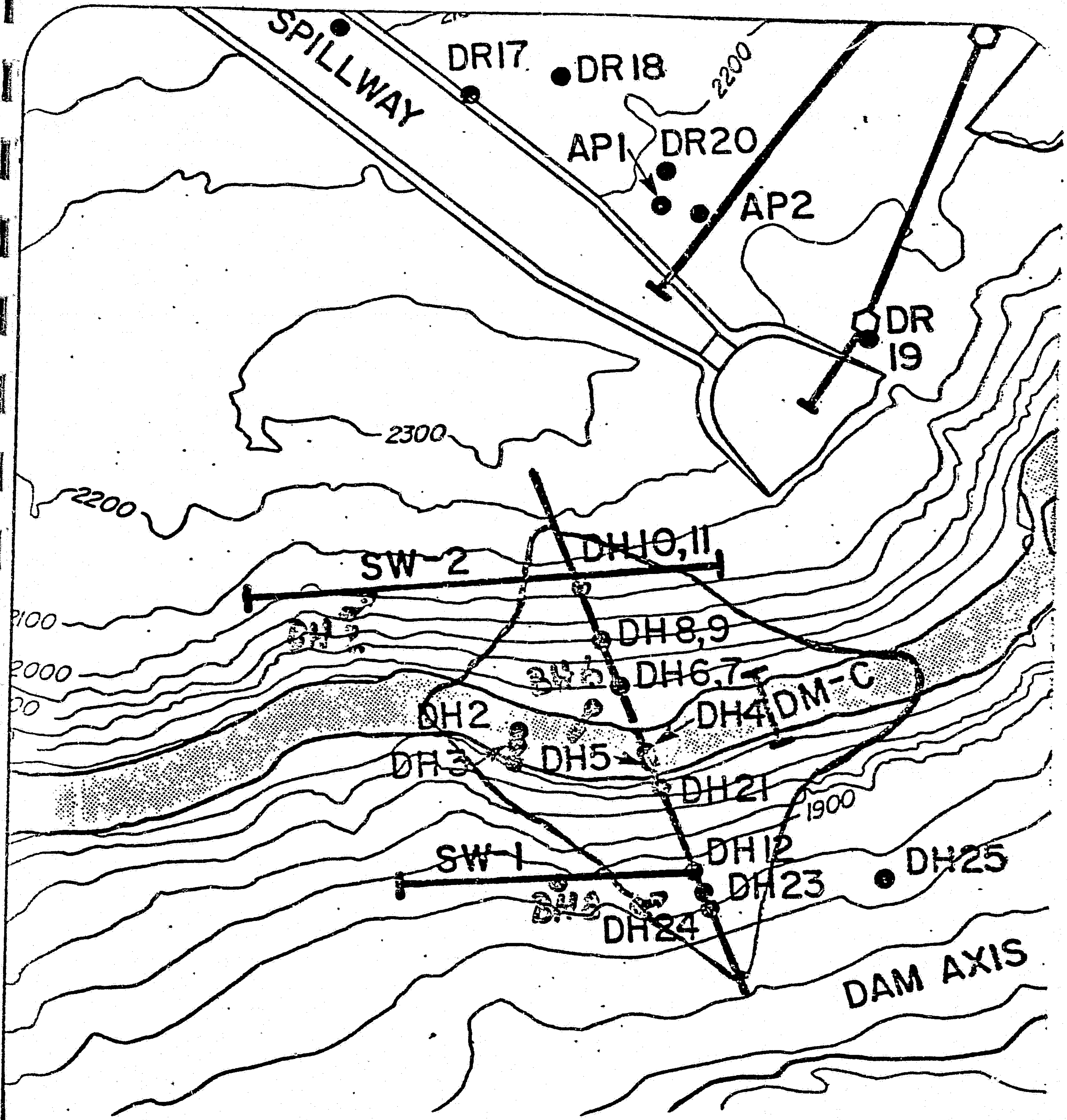

Tsusena Ck
Deadman Ck
SEISMIC LINES
BORROW AREA "D"
QUARRY "B"
RIVER
WATANA DAM
BORROW AREA "E"
Susitna R.
QUARRY "A"
FOG LAKES
FOG LAKES

47



Summer 1980
Winter 1980

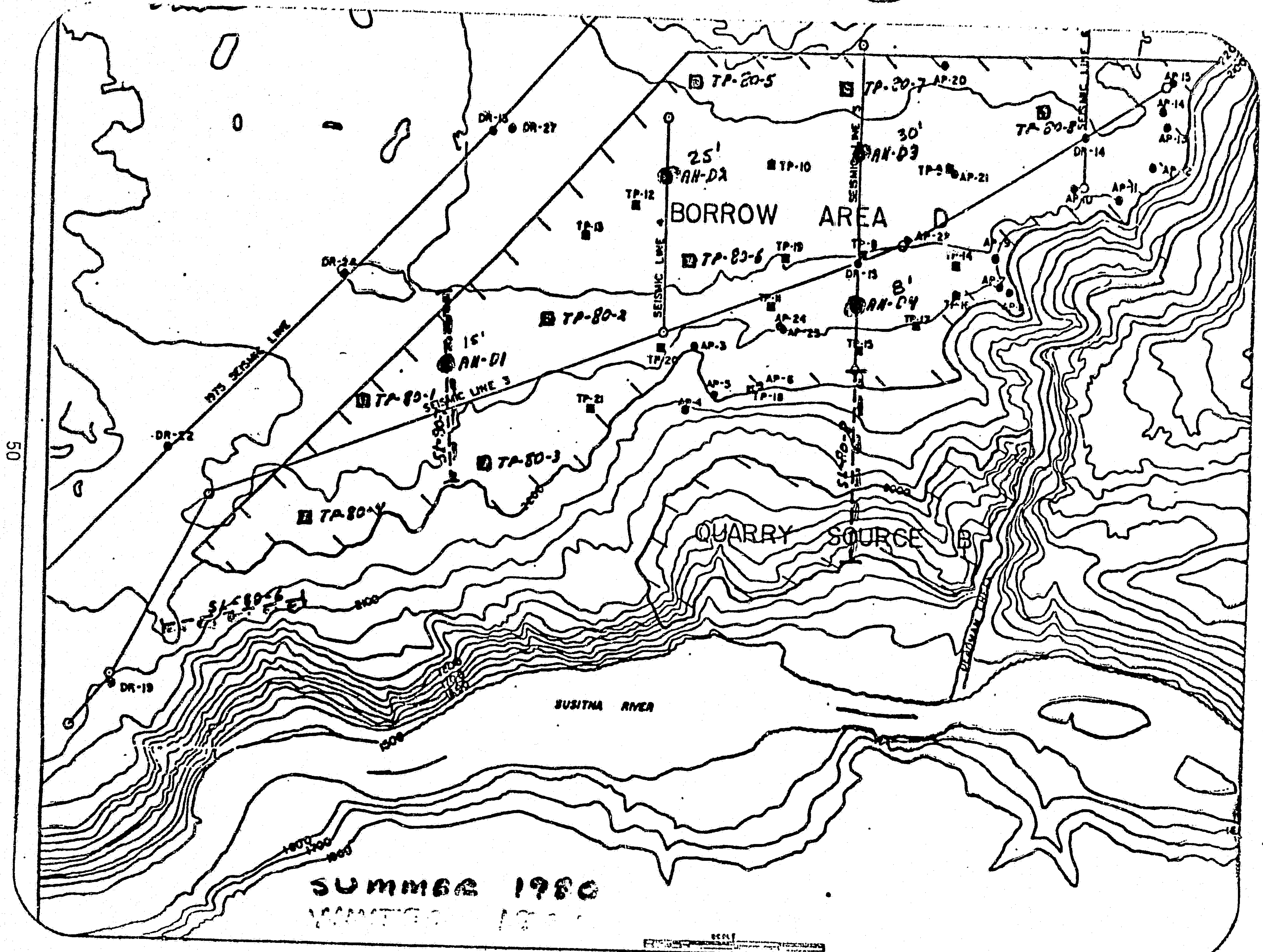


Watana

Summer 1980

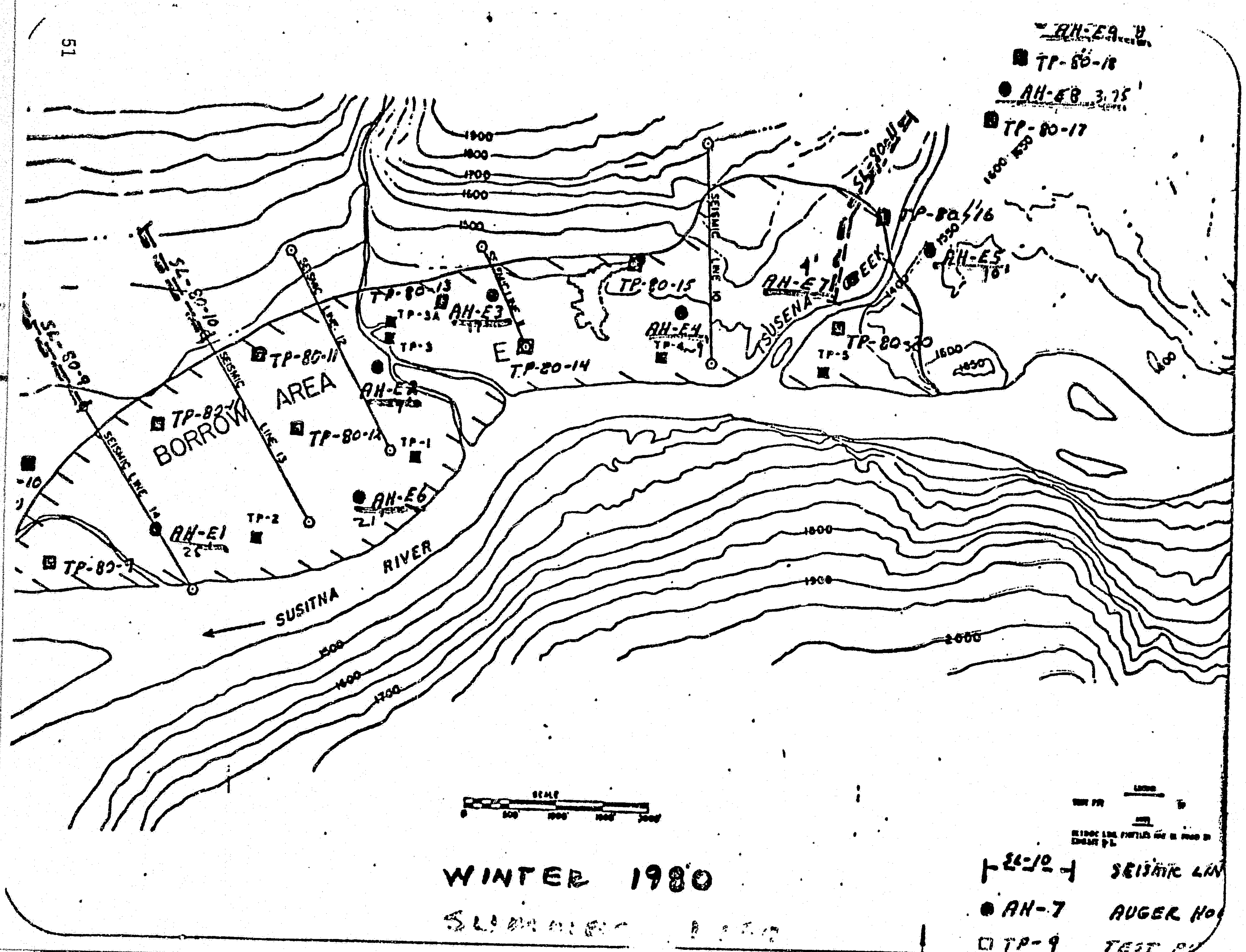
Drilling Program

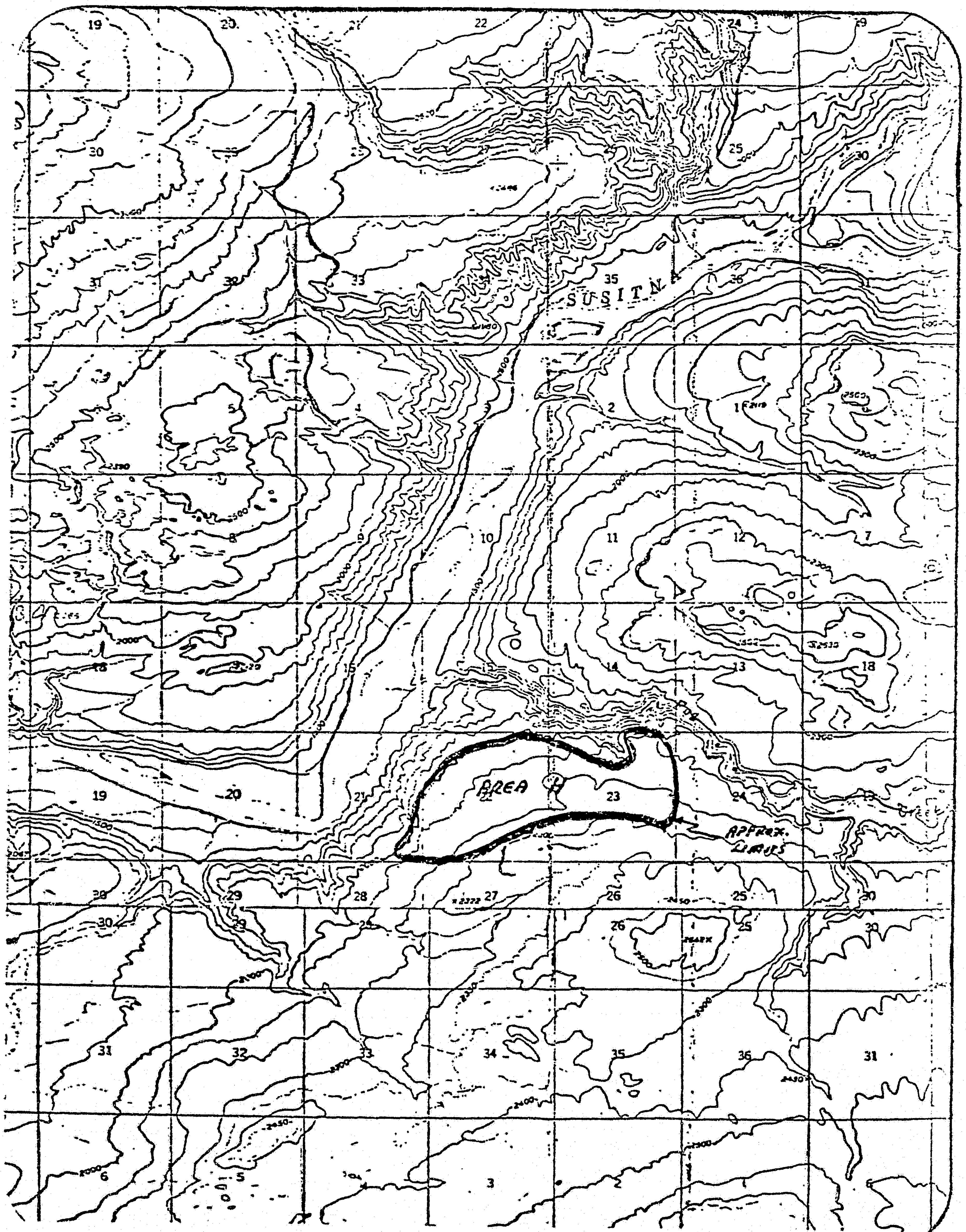
0 0 2 3 4



BORROW AREA D
QUARRY SOURCE B
SUSITNA RIVER
SEISMIC LINE 3
SEISMIC LINE 4
1973 SEISMIC LINE
TP-80-1
TP-80-2
TP-80-3
TP-80-4
TP-80-5
TP-80-6
TP-80-7
TP-80-8
AN-D1
AN-D2
AN-D3
AN-D4
15'
25'
30'
8'
DR-13
DR-14
DR-19
DR-22
DR-27
TP-10
TP-12
TP-13
TP-15
TP-18
TP-19
TP-20
TP-21
AP-3
AP-4
AP-6
AP-10
AP-11
AP-14
AP-15
AP-20
AP-21
AP-24
AP-25
SUMMER 1980

50


51
TP-80-18
AH-E8
TP-80-17
TP-80-16
AH-E5
SEISMIC LINE 10
SEISMIC LINE 11
SEISMIC LINE 12
SEISMIC LINE 13
SEISMIC LINE 14
TP-80-13
TP-3A
TP-3
AH-E3
TP-80-14
TP-80-15
AH-E4
AH-E7
TSUSENA CREEK
TP-80-20
TP-80-11
BORROW AREA E
AH-E2
TP-80-12
TP-1
AH-E6
TP-2
AH-E1
SUSITNA RIVER
1500
1600
1700
1800
1900
2000
SCALE
0
500
1000
WINTER 1980
AH-7
AUGER HO
TP-9
TEST P


SUSITN
AREA H
APPROX. LIMITS

SUMMARY

1980 DRILLING PROGRAM - WATANA

BORING	BH-2	BH-6	BH-8
BEARING ANGLE	N45°E 55°	S45°W 60°	N60°E 60°
	INTO RIGHT ABUTMENT	RIGHT ABUTMENT UNDER RIVER	TOWARDS RIVER — WET MUSKEG AREA
DEPTH	401 FT (328 VERTICAL)	740 FT (640 VERTICAL)	376 FT (326 VERTICAL)
OVERBURDEN	5 FT	8 FT	8 FT
WEATHERING	100 FT ALTERED	25 FT ROCK	0-25 FT ANDESITE 50-55 FT OLD DIORITE SURFACE
BEDROCK	ANDESITE) 120- DIORITE) 150 CONTACT PHASE	GRANODIORITE	ANDESITE) CON- DIORITE) TACT 45-50 FT
WATER LOSS	SHEAR ZONE 90-133 POOR WATER CIRCULATION	ALTERED ZONES: 50-70 FT 150-160 FT 320-335 FT 440-500 FT FRACTURED AND HIGHLY ALTERED ZONES	ALTERED DIORITE ZONE APPROXIMATELY 50-70 FRACTURE ZONES APPROXIMATELY 1 FT, WATER CIRCULATION GOOD IMPLYING TIGHT, NO WATER P TEST DATA AVAILABLE
SPECIAL FEATURES	QUITE HIGHLY FRACTURED	QUITE HIGHLY JOINTED AND CALCITE COATED WITH NEARLY VERTICAL ORIENTATION	

MATERIALS:

ROCKFILL AND AGG. - QUARRY "A" AND/OR "B"

CORE - BORROW AREA "D"

FILTER/AGG. - BORROW AREA "E"

LAB TESTING

BORROW AREA "D" COMPOSITE

GRADATION

TRIAXIAL

COMPACTION

CONSOLIDATION

PERMEABILITY (MINUS 1")

SPECIFIC GRAVITY

BORROW AREA "E"

GRADATION

PETROGRAPHIC ON SAND

PROBLEMS:

BURIED CHANNEL - PERVIOUS ZONES

PERMAFROST - DISCONTINUOUS, DEEP IN LEFT ABUT.; WITHIN 1° OF FREEZING

ARTESIAN PRESSURES

SUSITNA FAULT?

TALKEENTA THRUST THRU RESERVOIR

UNDERGROUND STRUCTURES

ROCK CONDITIONS - FAVORABLE

SOME SUPPORTS REQUIRED

SUMMARY

ADDITIONAL EXPLORATION

GENERAL - ROCK STRUCTURE

- RIVER CHANNEL
- FOG LAKE FAULTING, LEAKAGE

RIGHT ABUT.- SLIDE BLOCK (?)

- OVERBURDEN THICKNESS

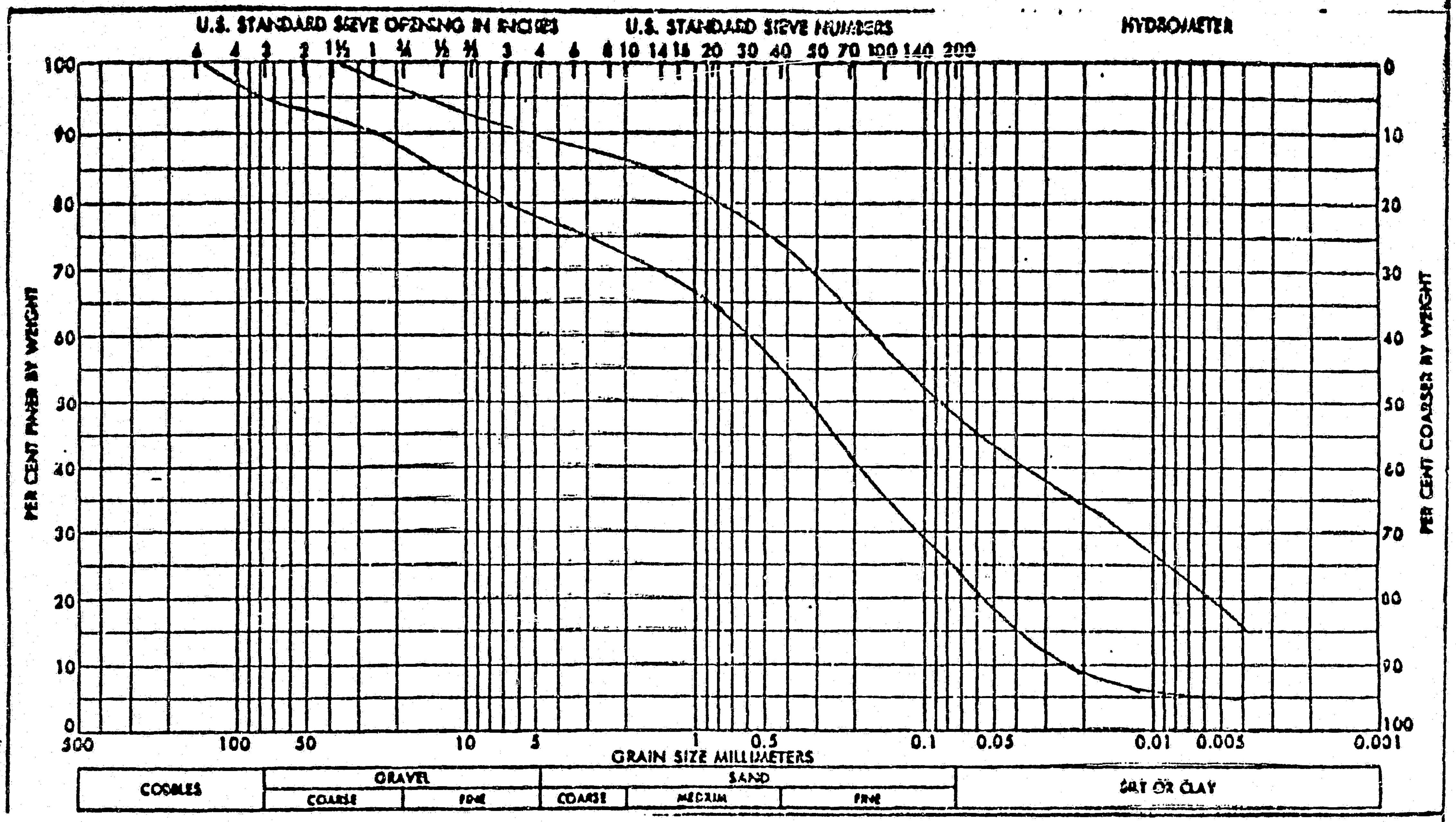
LEFT ABUT. - PERMAFROST

BORROW AREAS - LAKE DEPOSITS

SPILLWAY - BURIED STREAM CHANNEL

DOWNSTREAM - SUSITNA FAULT?

Chart D-2



Envelope of gradation curves derived from tests of samples from test pits 8 thru 19, Borrow area D.

DEVIL CANYON

STRUCTURE: 635' HIGH CONCRETE GRAVITY-ARCH DAM

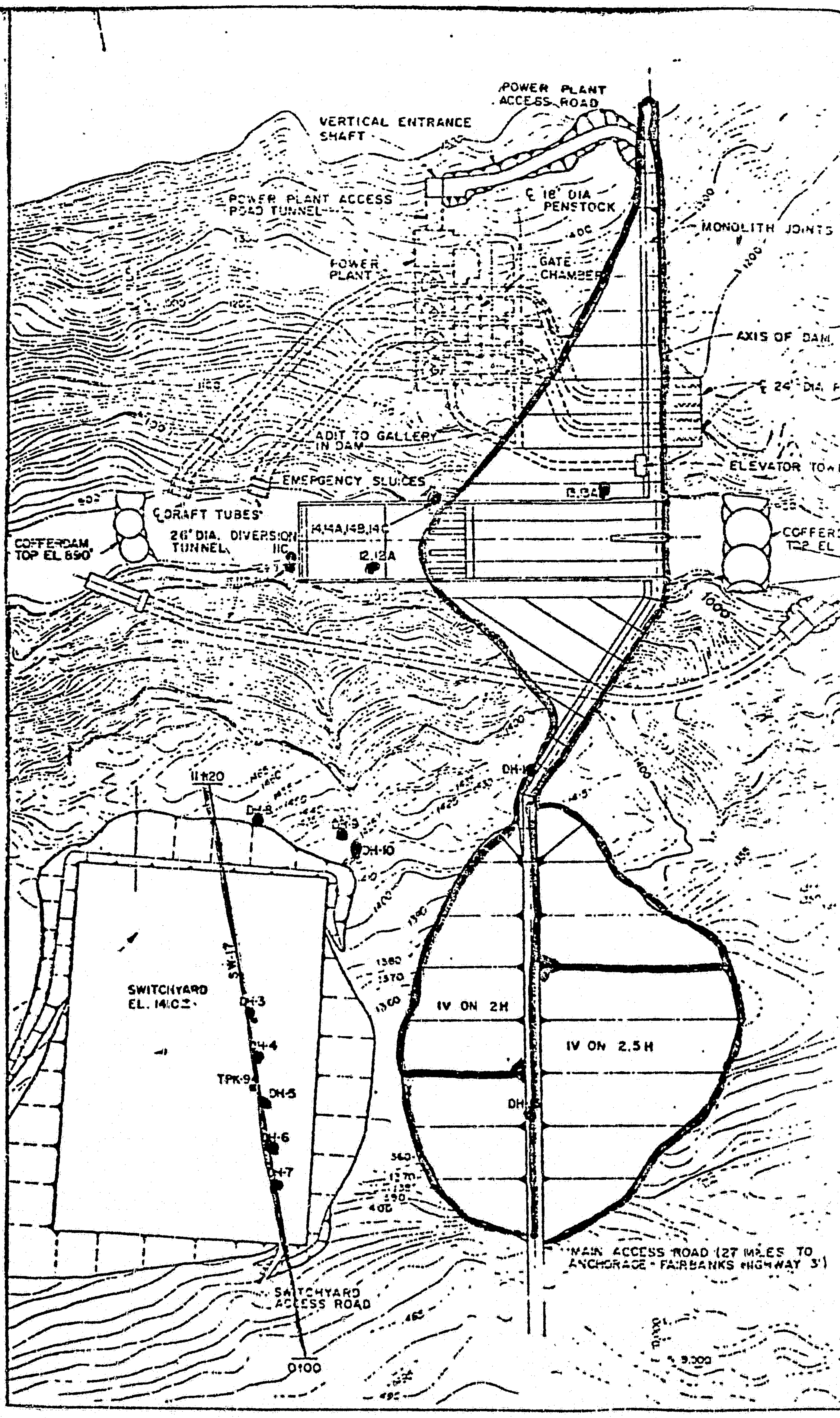
INVESTIGATION:

- USBR 1957-'58; COE 1978
  - 22 BOREHOLES 20'-150' DEEP
  - 19 TRENCHES AND TEST PITS
- 3300 LF SEISMIC
- LAB TESTS
  - PETROGRAPHIC
  - ELASTIC PROPERTIES
  - UNCONFINED COMPRESSIVE STRENGTH

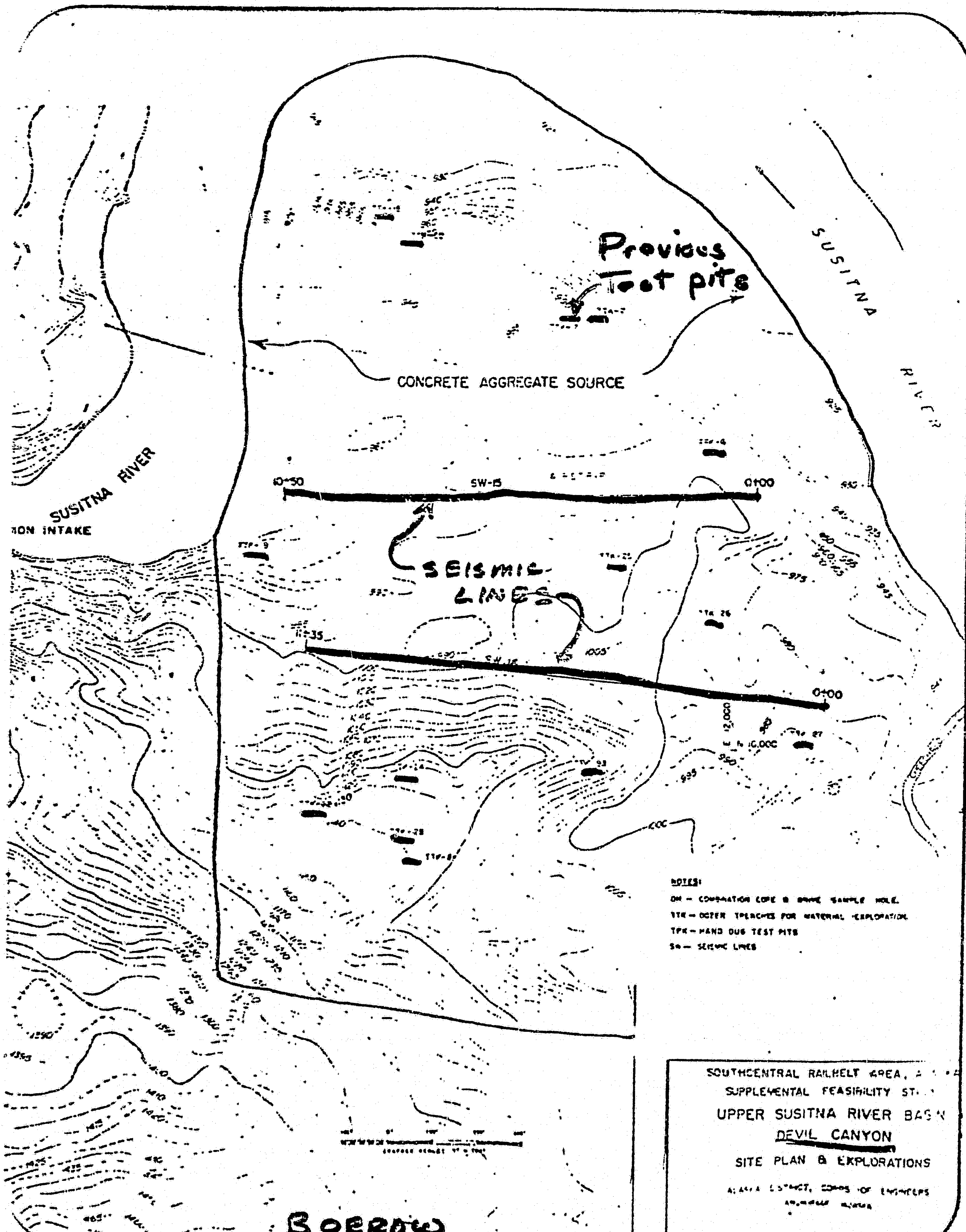
SIGNIFICANT FEATURES:

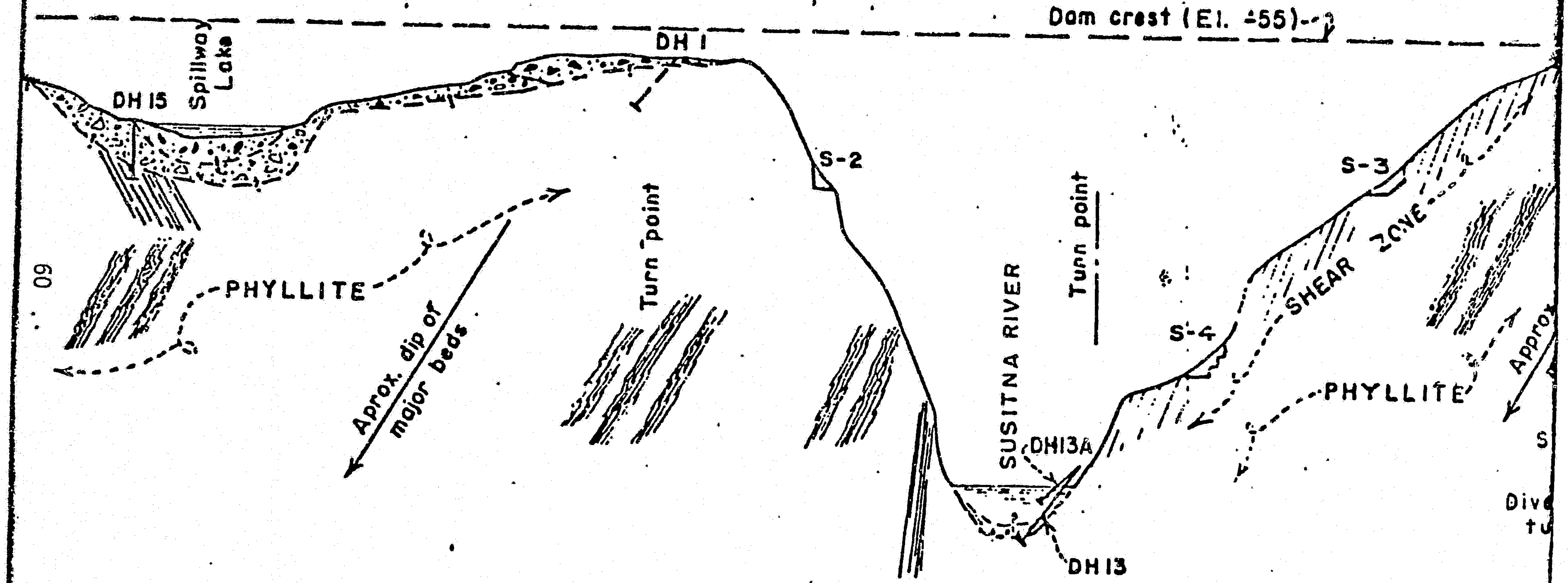
- 35' ± ALLUVIUM OVER BEDROCK
- SHEAR ZONES AND FAULTS - BOTH ABUTS.
- 3 JOINT SETS (PROM $N25^{O}W$)
- BEDDING DIPS SOUTH
- 35'-50' WEATHERED ROCK
- 8.5 AT 40 MI. OR 7.0 AT 10 MI. EARTHQUAKE

DEVIL CANYON - CORPS EXPLORATION



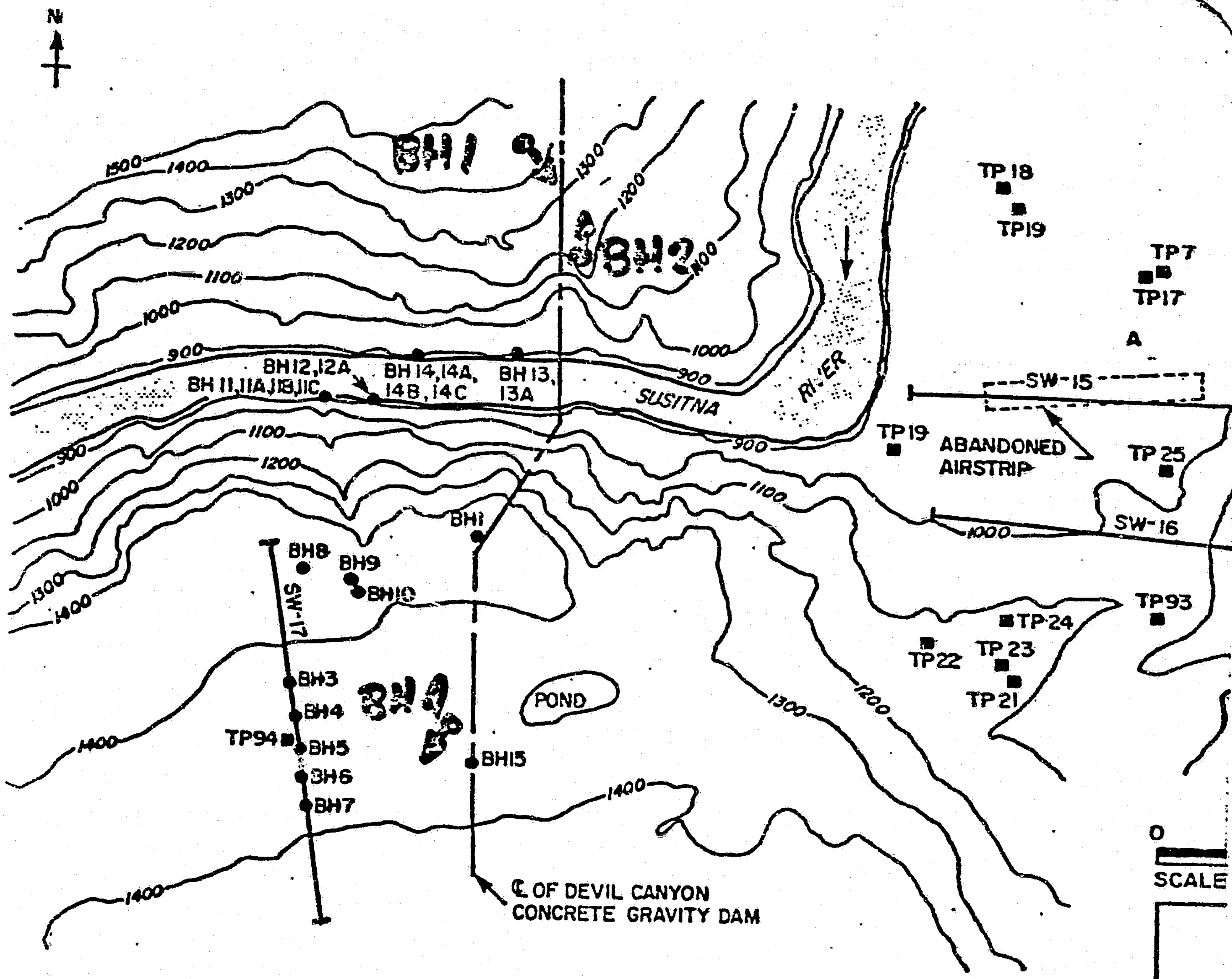
DEVIL CANYON DAM


Previous Test pits
SUSITNA RIVER
CONCRETE AGGREGATE SOURCE
SUSITNA RIVER
SW-15
0+00
SEISMIC LINES
0+00
SOUTHCENTRAL RAILBELT AREA,
SUPPLEMENTAL FEASIBILITY ST
UPPER SUSITNA RIVER BAS
DEVIL CANYON
SITE PLAN & EXPLORATIONS
BORROW



Dam crest (El. 455)
DH 1
DH 15
Spillway Lake
S-2
S-3
S-4
Turn point
Turn point
PHYLLITE
Aprox. dip of major beds
SUSITNA RIVER
SHEAR ZONE
PHYLLITE
DH13A
DH 13

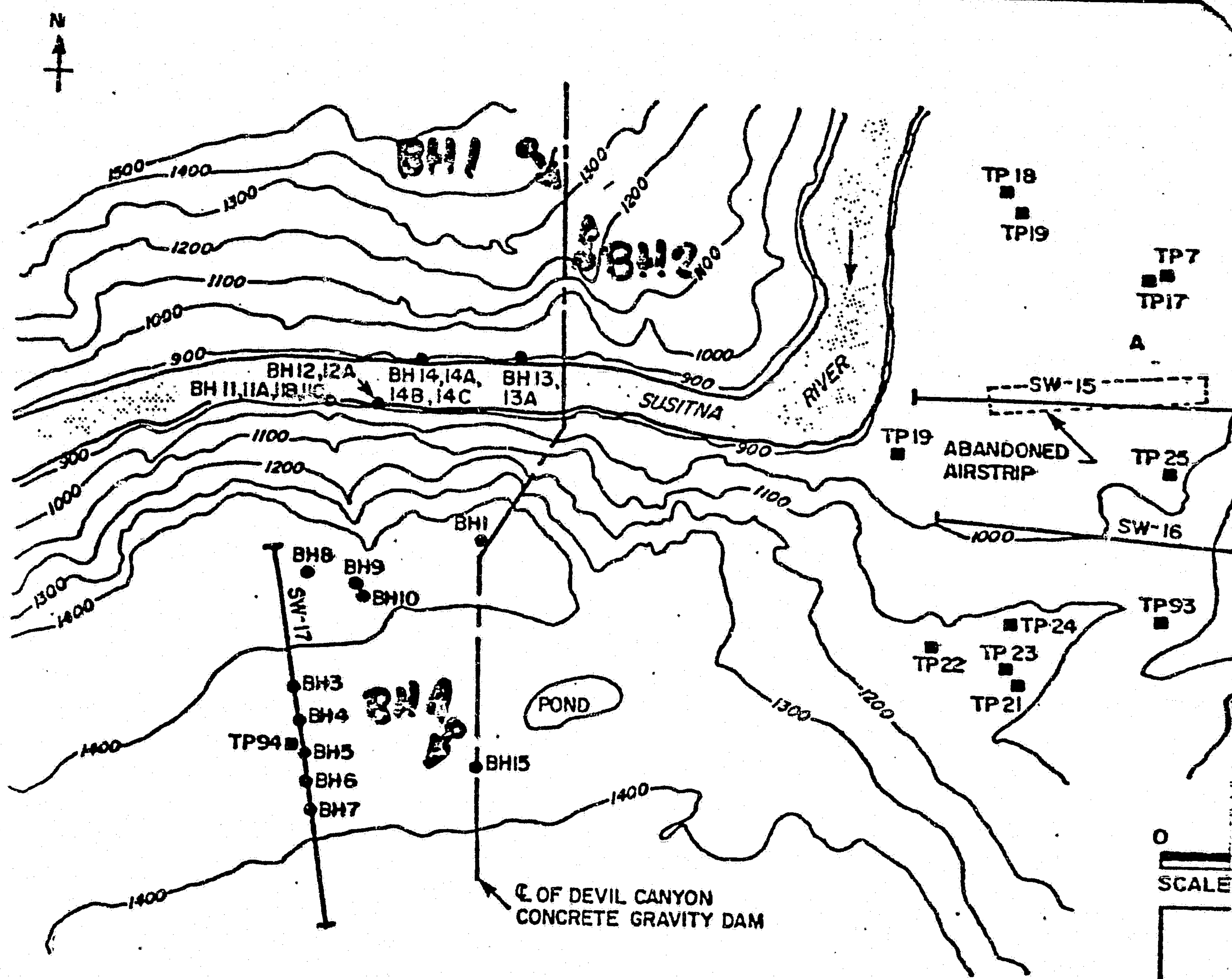
SECTION C-C



REF. U.S. ARMY CORPS OF ENGINEERS DEVIL CANYON
SITE PLAN AND LOCATION

Devil Canyon

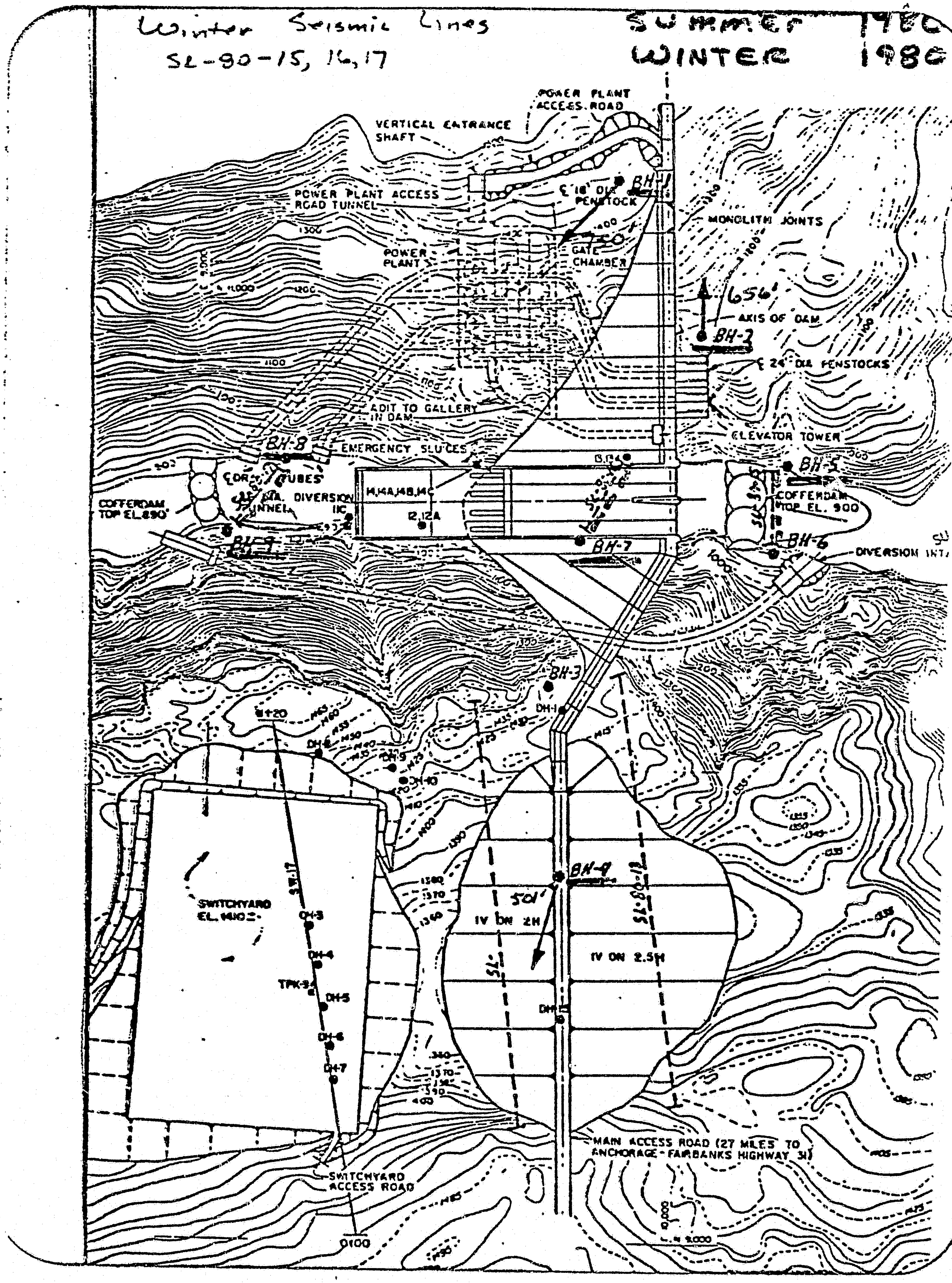
Drilling Program
Summer 1980
(ACRES)

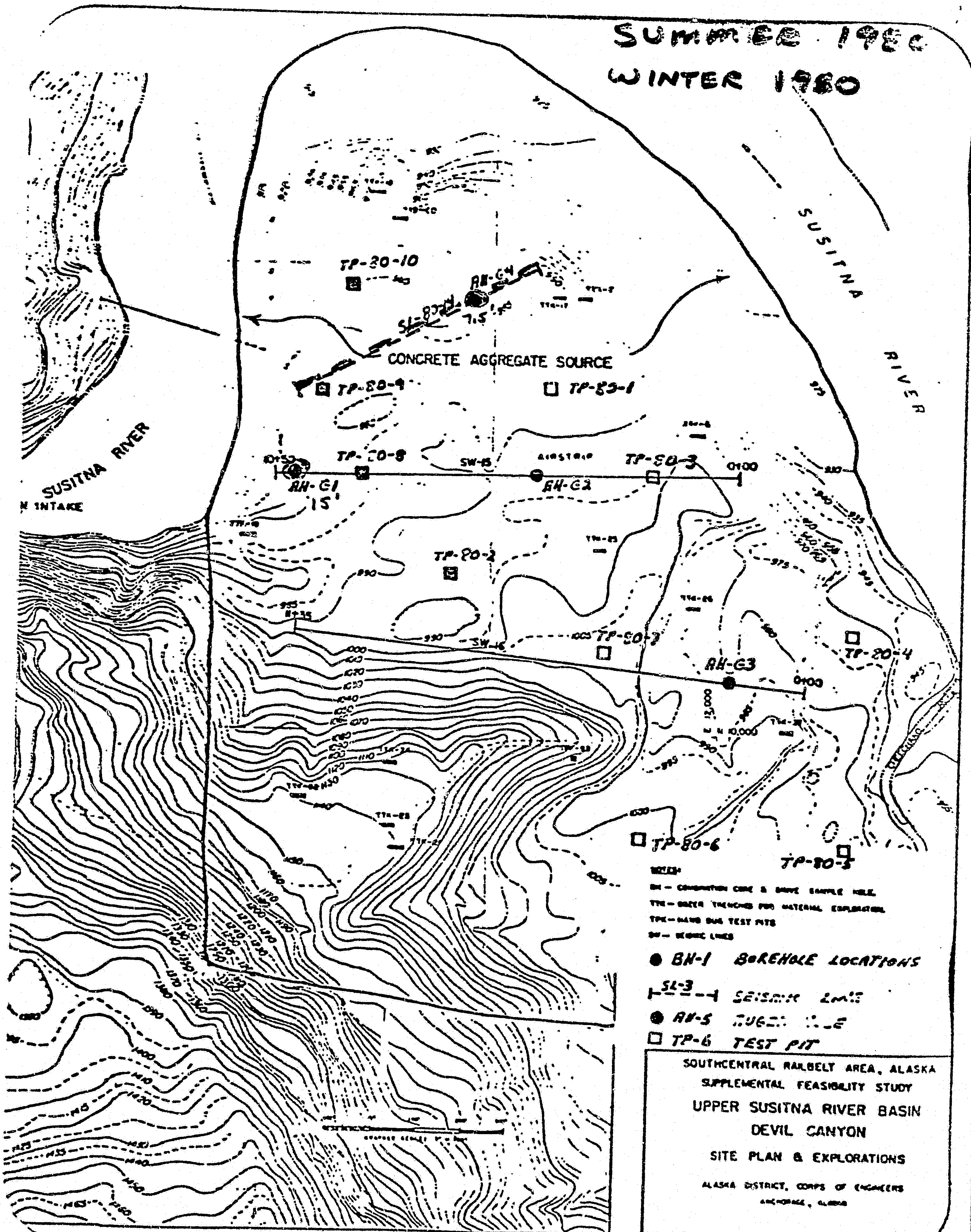


REF. U.S. ARMY CORPS OF ENGINEERS DEVIL CANYON SITE PLAN AND LOCATION

Devil Canyon

Drilling Program
Summer 1980
(ACRES)


Winter Seismic Lines
SL-80-15, 16, 17
SUMMER 1980
WINTER 1980
POWER PLANT ACCESS ROAD
VERTICAL ENTRANCE SHAFT
POWER PLANT ACCESS ROAD TUNNEL
POWER PLANT
GATE CHAMBER
MONOLITH JOINTS
AXIS OF DAM
656'
BH-1
BH-2
BH-3
BH-4
BH-5
BH-6
BH-7
BH-8
BH-9
ADIT TO GALLERY IN DAM
EMERGENCY SLUICES
ELEVATOR TOWER
COFFERDAM TOP EL. 890
COFFERDAM TOP EL. 900
DIVERSION TUNNEL
DIVERSION INT.
SWITCHYARD EL. 1410
SWITCHYARD ACCESS ROAD
MAIN ACCESS ROAD (27 MILES TO ANCHORAGE - FAIRBANKS HIGHWAY 3)
IV ON 2H
IV ON 2.5H
501'
SL-80-17
SL-80-15
SL-80-16



REVISION 1 8/13/80

FIGURE 2

SUMMARY

1980 DRILLING PROGRAM - DEVIL CANYON

	BH-1	BH-2	BH-4
BEARING ANGLE	S23°E 67°	N 60°	S15°W 60°
	RIGHT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT
DEPTH	750 (690 VERTICAL)	656 (563 VERTICAL)	500 (434 VERTICAL)
OVERBURDEN	12 FT GRAVEL	SHALLOW 2 FT	12 FT
WEATHERING	25 FT	20 FT	15 FT
BEDROCK	PHYLLITE-ARGILLITE, BELOW 385 (355) CONGLOMERATE	PHYLLITE } GRANODIORITE } AT 650 FT	METASEDIMENTARY: ARGILLITE TO GREYWACKE
WATER LOSS	55- 85) 100-130) 250-265) 280-295) FRACTURE 460-490) ZONES 595-615) WITH HIGH 655-670) WATER TAKE	REHEALED FRACTURES AND FILLED JOINTS THROUGHOUT, HOWEVER WATER CURCULATION GOOD AND LOW PERMEABILITY TEST RESULTS	175-185 INTERMITTENT SHEAR ZONES HARD PHYLLITE FAIRLY GOOD WATER CIRCULATION THROUGHOUT
SPECIAL FEATURES	CONGLOMERATE AND POSSIBLE FLOW PODS AREAS - EXTENT NOT KNOWN		DRILLED SUBPARALLEL TO THE BEDDING - NO MAJOR SHEAR ZONES ENCOUNTERED

MATERIAL SOURCES:

CONCRETE AGG. AND EMBANKMENT

MTLS. READILY AVAILABLE 1000' U/S

MARGINAL FREEZE/THAW RESISTANCE

IMPERVIOUS - PROCESSED

PROBLEMS:

LEFT ABUT.

SOUTHERLY DIPPING BEDS REQUIRED EXTENSIVE DENTAL WORK

ROCK SUPPORT REQUIRED

THRUST BLOCK - ANCHOR (DEEP)

RIGHT ABUT.

BEDDING DIPS APPROXIMATELY 60° SE (UNFAVORABLE)

SHEAR ZONES - PARALLEL TO THE RIVER

SADDLE DAM

E-W TRENDING BURIED CHANNEL

90' OVERBURDEN

PERMAFROST

DEEP CUTOFF

POSSIBLE SHEAR ZONE

UNDERGROUND STRUCTURES:

ROCK IMPROVES WITH DEPTH

DIVERSION TUNNEL LINING REQUIRED

SUMMARY:

EXTENSIVE GROUTING

DETAILED FOUNDATION AND ABUTMENT EXPLORATION REQUIRED

PILOT TUNNELS RECOMMENDED

AMPLE AGGREGATE AVAILABLE, PROCESSING REQUIRED

VEE CANYON

STRUCTURE: 470' HIGH EARTH DAM

INVESTIGATION:

1960-'62 USBR

13 BOREHOLES, 1646LF, 180' MAX.

16 DOZER TRENCHES

SIGNIFICANT FEATURES:

VERY STEEP CANYON (800')

125' OVERBURDEN

POOR QUALITY ROCK

SADDLE DAM

400' OVERBURDEN

PERMAFROST TO 60'

ROCKLINE BELOW EXISTING RIVER V.C.

MATERIAL SOURCES:

NOT DELINEATED

GLACIO - FLUVIAL FOR EMBANKMENT

RIVER CHANNEL FOR AGG.

PROBLEMS:

ROCK SLOPE STABILITY - EXCAVATION

LEFT ABUT - HEAVY TALUS

PERMAFROST

POOR ROCK QUALITY - HEAVY TUNNEL SUPPORTS

400' OVERBURDEN UNDER SADDLE DAM

SUMMARY:

ADDITIONAL EXPLORATION REQUIRED.

SITE UNSUITABLE FOR CONCRETE DAM

DENALI

STRUCTURE: 235' HIGH EARTH DAM

INVESTIGATION:

1958-'59 USBR

5 BOREHOLES APPROXIMATELY 200' DEEP

14 TEST PITS

LAB TESTS

CONSOLIDATION

GRADATION

INDEX TESTS

PETROGRAPHIC

SIGNIFICANT FEATURES:

RELATIVELY LOOSE SANDS AND GRAVELS OF UNKNOWN THICKNESS

PERVIOUS STRATA - RIGHT ABUTMENT

100' ± PERMAFROST - BOTH ABUTS.

COMPRESSIBLE STRATA - BOTH ABUTS.

MAXIMUM EARTHQUAKE MAGNITUDE

8.5 AT 40 MILES

MATERIAL SOURCES:

PERVIOUS - ADEQUATE SUPPLY, 0.5 TO 5 MILE HAUL

IMPERVIOUS - PROCESS FROM TILL

PROBLEMS:

DEEP PERMAFROST

COMPRESSIBLE FOUNDATION MTLS.

EXCESSIVE FOUNDATION TREATMENT

PERVIOUS STRATA - RIGHT ABUT.

DEEP CUTOFF

LIQUIFACTION

SUMMARY:

MOVE SITE 8000' D/S

EXTENSIVE FIELD INVESTIGATIONS REQUIRED

SCOPE

6.01	REVIEW PREVIOUS STUDIES
6.02	TUNNEL ALTERNATIVES
6.03/6.06	ALTERNATIVE DAM SITES
6.04	EVALUATE ARCH DAM
6.05	REPORTING
6.08	ALTERNATIVE DAMS AT DEVILS CANYON

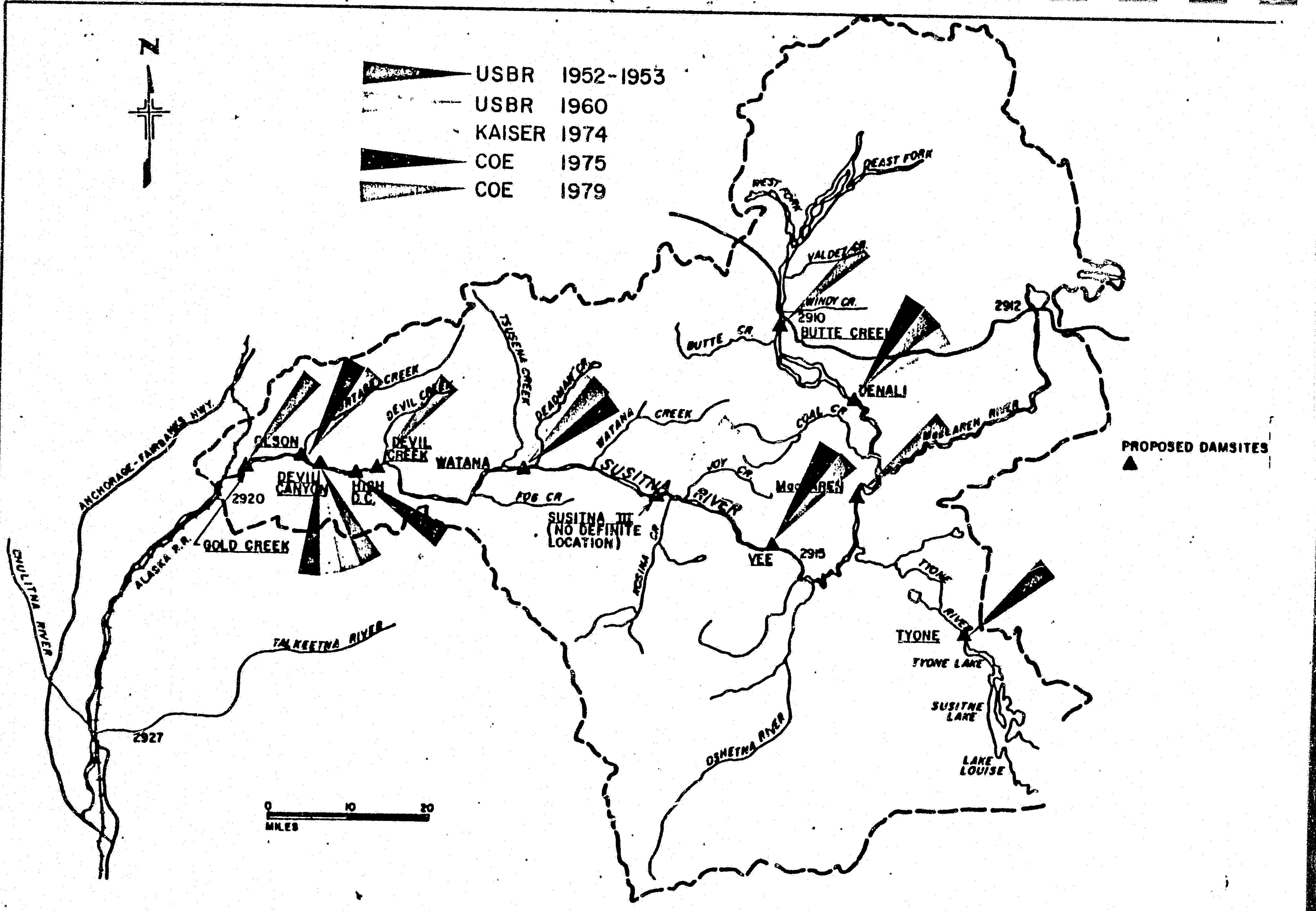


FIGURE I - LOCATION OF DAMSITES PROPOSED BY OTHERS

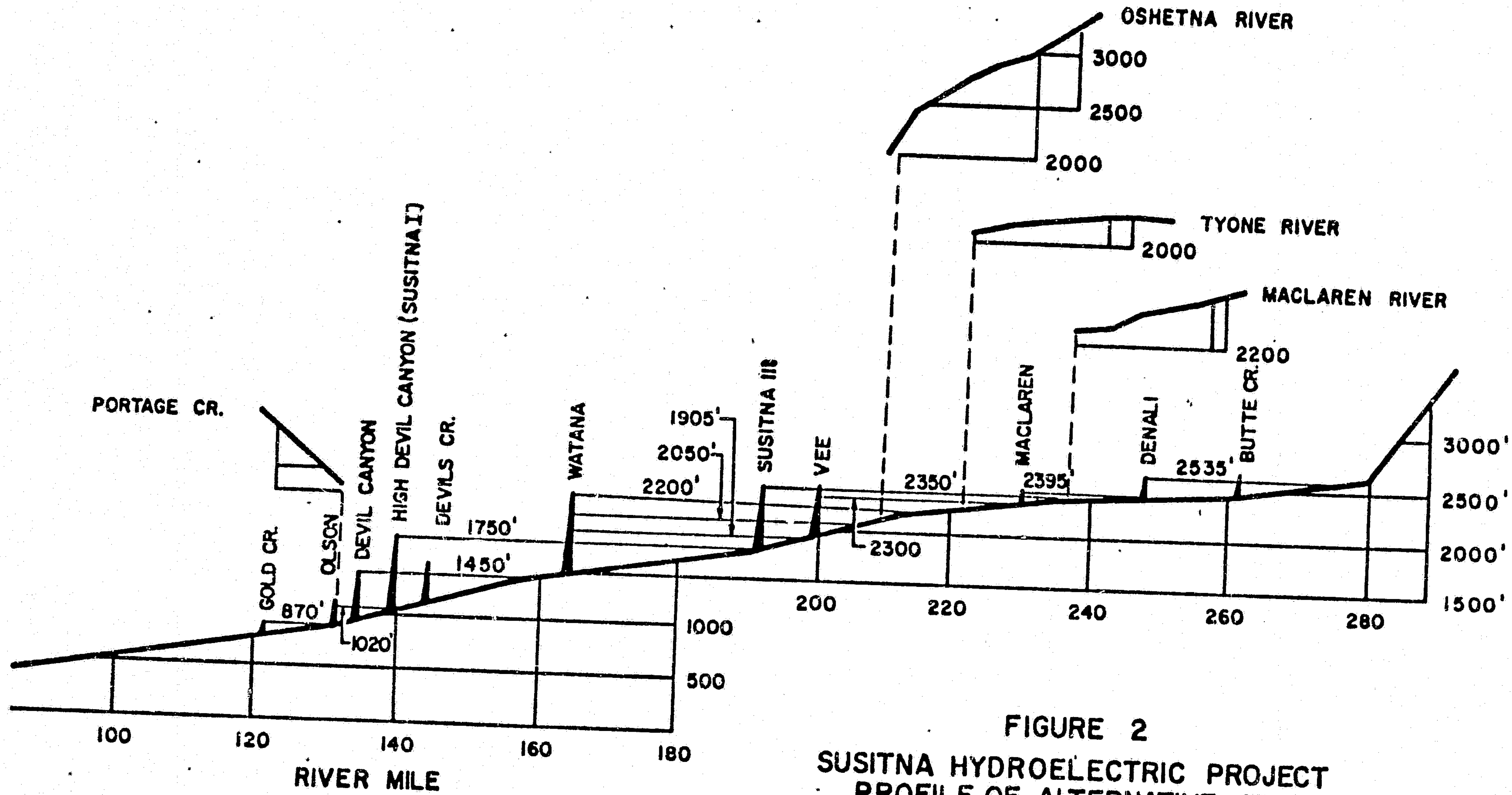
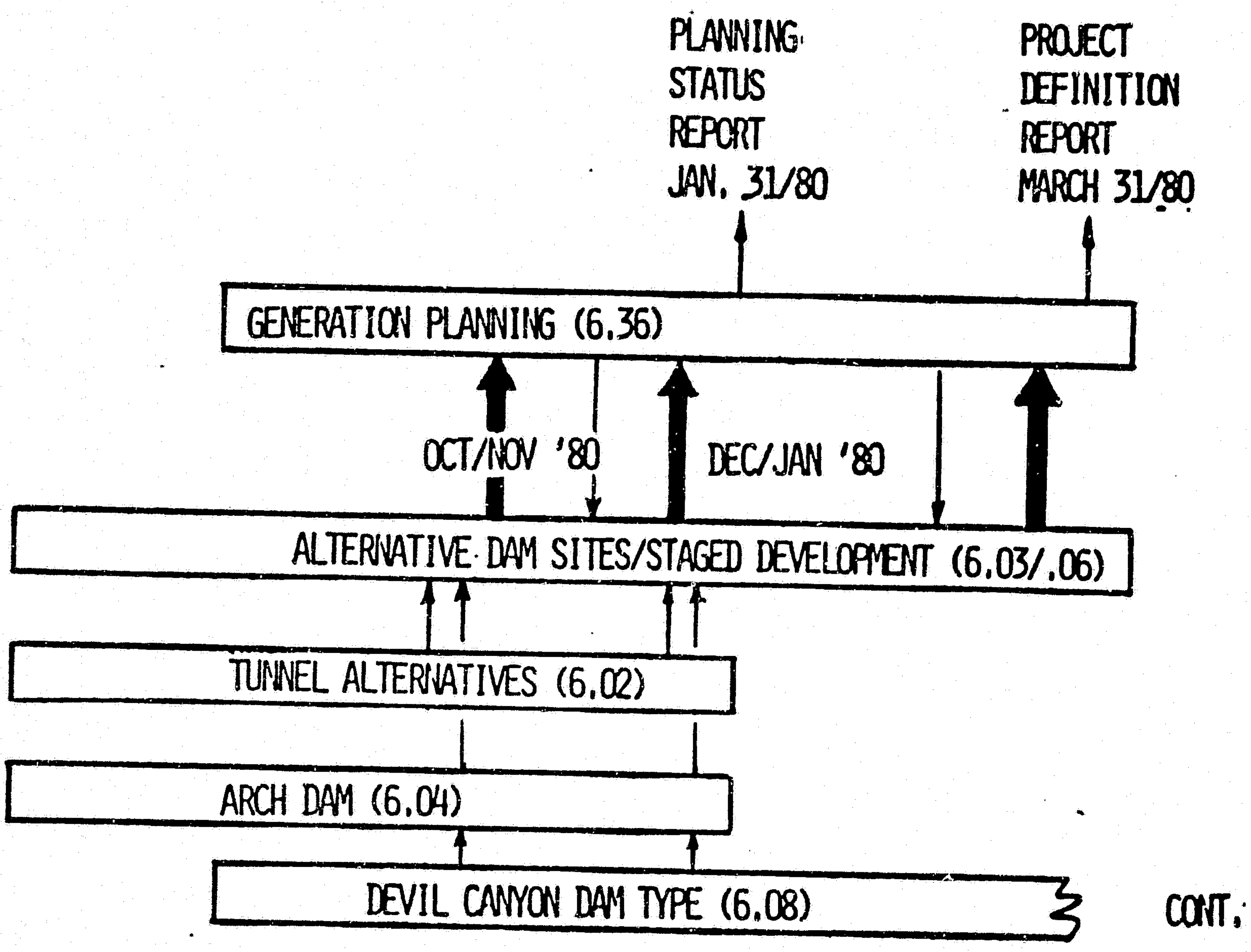


FIGURE 2
SUSITNA HYDROELECTRIC PROJECT
PROFILE OF ALTERNATIVE SITES

PROJECT DEFINITION STUDIES



TUNNEL ALTERNATIVES (6.02)

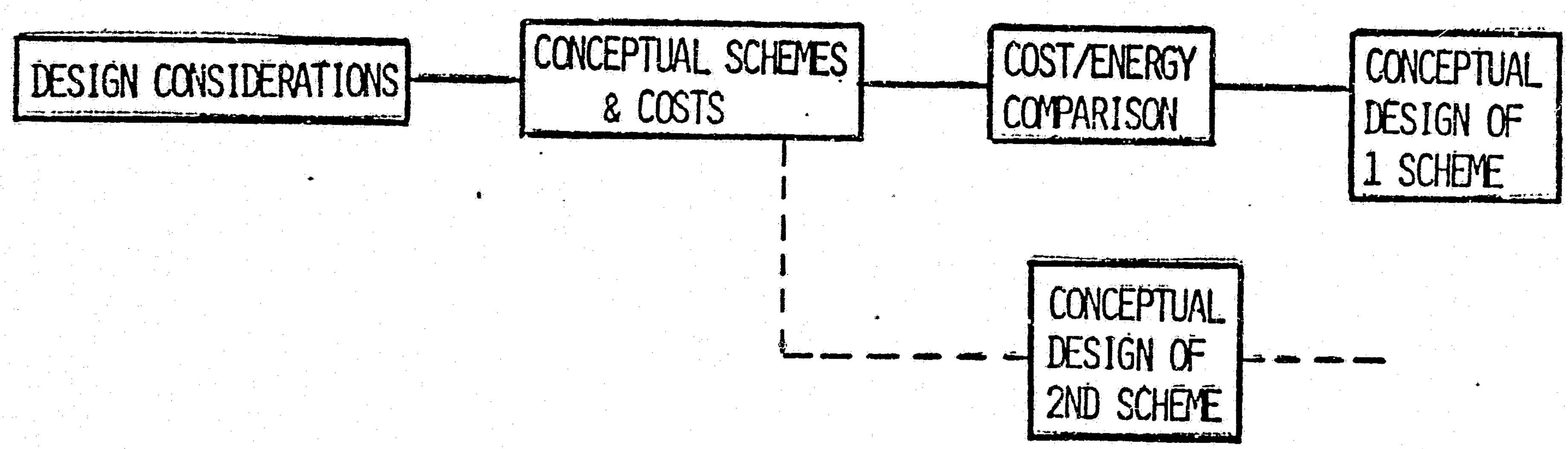
OBJECTIVES

INVESTIGATE FEASIBILITY OF TUNNEL VS. US CORPS SCHEME.

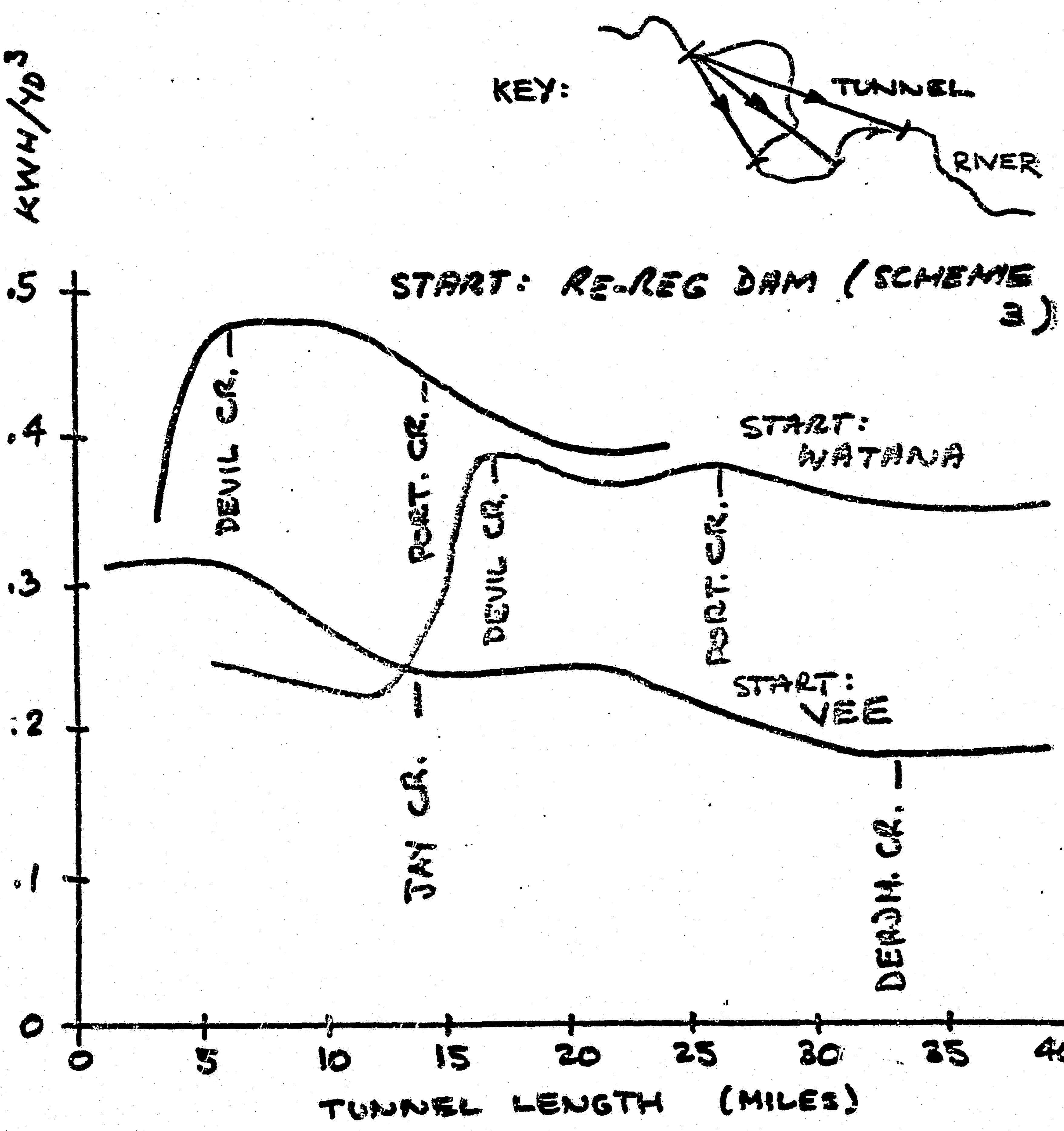
ADD: SMALLER CAPACITY TUNNEL SCHEME

GENERAL APPROACH

TUNNEL ALTERNATIVES (6.02)



TUNNEL POTENTIAL



TUNNEL ALTERNATIVE STUDY METHOD

1. DEVELOP GEOLOGY
   a. REPORTS
   b. MAPS
   c. EXPLORATION
2. SELECT POSSIBLE TUNNEL ALIGNMENTS BASED ON GEOLOGY AND TOPO
3. PLOT SECTIONS ALONG TUNNEL ALIGNMENT
4. SELECT TUNNEL GRADE
5. SELECT TUNNEL SIZE BASED ON ECONOMICS
6. LOCATE ACCESS ADITS (AT LEAST 2)
7. SELECT SUITABLE TUNNELING METHODS
8. ESTIMATE TUNNELING COST
9. MAKE ADJUSTMENTS IN: (AS MORE INFORMATION BECOMES AVAILABLE)
   a. ALIGNMENT
   b. GRADE
   c. TUNNELING METHODS
   d. COST

HISTORICAL PRECEDENCE - TUNNELING

A. TUNNELING FILE (ENR, TUNNELS & TUNNELING, CE, ETC.)
   1. WORLD WIDE
   2. METHODS - TECHNIQUES
   3. PRODUCTION RATES
   4. COSTS

B. OTHER JOBS
   1. PEPCO - UPH
   2. TARP - CHICAGO
   3. METRO - WASHINGTON
   4. MARTA - ATLANTA
   5. KEMANO - B.C.
   6. SWEDISH OIL STORAGE
   7. CHURCHILL FALLS - LABRADOR
   8. BATH CO. - VIRGINIA
   9. SNOWY MTS. - AUSTRALIA
   10. NAVAJO

C. TUNNELING METHODS
   1. DRILL & BLAST
   2. MOLE
   3. ROAD HEADER

SNOWY MOUNTAIN - AUSTRALIA

POWERHOUSE ABOUT 1,100 FT DEEP
GRANITE AND GRANITE-GNEISS ROCKS
TUNNEL LENGTH ABOUT 2 MILES

KEMANO - B.C.

TWO TEN MILE TUNNELS
25 FT EXCAVATED DIAMETER
PORPHYRY, ANDESITE AND QUARTZ
DIORITE ROCK

TARP - CHICAGO

140 MILES OF SEWER TUNNEL
18 FT TO 35 FT DIAMETERS
TBM DRIVEN
LIMESTONE AND DOLOMITIC ROCKS

BATH CO. - VIRGINIA

THREE 7,000 FT LONG POWER TUNNELS
32 FT DIAMETER TUNNELS
DRILL AND BLAST EXCAVATION
SEDIMENTARY ROCKS

PEPCO

DEEP UNDERGROUND EXCAVATION
DRILL AND BLAST EXCAVATION
LARGE EXCAVATED VOLUME
METAMORPHIC ROCKS

SWEDISH OIL STORAGE

3.7×10^6 CY OF EXCAVATION
$12/CY
65 FT X 65 FT OPENING
GRANITE-GNEISS ROCK
UNLINED BELOW WATER TABLE

CHURCHILL FALLS - LABRADOR

ACRES DESIGN

GEOLOGY

A. VERY COMPLEX

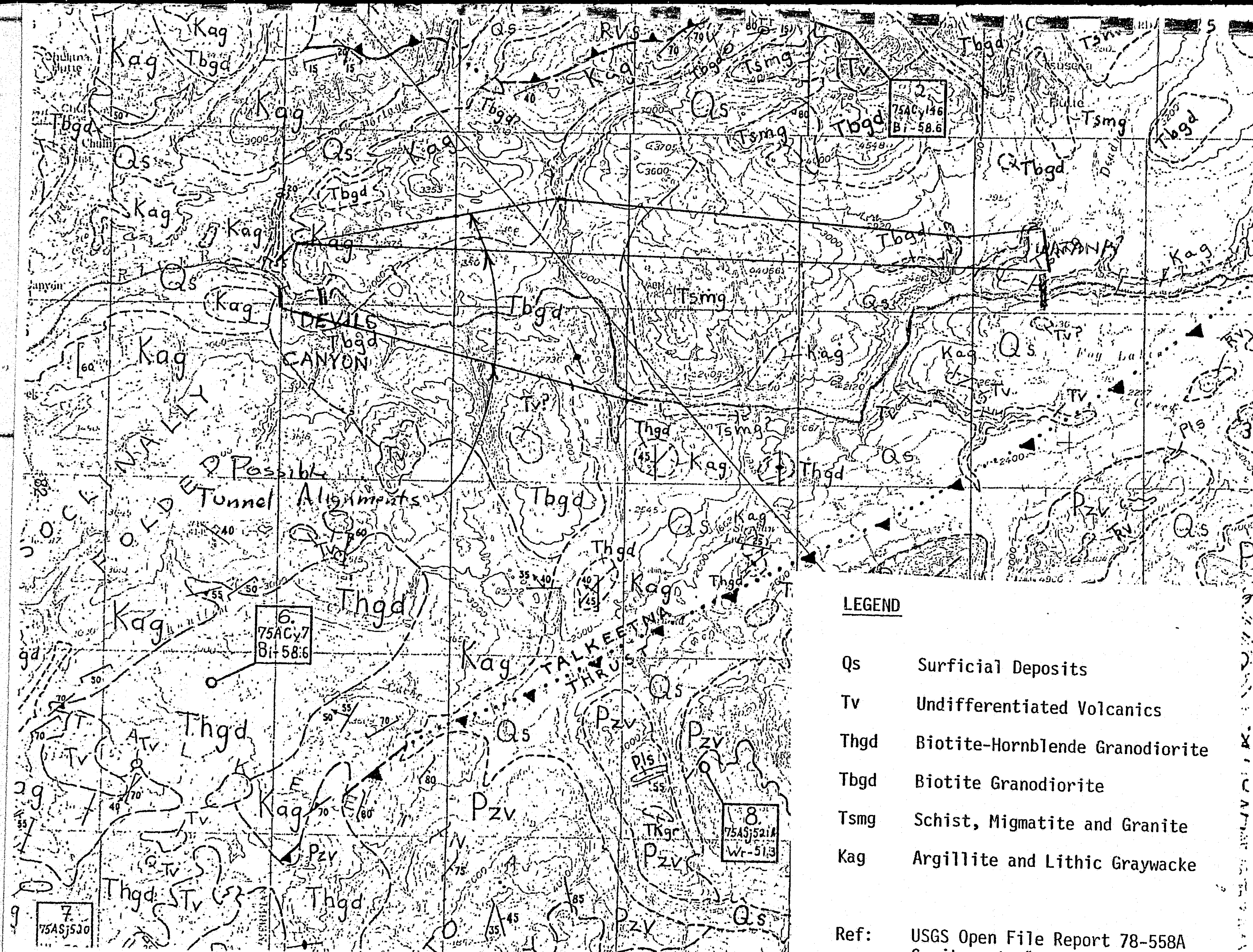
1. FOLDED
2. FAULTED - THRUSTED - SHEARED
3. INTRUDED
4. JOINTED

B. LITHOLOGIES

1. IGNEOUS
2. SEDIMENTARY
3. METAMORPHIC

C. STRUCTURAL TREND

1. NE-SW
2. NW-SE



LEGEND

Qs	Surficial Deposits
Tv	Undifferentiated Volcanics
Thgd	Biotite-Hornblende Granodiorite
Tbgd	Biotite Granodiorite
Tsmg	Schist, Migmatite and Granite
Kag	Argillite and Lithic Graywacke

Ref: USGS Open File Report 78-558A
Csejtey et al

Lithology

A. Volcanics
1. Latite, Rhyolite, Andesite, Basalt, Tuff
2. Stocks, Dikes

B. Granodiorite
1. Hornblende and/or Biotite,
2. Med. to Coarse Grained
3. Intruded

C. Schist, Migmatite, Granite
1. Flow foliation, moderately to well developed
2. Flow banded minerals

D. Argillite and Graywacke
1. Highly indurated
2. Grades to Phyllite, Slate

Structure

A. Very complex
1. Folded, Faulted, Thrusted, intruded
2. Metamorphism, plutonism

B. NE-SW Trend
1. Folds have axial plane slaty cleavage

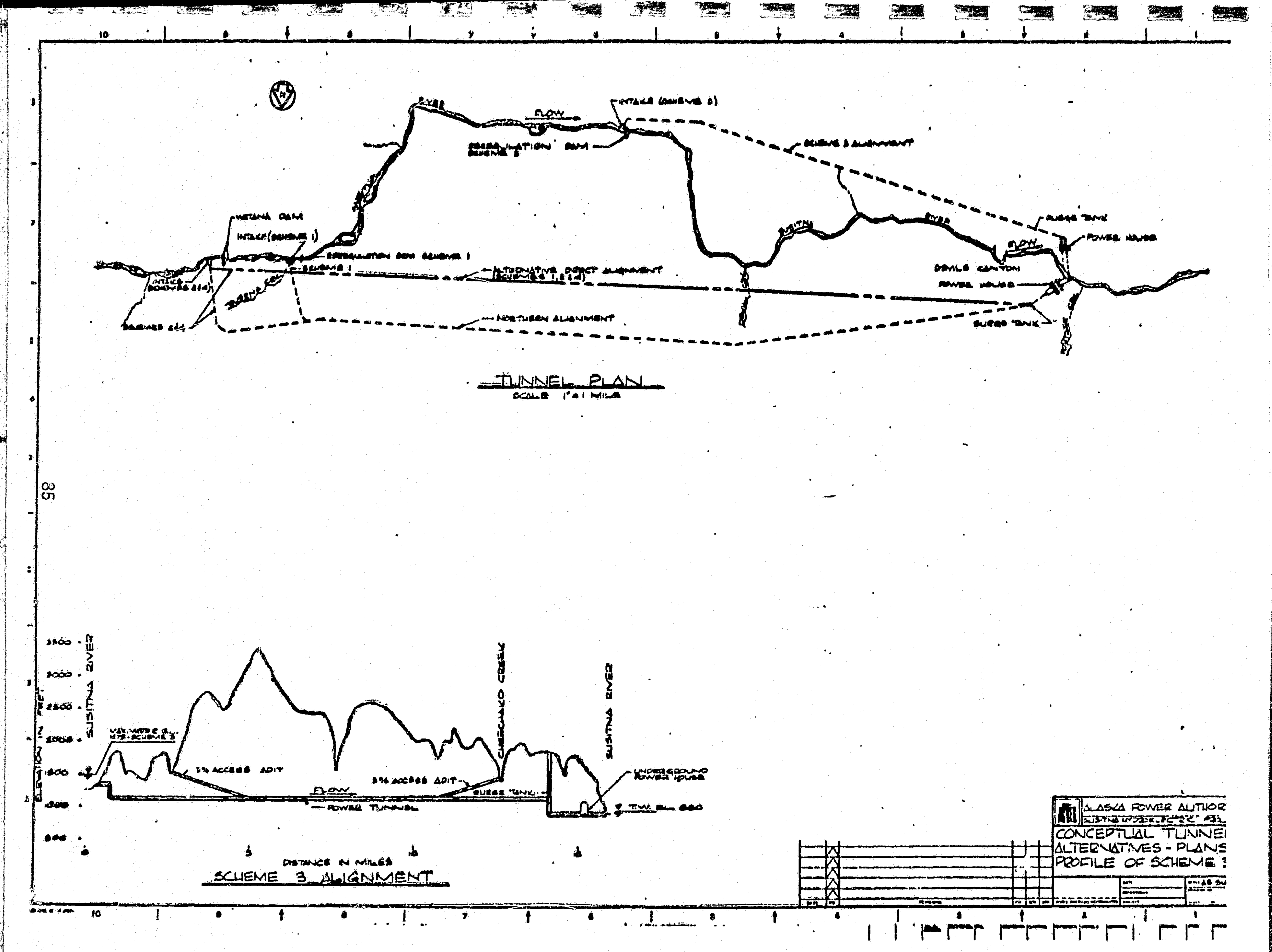
C NW-SE Secondary structure

Preliminary

TABLE 1

Susitna Tunnel Schemes
Physical Factors

	COE Devil Canyon	1	2	3	4
Reservoir Area (Acres)	7,500	320	-0-	3,900	-0-
River Miles Flooded	31.6	2.0	-0-	15.8	-0-
Tunnel Length (Miles)	--	27	29	15.5	29
Tunnel Volume (Yd^3)	--	10,749,000	11,545,000	4,285,000	6,494,000
Compensation Flow (cfs)	--	500 to 1000	500 to 1000	500 to 1000	500 to 1000
Downstream Reservoir Volume (Acre-Feet)	1,100,000	9,500	-0-	350,000	-0-
Devil Canyon Powerhouse Discharge	Constant	Peaking	Peaking	Constant	Constant
Dam Height (feet)	520	75	--	245	--



FLOW
INTAKE (SCHEME 3)
SCHEME 3 ALIGNMENT
REREGULATION DAM SCHEME 3
WATANA DAM
INTAKE (SCHEME 1)
REREGULATION DAM SCHEME 1
SCHEME 1
ALTERNATIVE DIRECT ALIGNMENT (SCHEMES 1, 2 & 4)
NORTHERN ALIGNMENT
SCHEMES 2 & 4
SURGE TANK
POWER HOUSE
DEVILS CANYON
POWER HOUSE
SURGE TANK
TUNNEL PLAN
SUSITNA RIVER
CHEECHAKO CREEK
SUSITNA RIVER
ELEVATION IN FEET
3% ACCESS ADIT
3% ACCESS ADIT
FLOW
SURGE TANK
POWER TUNNEL
UNDERGROUND POWER HOUSE
DISTANCE IN MILES
SCHEME 3 ALIGNMENT
ALASKA POWER AUTHOR
CONCEPTUAL TUNNEL
ALTERNATIVES - PLANS
PROFILE OF SCHEME 3

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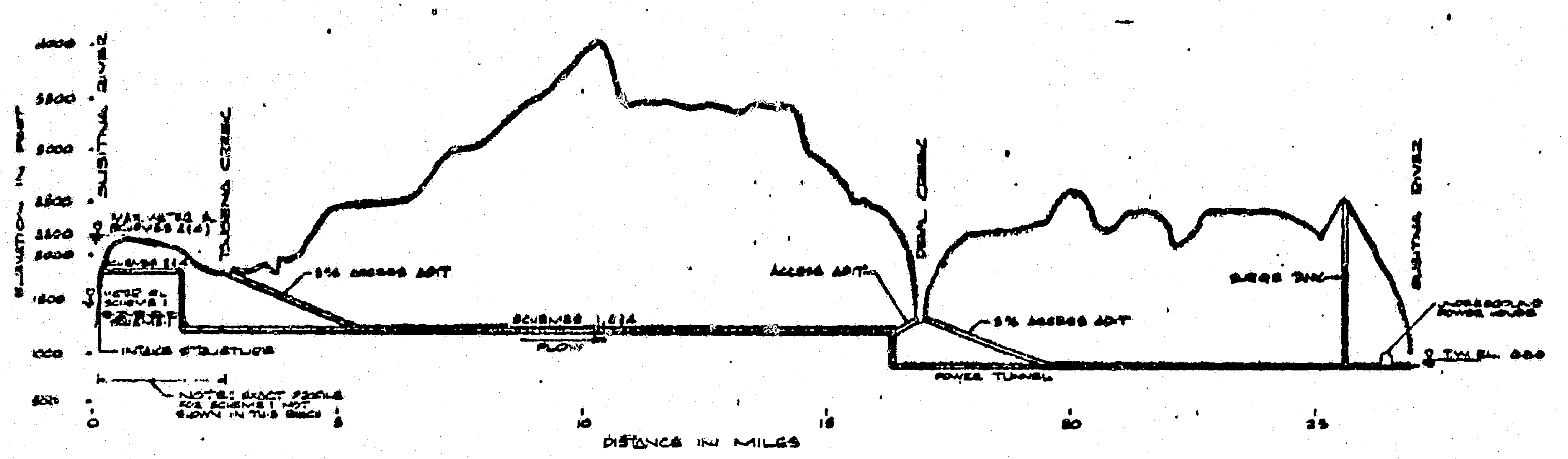
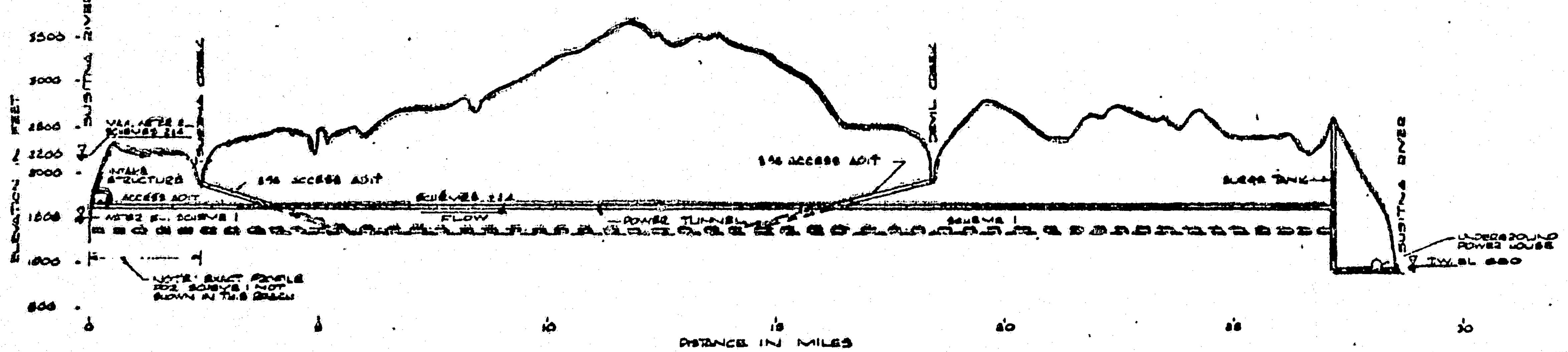


ALTERNATIVE DIRECT ALIGNMENT (SCHEMES 1,2&4)

98



NORTHERN ALIGNMENT (SCHEMES 1,2&4)

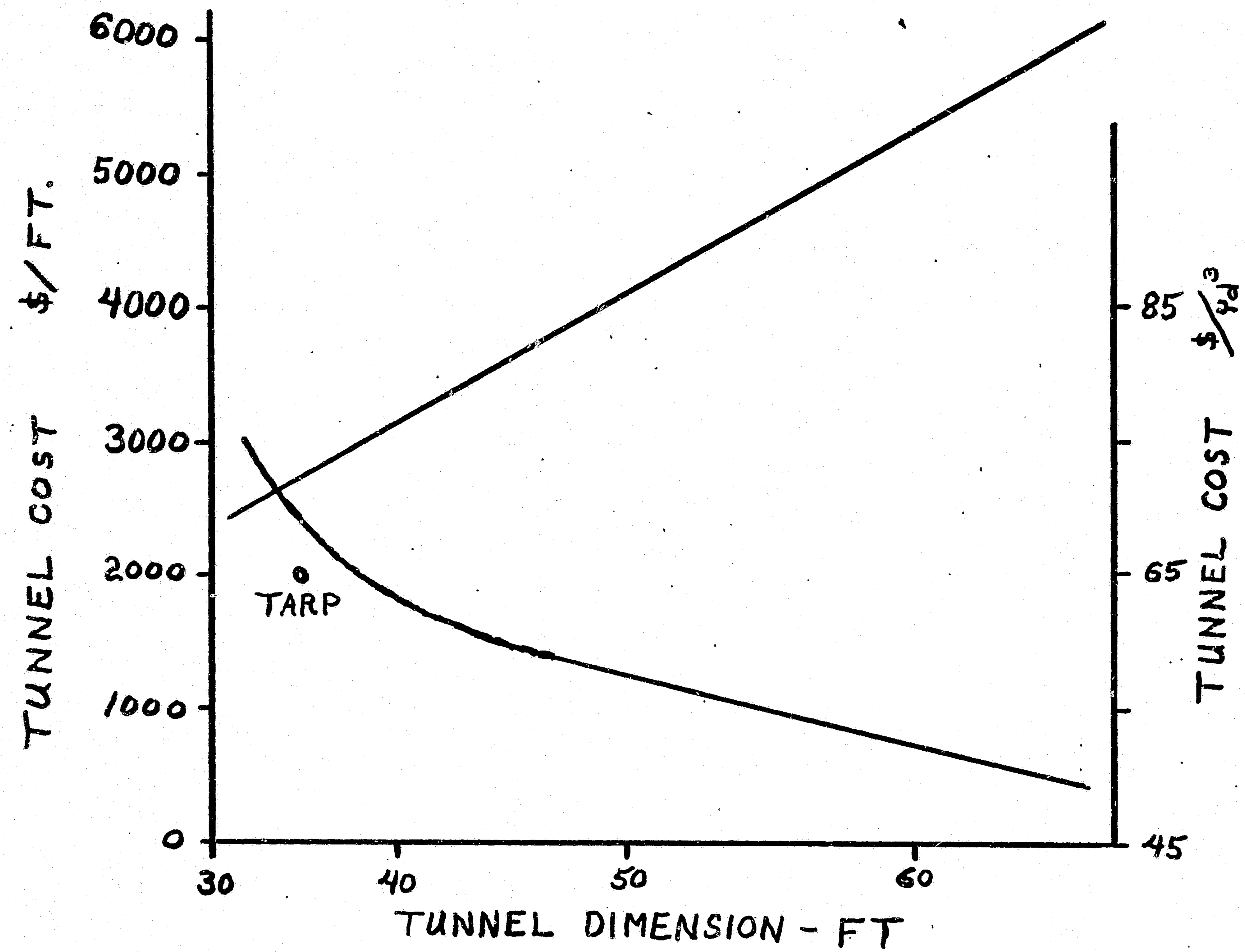
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

CONCEPTUAL TUNNEL ALTERNATIVES PROFILES SCHEMES 1,2&4

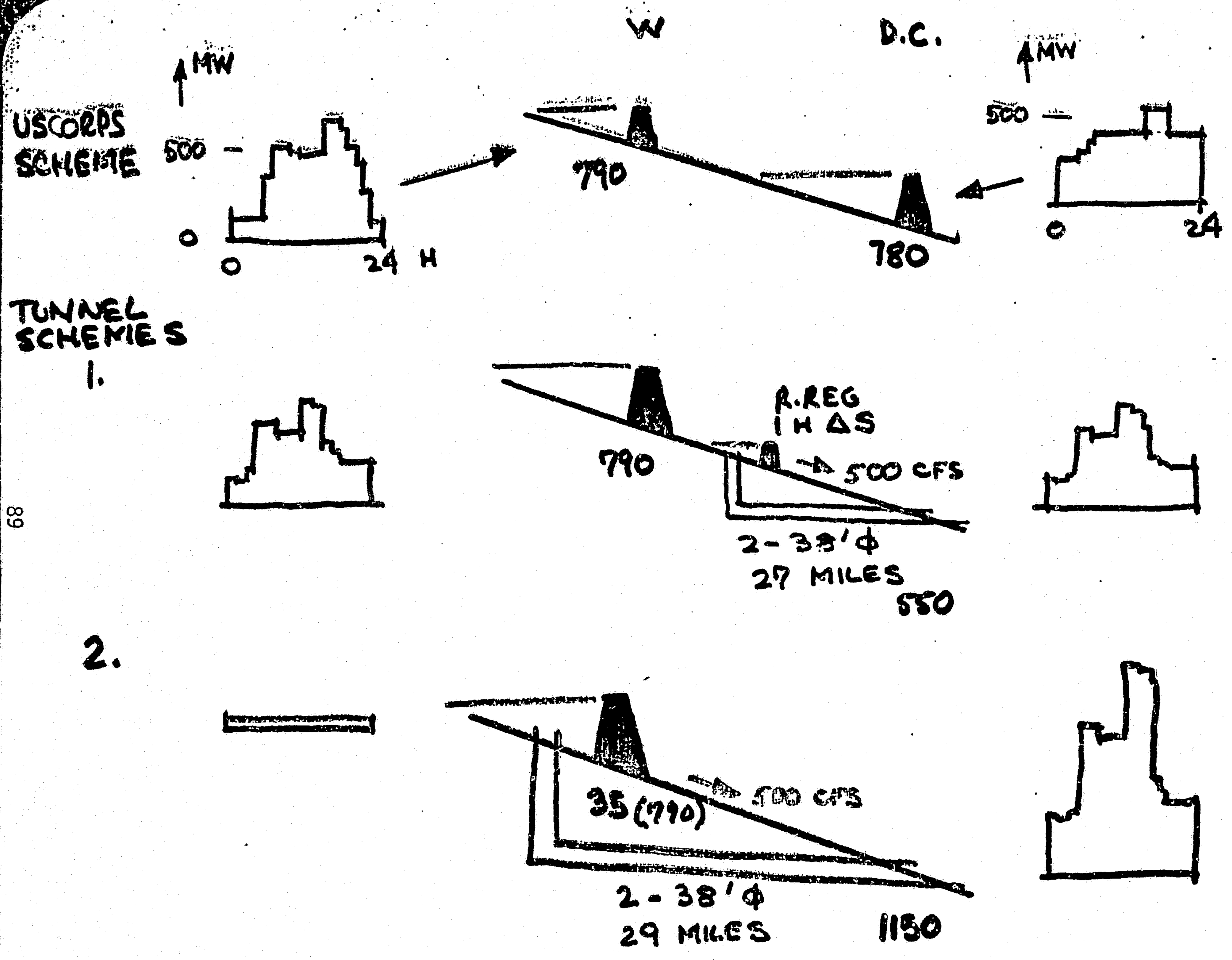
SUSITNA HYDROELECTRIC PROJECT
TUNNEL ALTERNATIVES COST ASSUMPTIONS

THE FOLLOWING ASSUMPATIONS HAVE BEEN USED IN DEVELOPING THE COST ESTIMATES FOR THE TUNNEL SCHEME ALTERNATIVES:

- TUNNEL LENGTH ~ 29 MILES
- TUNNEL CROSS SECTIONAL AREA 800 SF; 1250 SF; 1500 SF AND 3325 SF
- CONSTRUCTION ACCESS ~ 4 MILES OF 20 X 20 FT ADITS (ALL SCHEMES)
- 12 FT OF DRILLING DEPTH ADVANCES TUNNEL 10.5 FT PER ROUND
- SPECIFIC DRILLING ~ 3.16 FT/CY
- SPECIFIC CHARGE ~ 1.77 LB/CY
- DRILL PRODUCTION ~ 5 FT / MINUTE

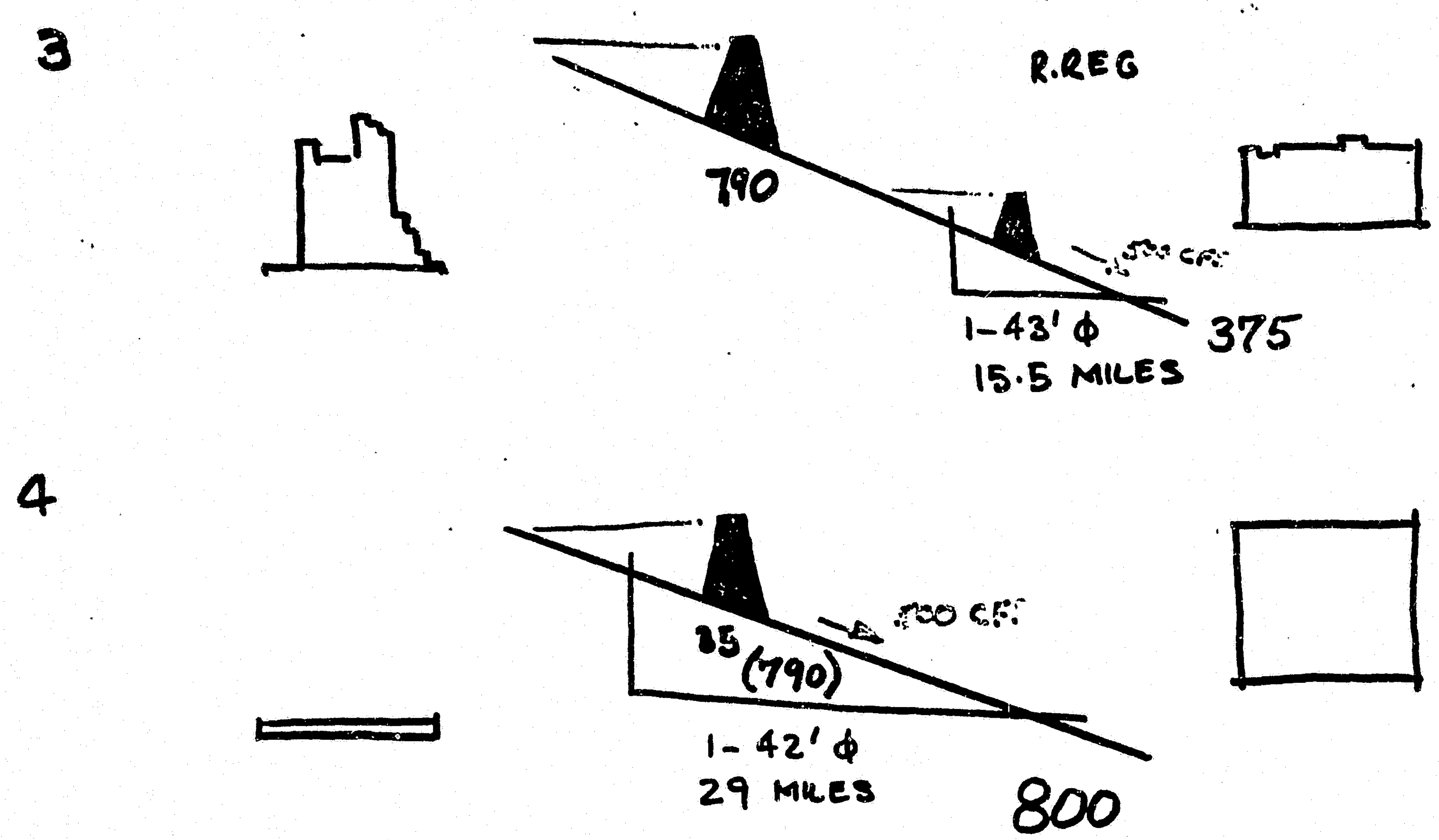


TUNNEL COST $/FT.
6000
5000
4000
3000
2000
1000
0
TARP
30
40
50
60
TUNNEL DIMENSION - FT
85
65
45
TUNNEL COST $/yd³



TUNNEL ALTERNATIVES - "PEAKING"

68



TUNNEL ALTERNATIVES – "BASE LOAD"

ECONOMICS OF TUNNEL ALTERNATIVES

			INST. CAP. U/S MW	INST. CAP. D/S MW	AV. AN. ENER. GWH		CAP COST 10^6 $	ENERGY COST $/1000 kwh
US CORPS DAMS			790	780	6855		2150	35
TUNNEL SCHEMES								
	CF .47	1.	790	550	5700	A	2250	45
						B	2300	50
						C	2750	55
	.47	2.	35 (790)	1150	4900	A	2100	50
						B	2200	50
						C	2650	65
	.78	3.	790	375	6029	A	1900	35
						B	1950	40
						C	2100	40
	.78	4.	35 (790)	800	5650	A	2050	40
						B	2100	45
						C	2400	50

B. 15 MILE HAUL

C. SENSITIVITY, 2 X TUNNEL COST

VOLUMES OF TUNNEL ALTERNATIVES

	Dam Volume 10^6 Yd^3	Tunnel Volume 10^6 Yd^3
U.S. Corps Watana Dam	57.6	--
Tunnel Schemes		
1	57.6	12.0
2	57.6	12.9
3	62.5*	4.4
4	57.6	7.9

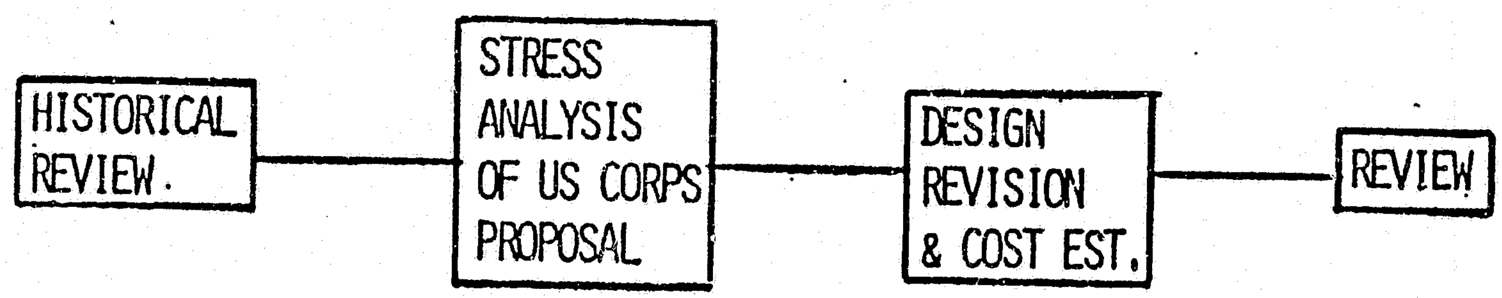
* NOTE: Includes 4.9 X 10^6 Yd^3 for rockfill re-regulation dam.

OBJECTIVES (6.04)

PRELIMINARY ASSESSMENT OF FEASIBILITY OF ARCH DAM AT DEVILS CANYON.

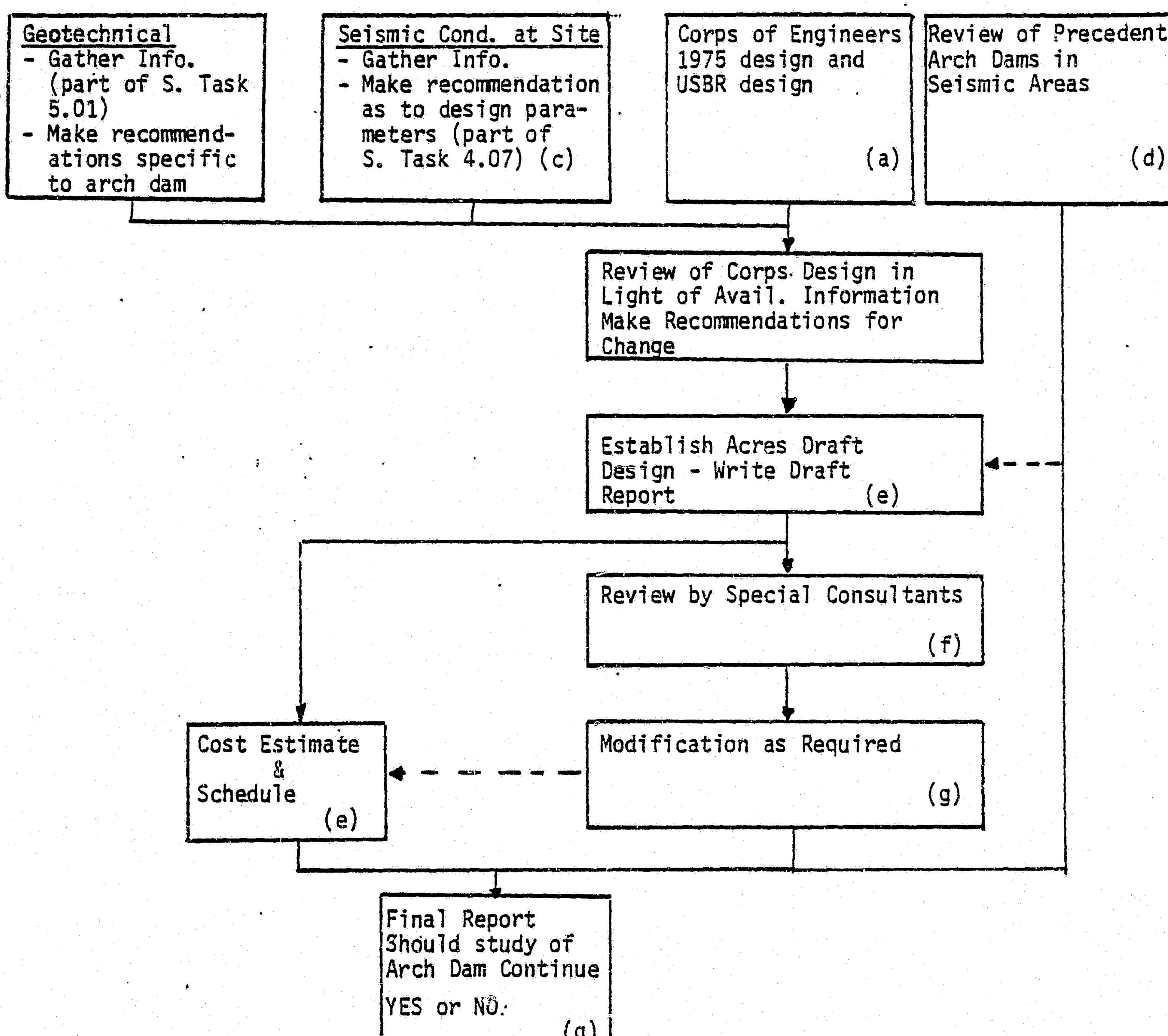
GENERAL APPROACH

ARCH DAM (6.04)



SUSITNA HYDROELECTRIC PROJECT

EVALUATION OF ARCH DAM AT DEVIL CANYON SITE LOGIC DIAGRAM



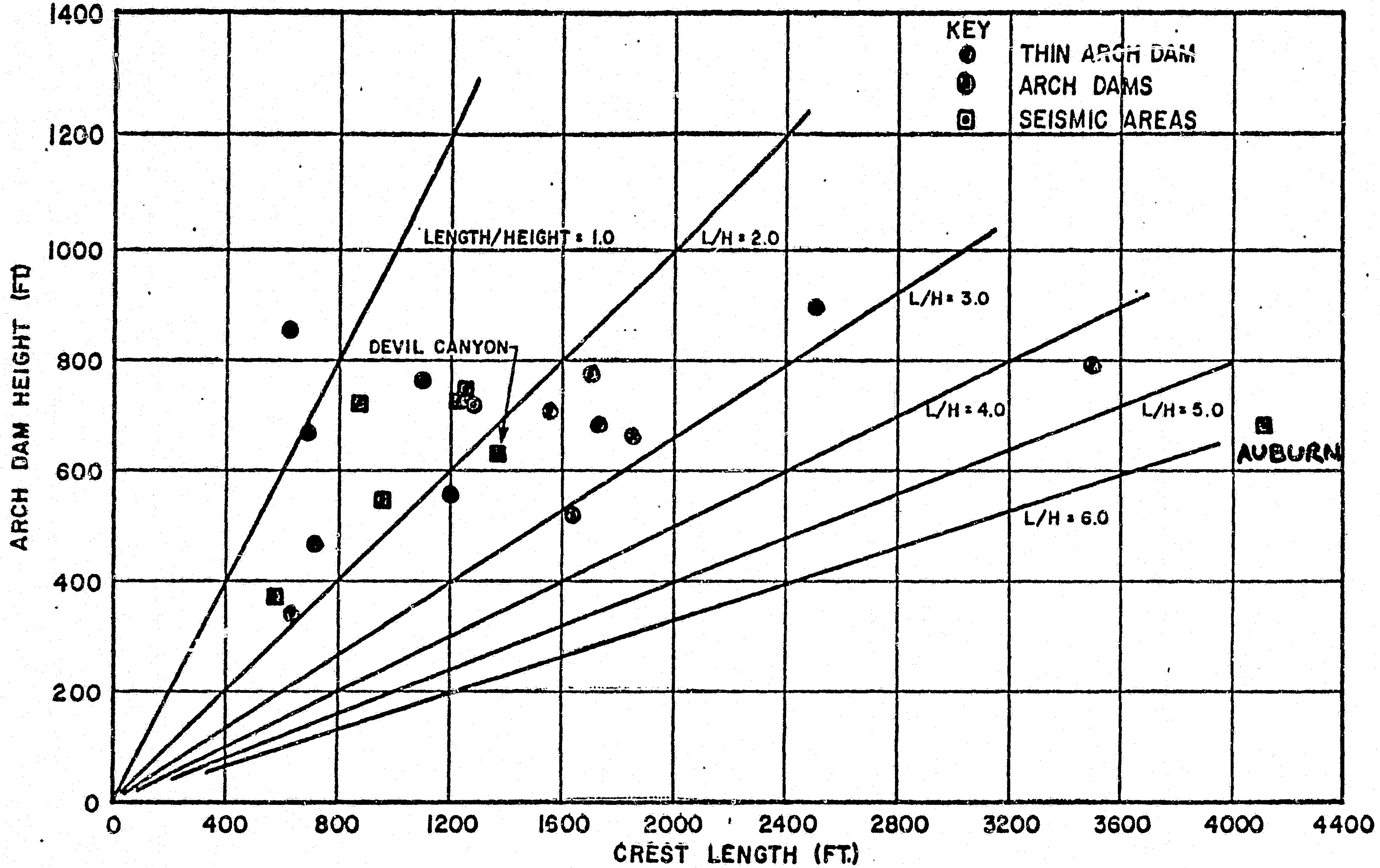
DEVIL CANYON ARCH DAM
CONSIDERATIONS

1. STABILITY
2. COMPRESSIBILITY
3. SEISMIC

DAM	LOCATION	HEIGHT	CREST LENGTH	BASE THICK.	MINIMUM THICK.	VOLUME	SEISMIC PARAMETERS	FOUNDATION	ABUTMENTS	REMARKS	CENT. ANGLE
Gokçekaya	Turkey	521 (159)	1620 (494)	74 (22.5)	20 (6)	933,000 (714,000)				Designed by EBASCO	107.4
Idikki	India	555	1200	80	25	613,000					
Auburn	California	685	4150	200	40	6,300,000				3 circular arcs Left 4000 ft rod 980' arc Center 1400 ft rod 1810' arc Right 4000 ft rod 1275' arc	
Pacoima	California	372 (113)	589 (180)	99 (30.2)	10.4 (3.2)	220,000 (168,000)	Seven significant faults within 3.8 miles (6 kM) radius of the site. 1952 - Earth - quake of 5.0 Rickter @ 15 mi. 1971 - San Fernando earthquake 6.6 Rickter @ 4 mi. measured (Horizontal (Acc. 1.25 g (in each (direction (Vertical Acc . (0.70 g base rock estimated at 0.6 to 0.8 g	Gneissic Qua sets divide angular bloc approximatel	rtz Joint rock into ks of y 4' 0"	- Built around 1930 - Constant angle arch - Earthquake loads not considered in design	

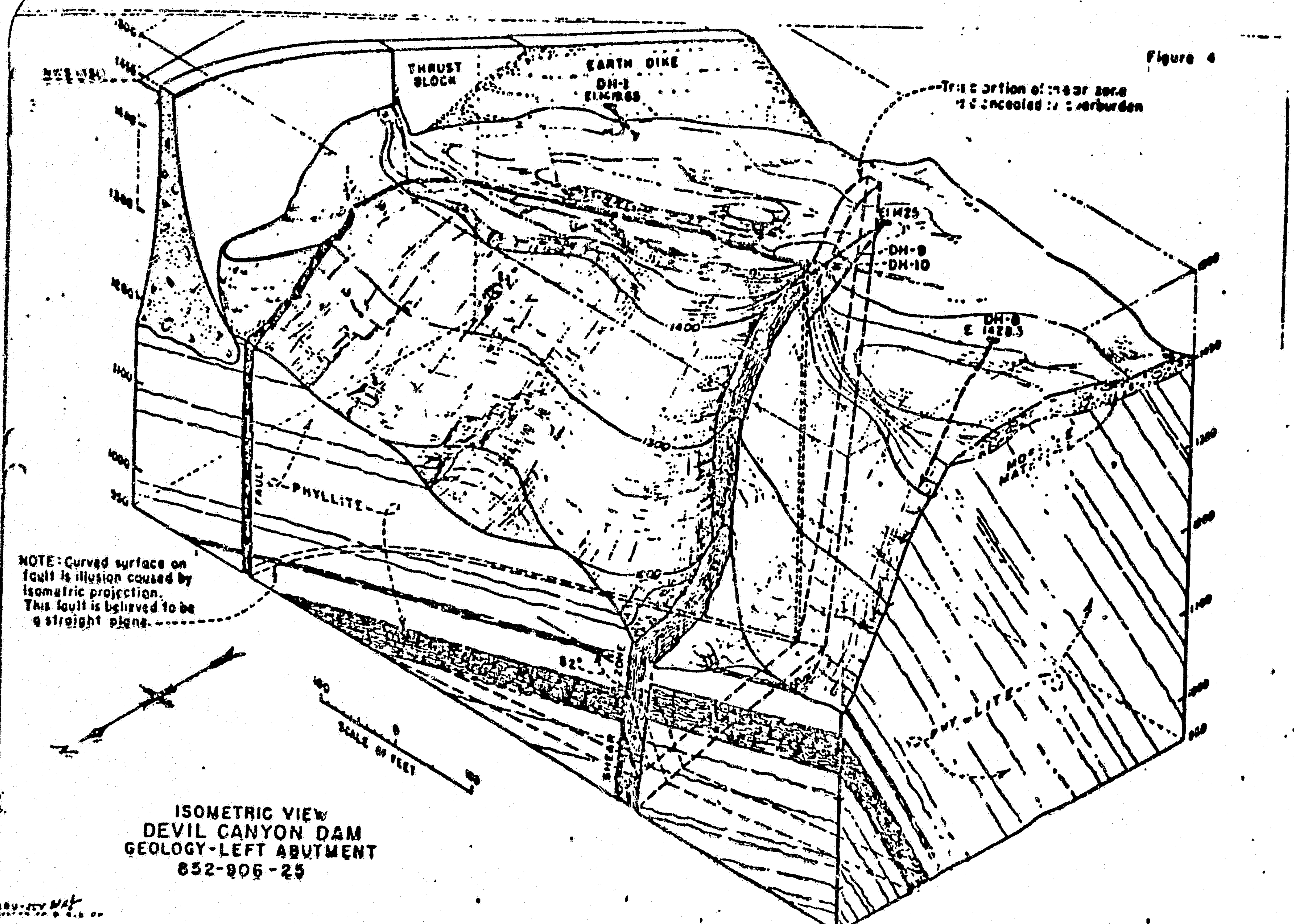
DAM	LOCATION	HEIGHT	CREST LENGTH	BASE THICK.	MINIMUM THICK.	VOLUME	SEISMIC PARAMETERS	FOUNDATION	ABUTMENTS	REMARKS	CENT. ANGLE
Contra (1965)	Ticino, Switzerland	722 (220)	1246 (380)			861,000 (658,000)					
Mratinje (1976)	Montenegro, Yugoslavia	722 (220)	879 (268)			971,000 (742,000)					
Glen Canyon (1964)	Arizona, USA	710 (216)	1560 (475)			4,901,000 (3,747,000)					
Luzzone (1963)	Ticino, Switzerland	682 (208)	1738 (530)			1,739,000 (1,330,000)					
Mohamed Reza Shah Pahlavi (1963)	Khouzestan, Iran	666 (203)	696 (212)			647,000 (497,000)					
Almendra (1970)	Salmanca, Spain	662 (202)	1860 (567)			2,188,000 (1,673,000)					
Inguri (1985)	Georgia, USSR	892 (272)	2513 (766)	282	33 (10 m)	4,967,000 (3,800,000)				ENR Dec. 14, 1978 + Dave Shandalov Info Thin Arch	
Vaiont (1961)	Veneto, Italy	858 (262)	624 (190)			460,000 (352,000)				Overtopped by 400 ft high wave on Oct. 9, 1963. Minor chipping of the top 3 ft due to boulders was the only damage.	
Sayan-Shusen (1980)	Krasnoyarsk, USSR	794 (242)	3504 (1068)			11,916,000 (9,117,000)					
Chirkei (1975)	North Caucusas, USSR	764 (233)	1109 (338)	98 (30 m)	21 (6.5 m)	1,602,000 (1,226,000)					
Mauvoisin (1957)	Valais, Switzerland	777 (237)	1706 (520)			2,655 (2,030)					
El Cajon (1984)	Yoro/Cortes, Honduras	741 (226)	1253 (382)			1,924,000 (1,472,000)					

DAM	LOCATION	HEIGHT	CREST LENGTH	BASE THICK.	MINIMUM THICK.	VOLUME	SEISMIC PARAMETERS	FOUNDATION	ABUTMENTS	REMARKS	CENT. ANGLE
El Cajon (1984)	Yoro/Cortes Honduras	741 (226)	1253 (383)			1,924,000 (1,472,000)					
Hoover (1936)	Nevada, Arizona, U.S.A.	726 (221)	1244 (379)	660	45	4,400,00 (3,364,000)	Spaced between two faults about 900 ft apart			Gravity Arch	
Vidraru-Arges	Romania	548 (167)	588 (292)	82 (25.0)	20 (6.0)		Earthquake in 1977 with an intensity of 7-8 on the MSk scale at the site. 7 = 2-1/2 %g. 8 = 5% g. 9 = 10% g.			Measurements after the earthquake showed no odifications to normal behavior.	
Morrow Point	Colorado	465	720	51.65'	12.0	360,000	In design it is mood up a point				
Crystal Dam	Nestren Colorado	340	620			145,000					
Green Lake Dam	Sitka, Alaska	210	460	16 ft.		26,000	Miximum Credible earthquake Magnitude = 8 Richter @ 16 mi. Acceleration = 0.40 g. Duration = 45 sec. Design Earthquake Magnitude = 8 Richter @ 33 mi. Acceleration = 0.23 g. Duration = 40 sec.e	Competent massive graywecke		Unsymmetrical with	



ARCH DAM HEIGHT VS. CREST LENGTH

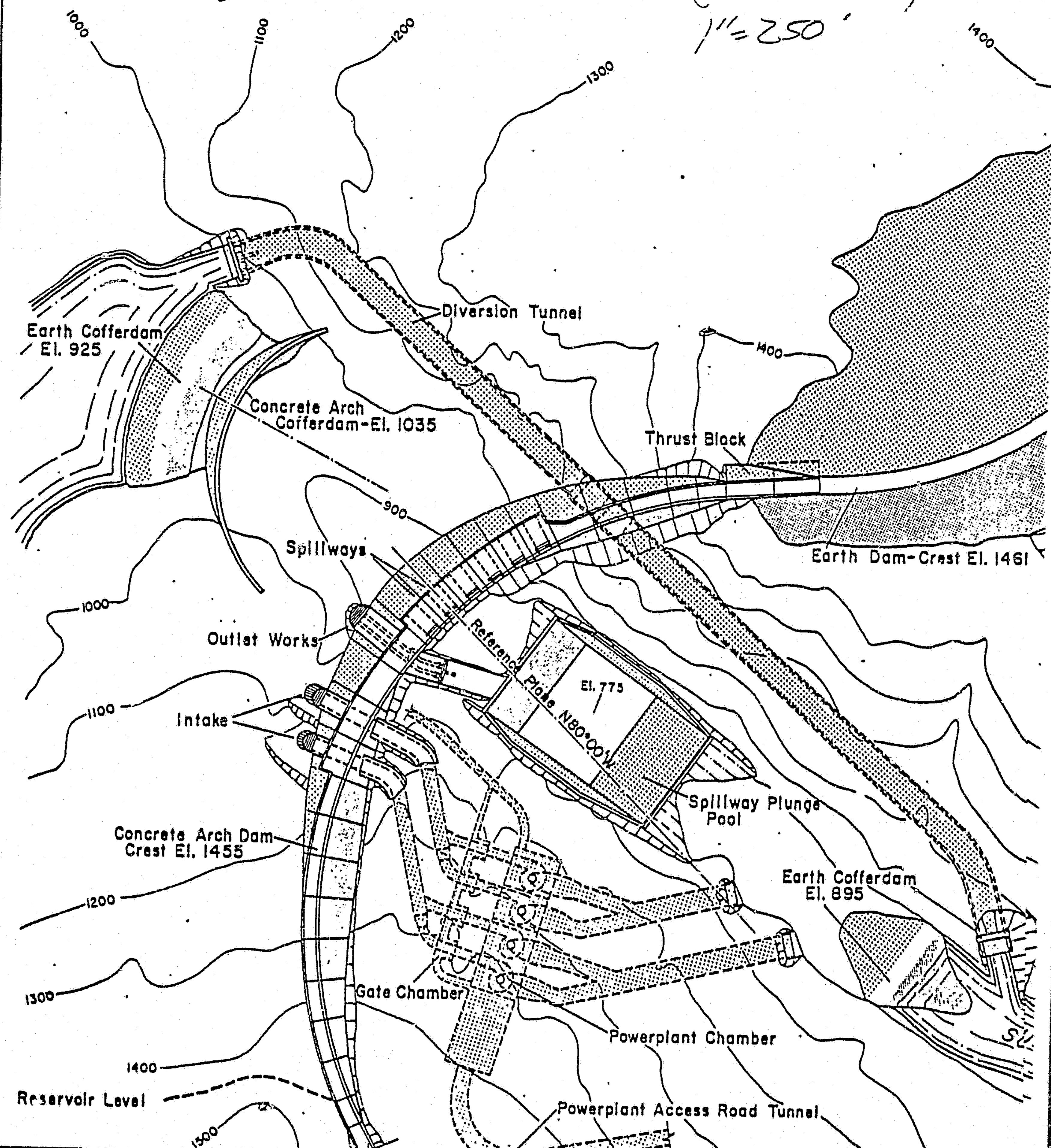
Figure 4

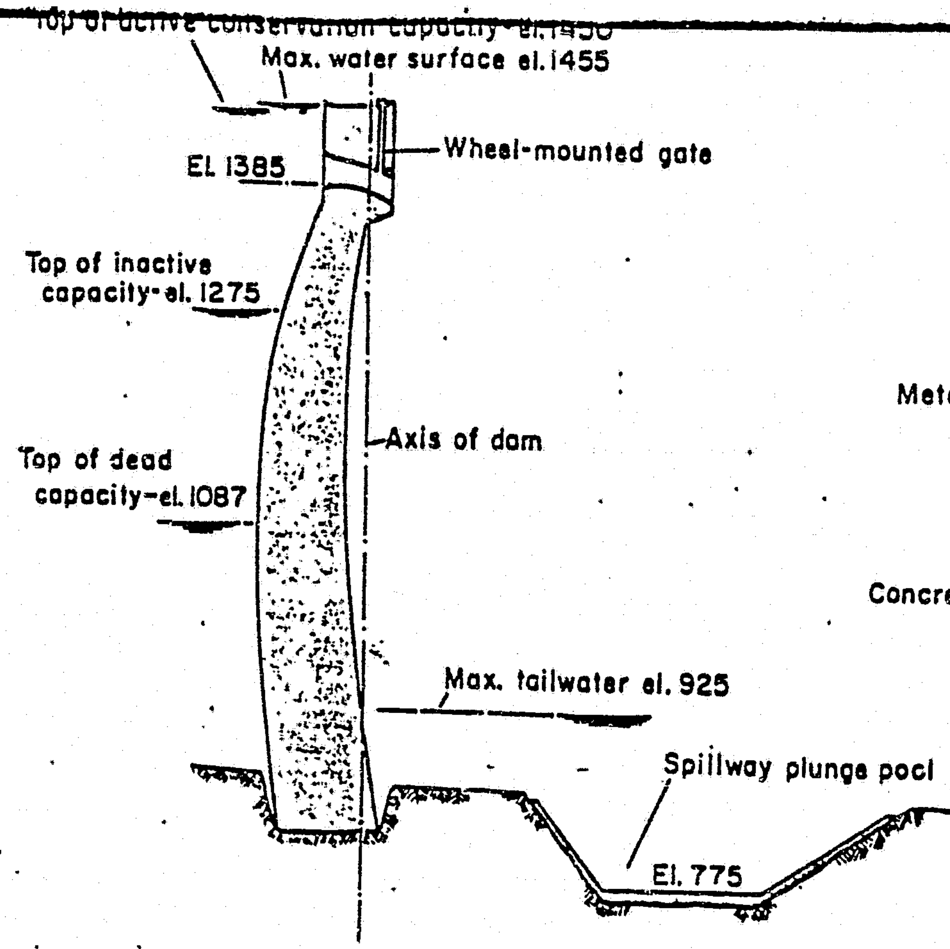


ISOMETRIC VIEW
DEVIL CANYON DAM
GEOLOGY-LEFT ABUTMENT
852-906-25

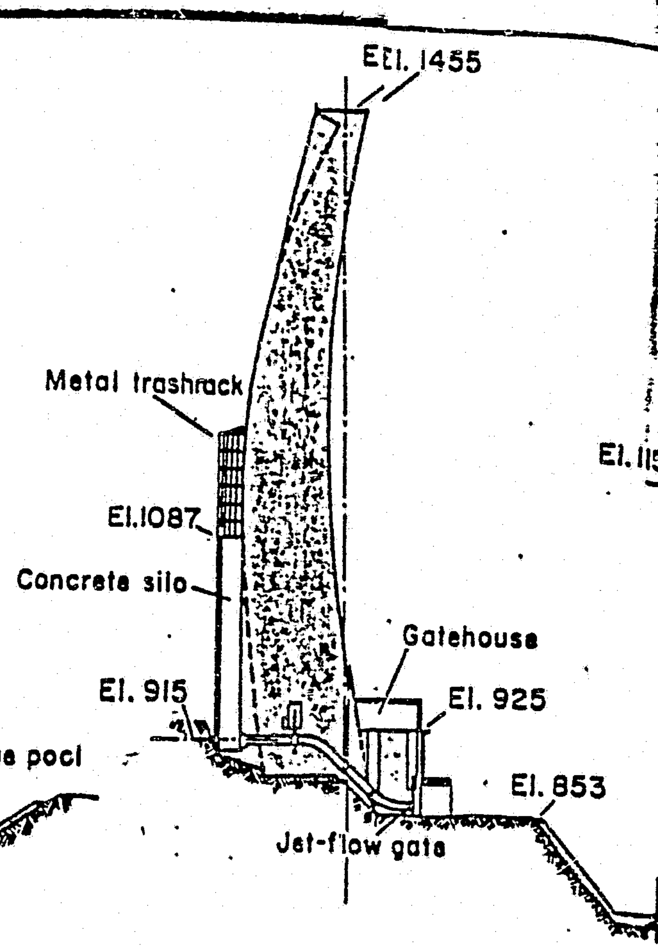
Top of active conservation capacity El. 1450 ... El. 1461

USBR ORIGINAL LAYOUT (THIN ARCH)
1" = 250'

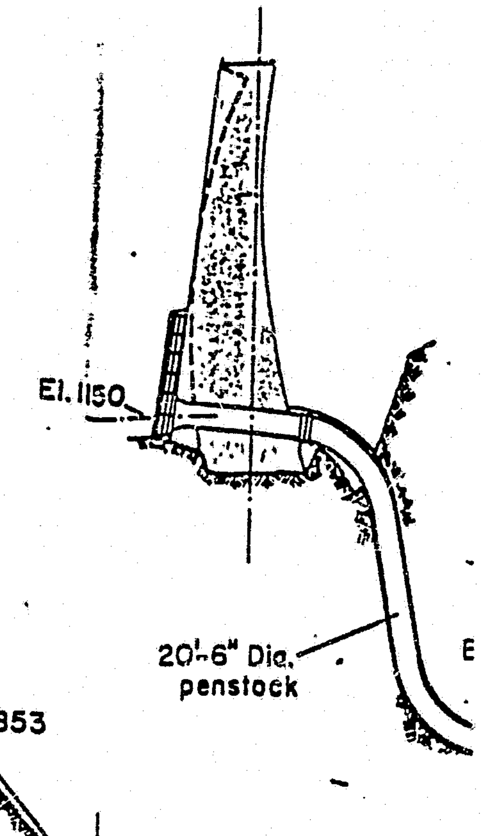




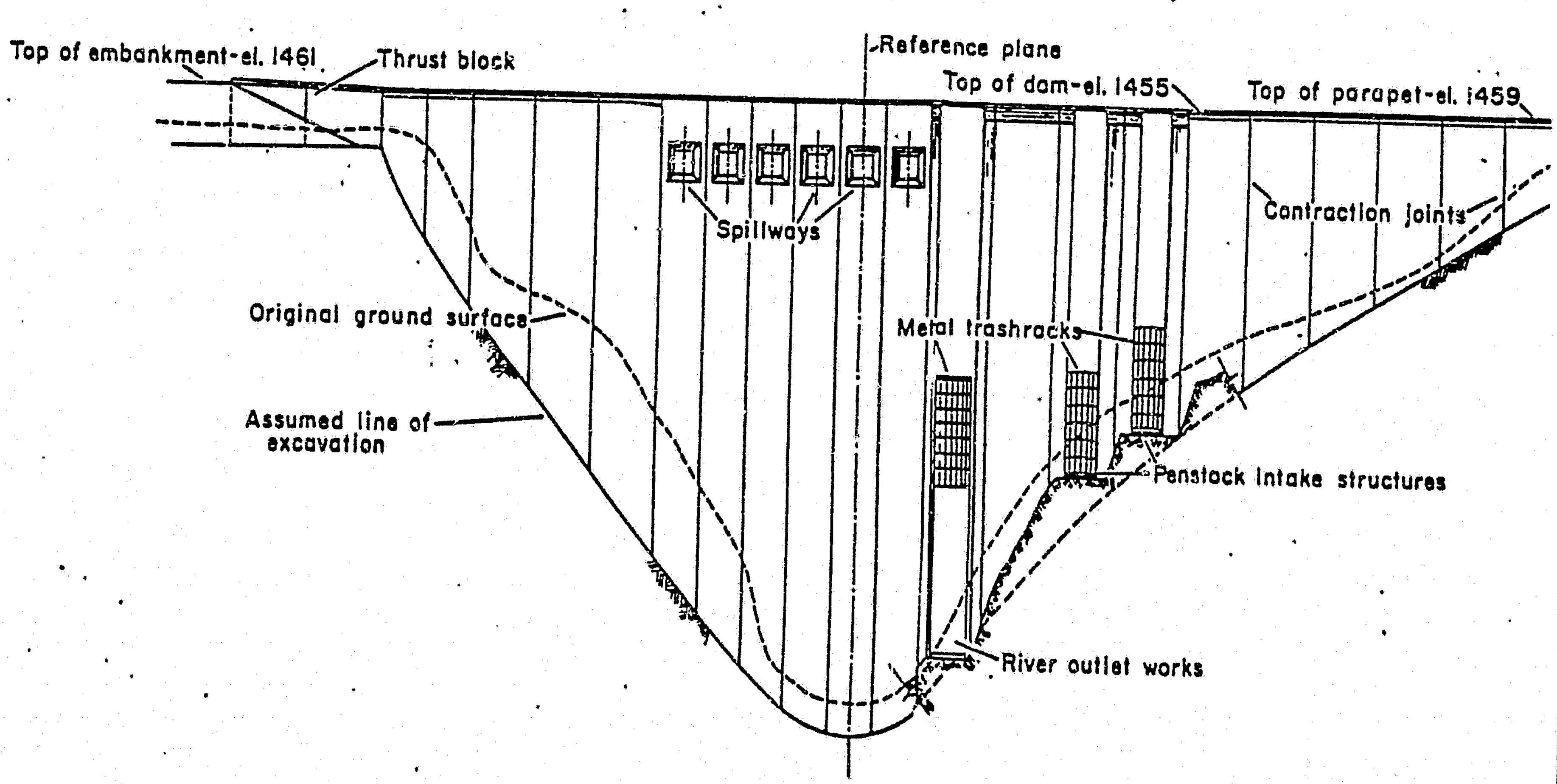
Section through spillway



Section through outlet works

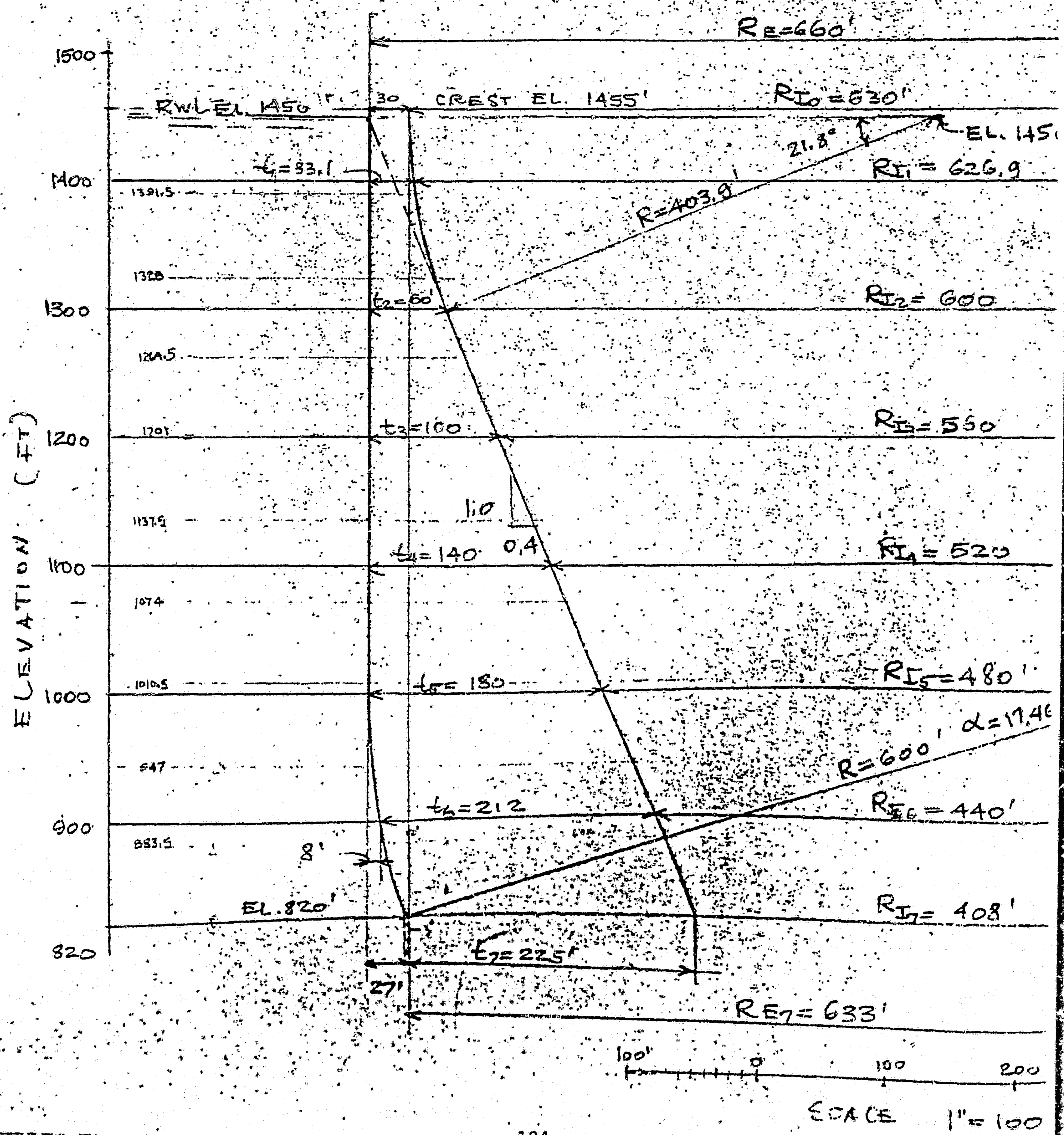


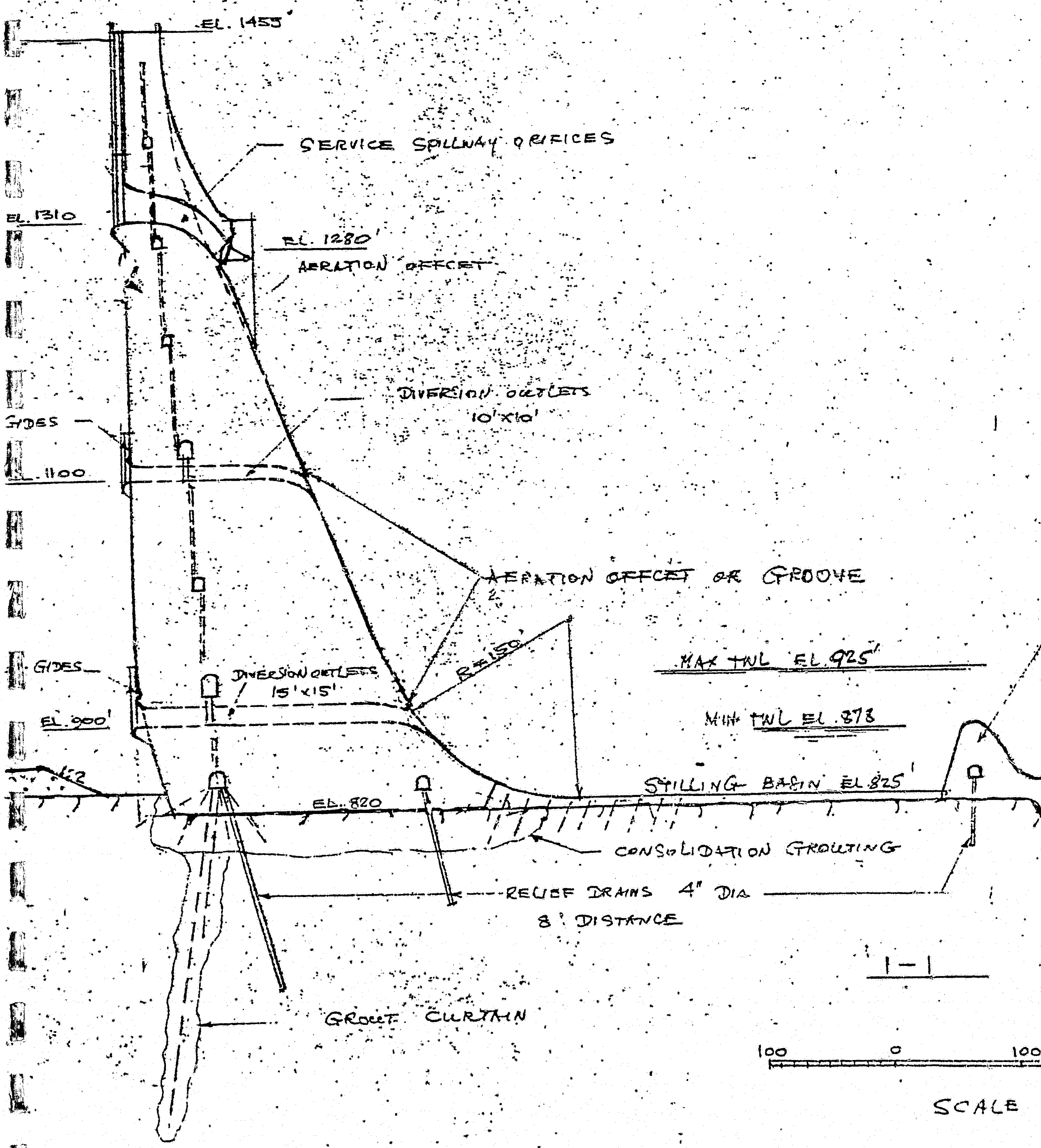
Sec



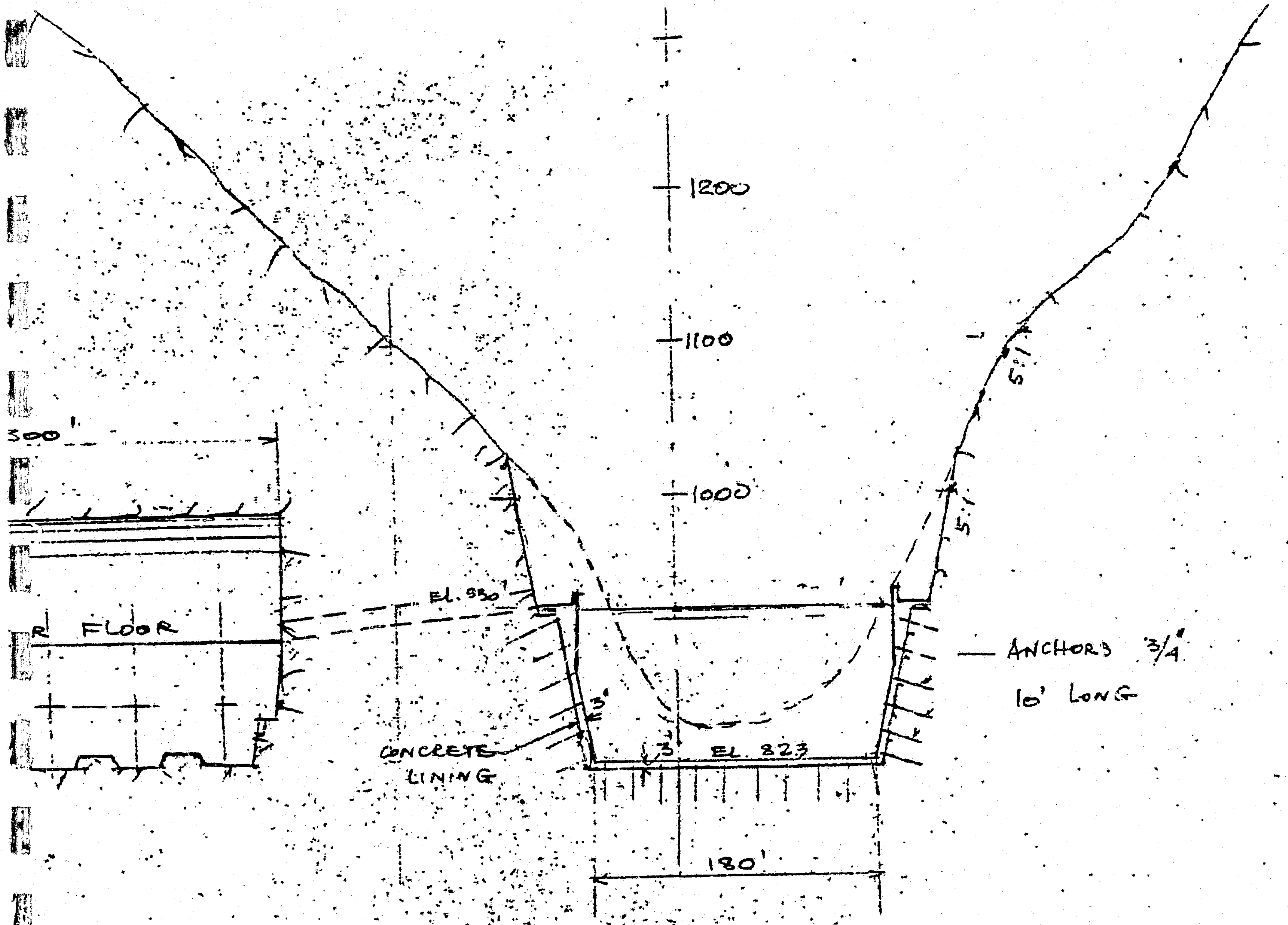
Upstream elevation

ACRES LAY-OUT (GRAVITY-ARCH)

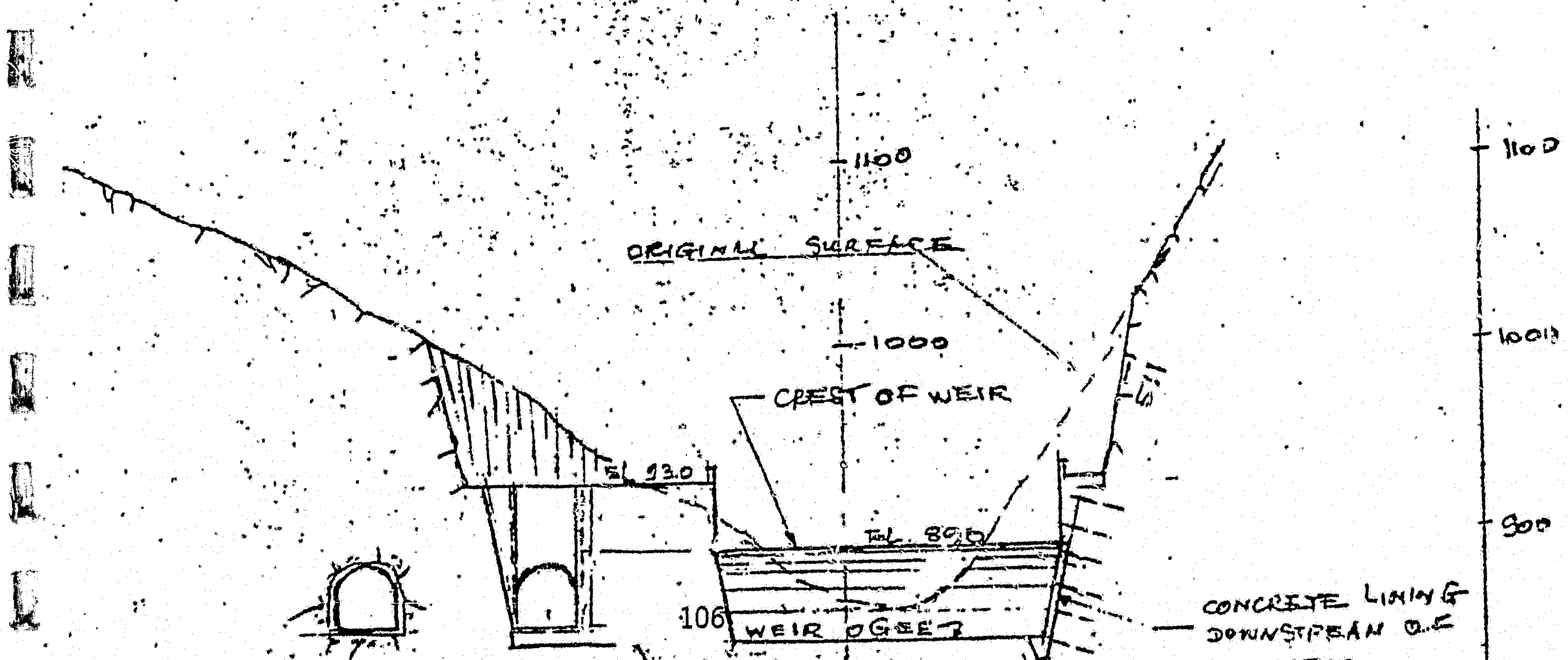




EL. 1455'
SERVICE SPILLWAY ORIFICES
EL. 1310
EL. 1280'
AERATION OFFSET
DIVERSION OUTLETS
10'x10'
GIDES
EL. 1100
AERATION OFFSET OR GROOVE
R=150
MAX TWL EL. 925'
GIDES
DIVERSION OUTLETS
15'x15'
EL. 900'
MIN TWL EL. 878
1:2
STILLING BASIN EL 825'
EL. 820
CONSOLIDATION GROUTING
RELIEF DRAINS 4" DIA
8' DISTANCE
1—1
GROUT CURTAIN
100
0
100
SCALE


1200
1100
1000
500'
FLOOR
EL. 930'
ANCHORS 3/4"
10' LONG
3'
CONCRETE LINING
3'
EL. 823
180'

5 - 5


1100
ORIGINAL SURFACE
1000
CREST OF WEIR
EL. 930
EL. 890
WEIR OGEE
CONCRETE LINING DOWNSTREAM OF WEIR
1100
1000
900

ARCH DAM ANALYSIS

ASSUMPTIONS

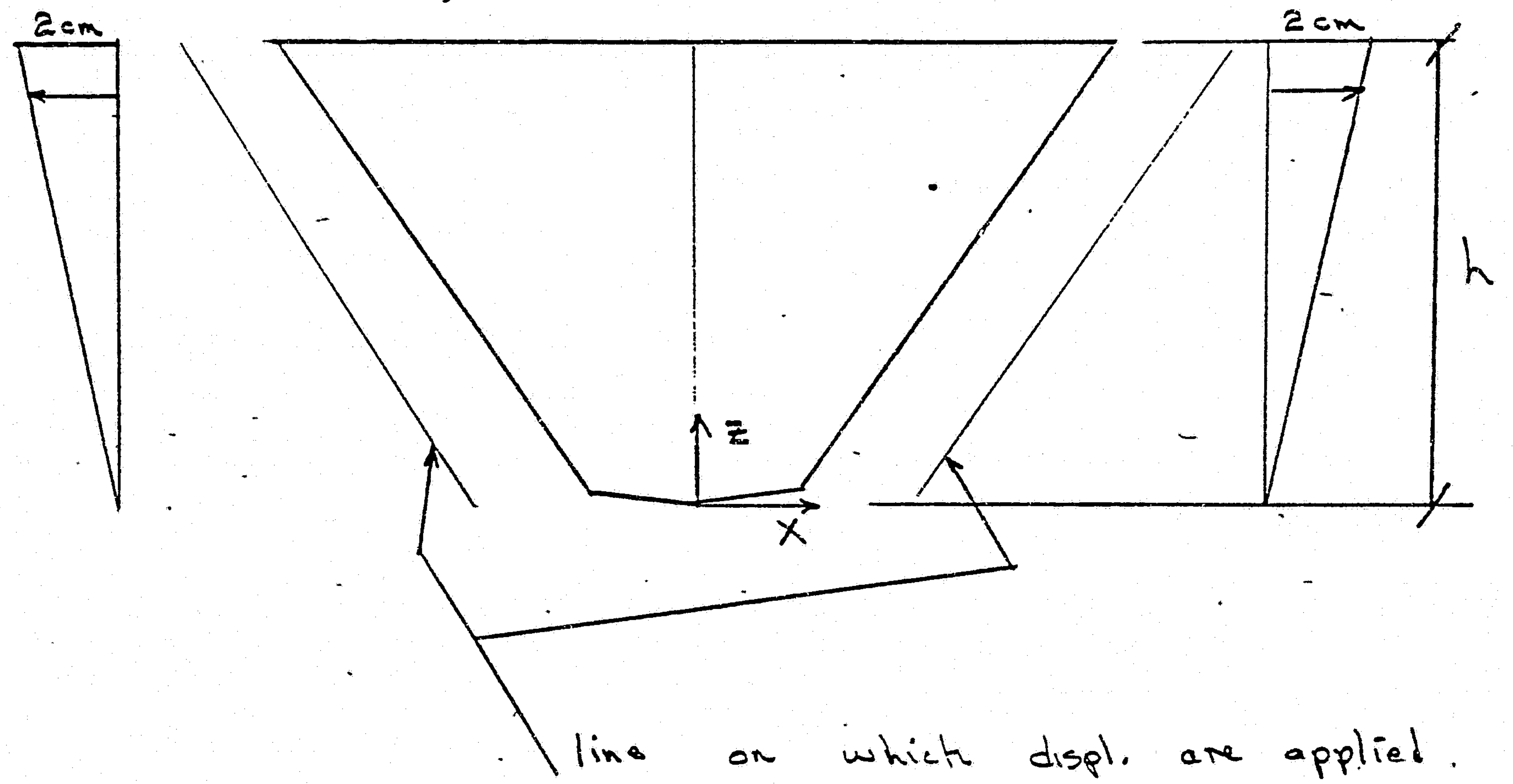
$E_{ROCK} = 1,750,000$ psi

$E_{CONC} = 3,500,000$ psi

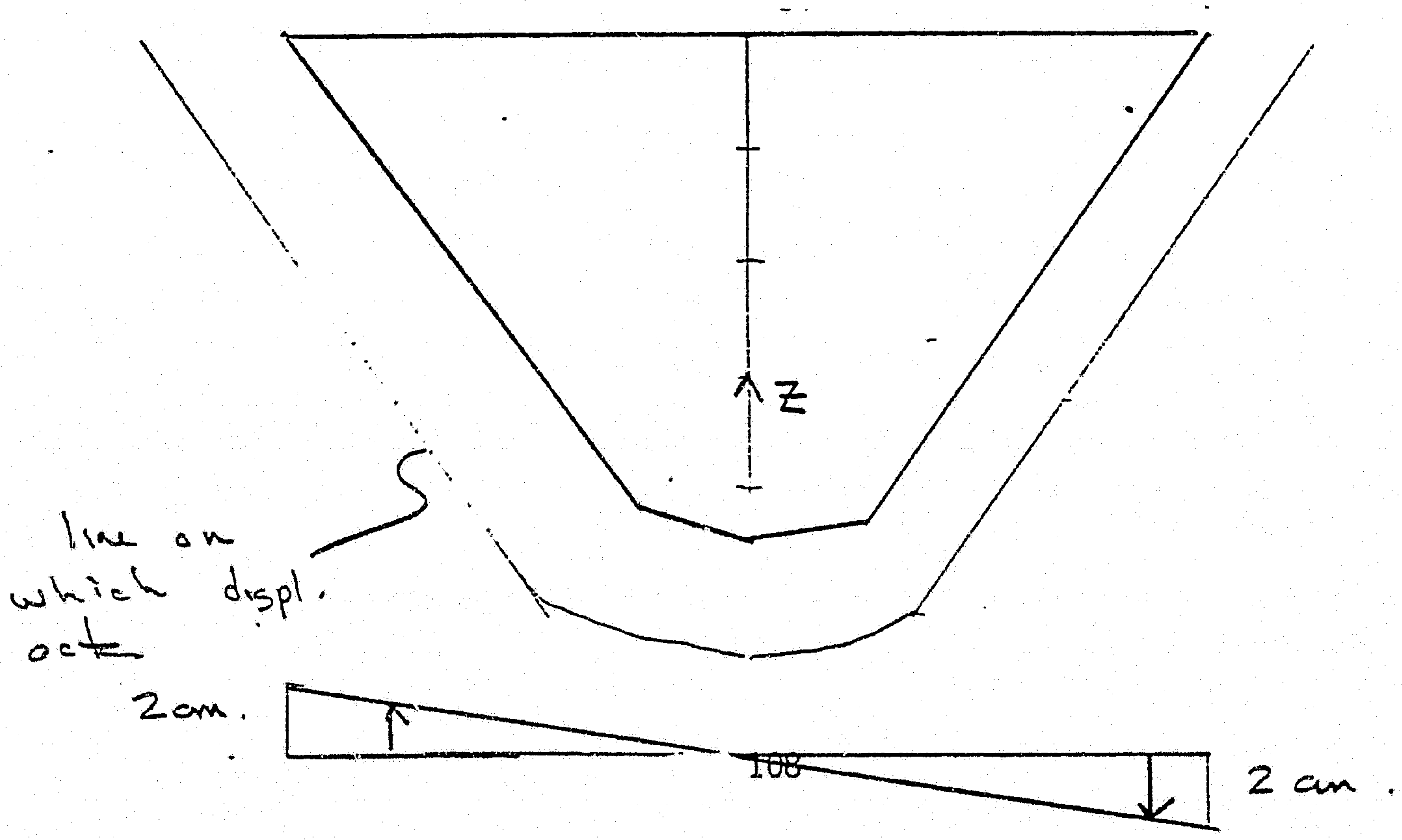
TENSILE STRESS IN CONCRETE IS
1/4 OF COMP STRENGTH
COMP. STRESS IN CONCRETE IS
1/2 OF COMP STRENGTH

Temperature stress −40°F differential (air/water) prescribed displacements :

i) X- DISPLACEMENT 2 CM. OUT.



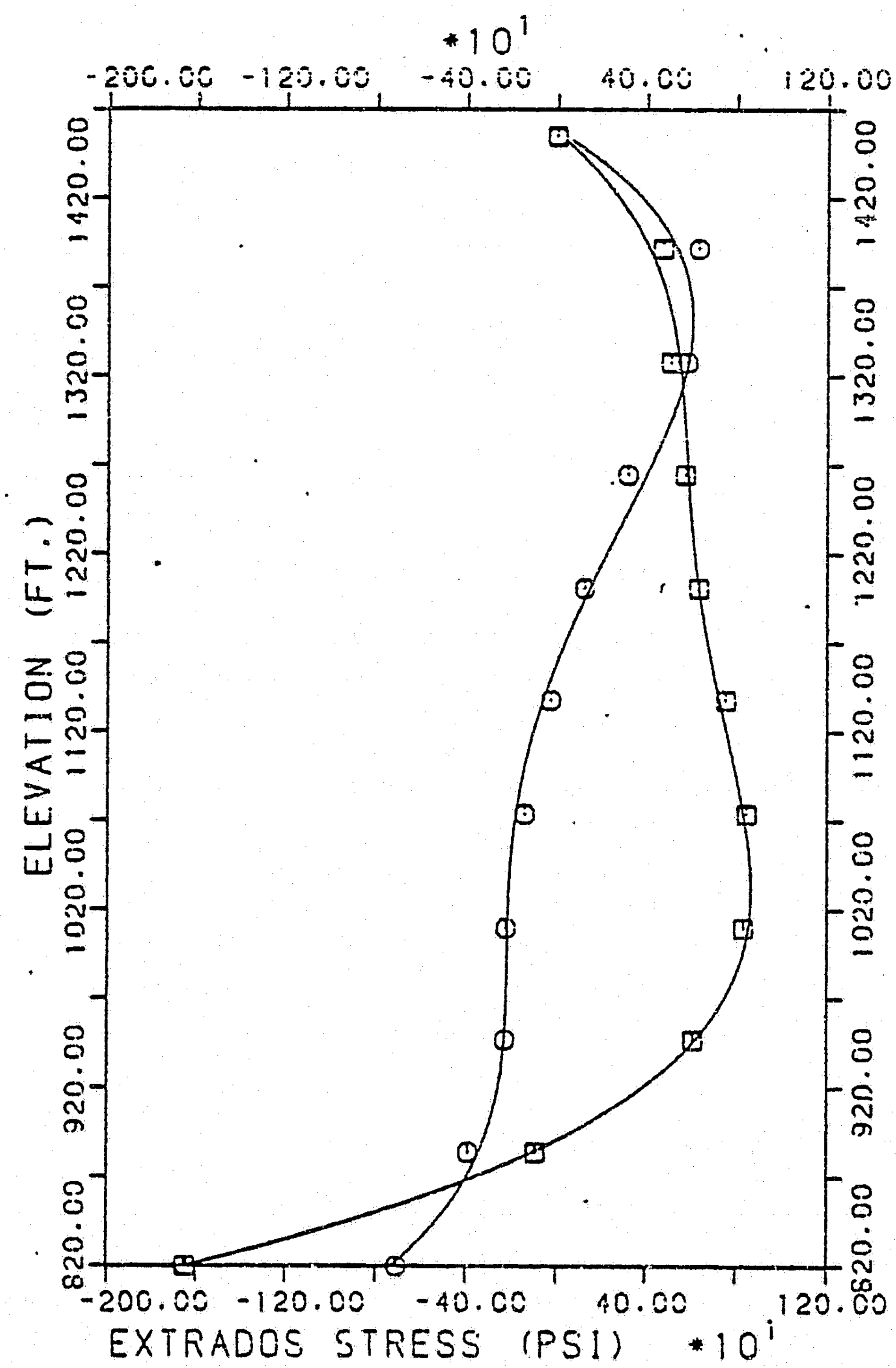
ii) Z - DISPLACEMENT.



PCA PRELIMINARY ANALYSIS PROGRAM

HYDROSTATIC, GRAVITY AND EARTHQUAKE (0.5G)

CROWN CANTILEVER STRESSES

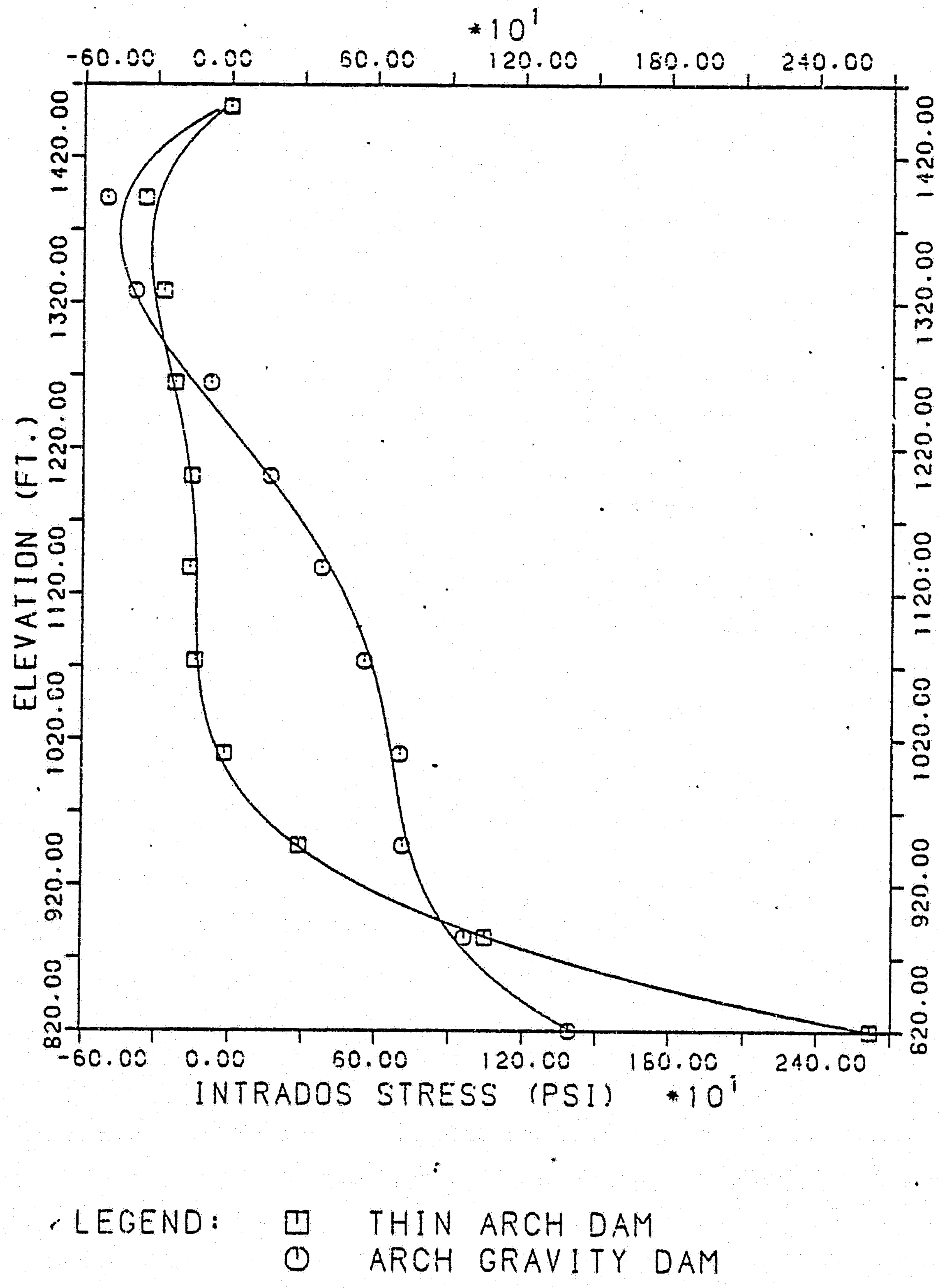


LEGEND: ⊡ THIN ARCH DAM
⊙ ARCH GRAVITY DAM

PCA PRELIMINARY ANALYSIS PROGRAM

HYDROSTATIC, GRAVITY AND EARTHQUAKE (0.5G)

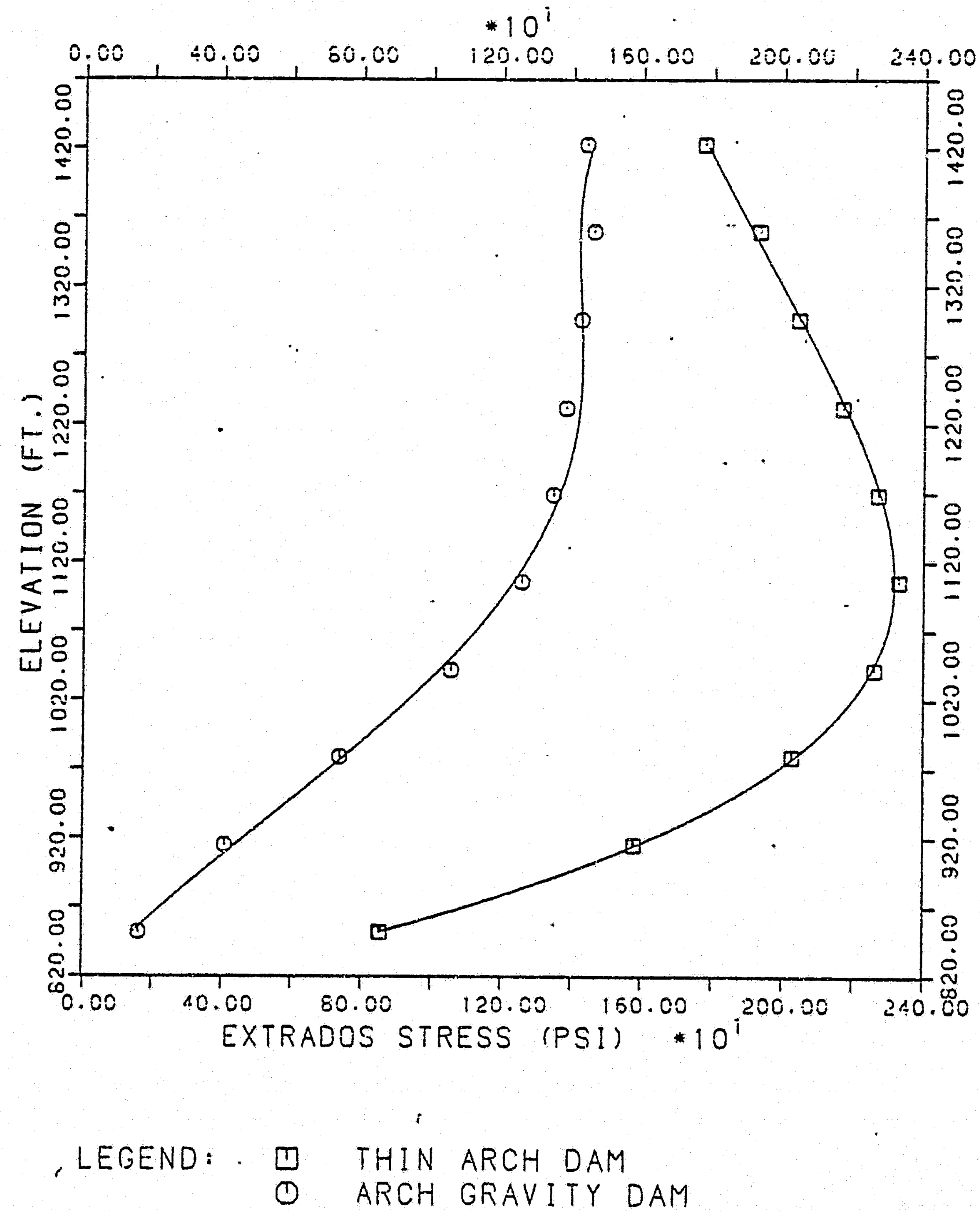
CROWN CANTILEVER STRESSES



PCA PRELIMINARY ANALYSIS PROGRAM

HYDROSTATIC, GRAVITY AND EARTHQUAKE (0.5G)

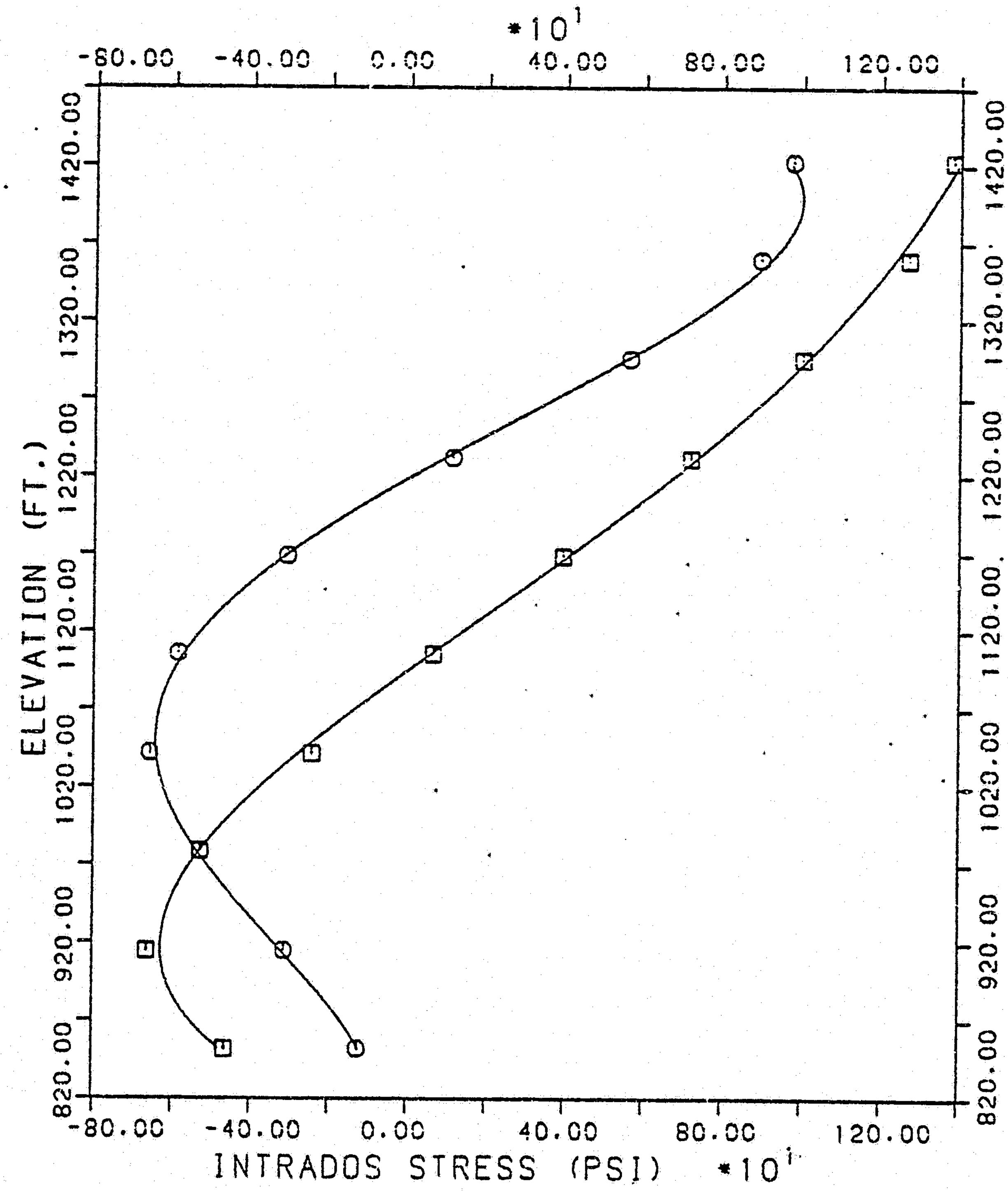
CROWN ARCH STRESSES



PCA PRELIMINARY ANALYSIS PROGRAM

HYDROSTATIC, GRAVITY AND EARTHQUAKE (0.5G)

CROWN ARCH STRESSES

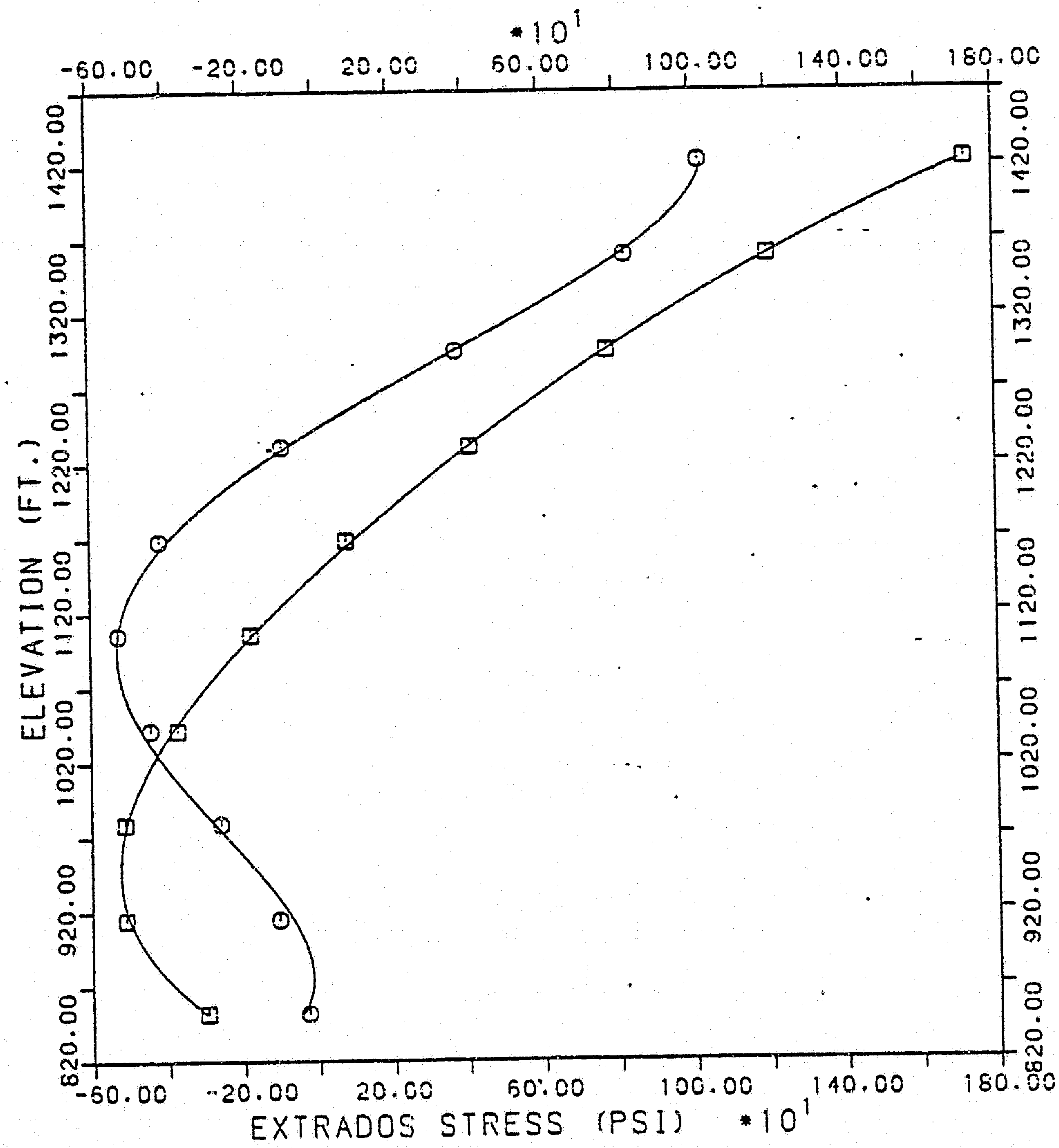


LEGEND: ☐ THIN ARCH DAM
◯ ARCH GRAVITY DAM

PCA PRELIMINARY ANALYSIS PROGRAM

HYDROSTATIC, GRAVITY AND EARTHQUAKE (0.5G)

ABUTMENT ARCH STRESSES

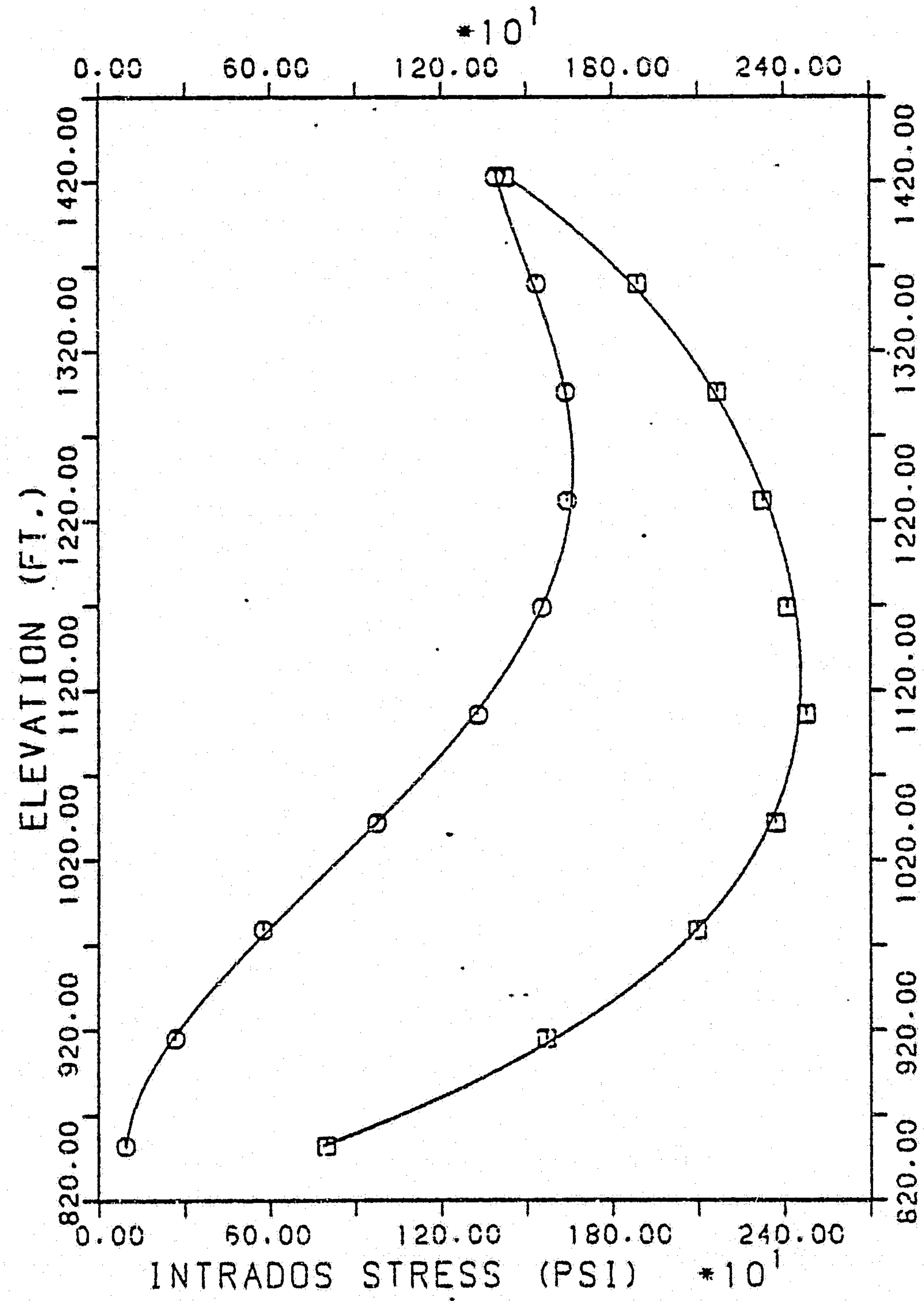


LEGEND: □ THIN ARCH DAM
ʘ ARCH GRAVITY DAM

PCA PRELIMINARY ANALYSIS PROGRAM

HYDROSTATIC, GRAVITY AND EARTHQUAKE (0.5G)

ABUTMENT ARCH STRESSES



LEGEND: □ THIN ARCH DAM
○ ARCH GRAVITY DAM

ADAP RESULTS.

SUSITNA ARCH GRAVITY DAM.

ELEVATION FT.	STRESSES (PSI) UPSTREAM CANTILEVER (1)	(2)	(3)	(4)	(5)	(6)	DOWNSTREAM CANTILEVER (1)	(2)	(3)	(4)	(5)	(6)
1455	0	0	0	0	0	0	0	0	0	0	0	0
1365	230	895	592	955	17T	0	75T	780T	395T	715T	14	7
1195	155	690	420	680	83T	5	140	612T	315	490	60	5
1037	135	510	270	400	90T	7	340	342T	445	550	70	10
890	80T	245	175T	270T	135T	2	590	235T	640	690	30	10
820	240T	160	500T	700T	160T	0	750	200T	800	840	0	12

ELEV.	STRESSES (PSI) EXTRADOS CROWN ARCH (1)	(2)	(3)	(4)	(5)	(6)	INTRADOS CROWN ARCH (1)	(2)	(3)	(4)	(5)	(6)
1455	525	1960	970	1320	0	12	360	280	500	670	50T	30
1365	520	1800	870	1220	35	10	277	450T	384	490	143T	10
1195	440	1270	600	760	38T	7	37	1325T	75	110	310T	36
1037	280	855	335	390	81T	11	113T	1470T	123T	135T	354T	47
890	25	390	35	45	136T	16	40T	1260T	50T	62T	283T	36
820	120T	100	125T	130T	170T	21	80	1120T	100	125	210T	30

(1) HYDROSTATIC + GRAVITY
(2) HYDROSTATIC + GRAVITY + TEMP
(3) HYDROSTATIC + GRAVITY + EQ (0.25G)
(4) HYDROSTATIC + GRAVITY + EQ (0.50G)
(5) 2 CM X-DISPL @ TOP → 0 @ base
[illegible] @ TOP → 0 @ base

SUSITNA THIN ARCH DAM

ELEVATION (FT)	STRESSES (PSI) UPSTREAM CANTILEVER ①	②	③	④	⑤	⑥	DOWNSTREAM CANTILEVER ①	②	③	④	⑤	⑥
1455	0	0	0	0			0	0	0	0		
1365	140	438	395	650			130	240	330	580		
1195	340	1080	552	765			30	995^{T}	180	330		
1037	500	1280	611	722			60^{T}	1210^{T}	75^{T}	90^{T}		
890	60^{T}	270	163^{T}	265^{T}			630	285^{T}	675	720		
820	560^{T}	980^{T}	1400^{T}	1600^{T}			1960	600	1980	2020		
815*	/											

ELEVATION (FT).	STRESSES (PSI) EXTRADOS CROWN ARCH ①	②	③	④	⑤	⑥	INTRADOS CROWN ARCH ①	②	③	④	⑤	⑥
1455	730	2270	1320	1820			190	0	650	980		
1365	844	2200	1284	1724			320	150^{T}	640	960		
1195	990	1960	1225	1460			170	1195^{T}	270	370		
1037	840	1690	940	1040			100^{T}	1640^{T}	125^{T}	150^{T}		
890	290	820	300	310			155	1635^{T}	166	175		
820	170^{T}	220^{T}	180^{T}	240^{T}			570	1550^{T}	600	620		
815												

① HYDROSTATIC + GRAVITY

② HYDROSTATIC + GRAVITY + TEMP. (AIR = - 40°F, STRESS FREE = 35..

③ HYDROSTATIC + GRAVITY + EQ (0.25g)

④ HYDROSTATIC + GRAVITY + EQ (0.50g)

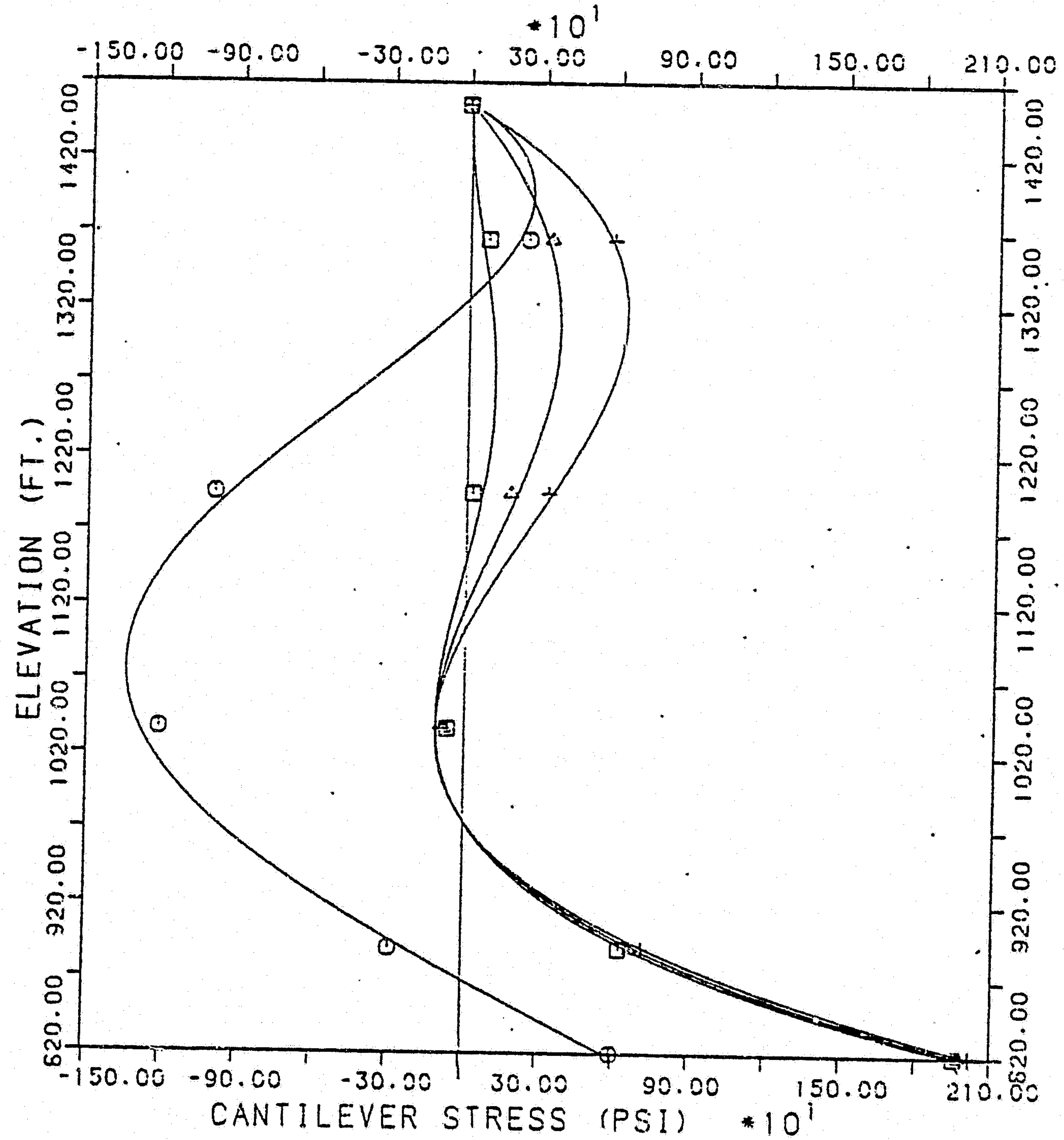
⑤

⑥

ADAP RESULTS: SUSITNA THIN ARCH DAM

CROWN CANTILEVER STRESSES

INTRADOS

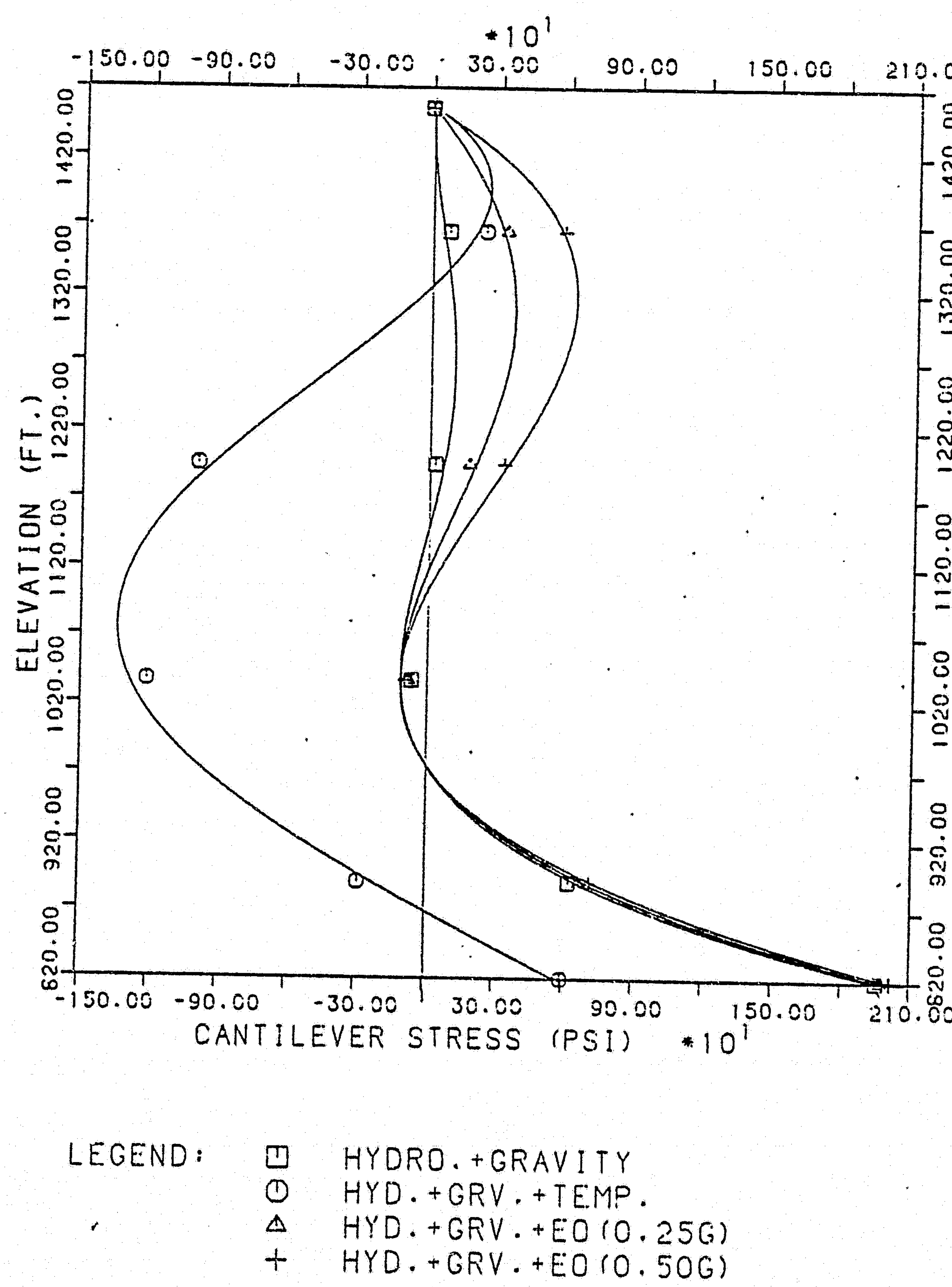


LEGEND:
- □ HYDRO.+GRAVITY
- ⊙ HYD.+GRV.+TEMP.
- △ HYD.+GRV.+EQ(0.25G)
- + HYD.+GRV.+EQ(0.50G)

ADAP RESULTS: SUSITNA THIN ARCH DAM

CROWN CANTILEVER STRESSES

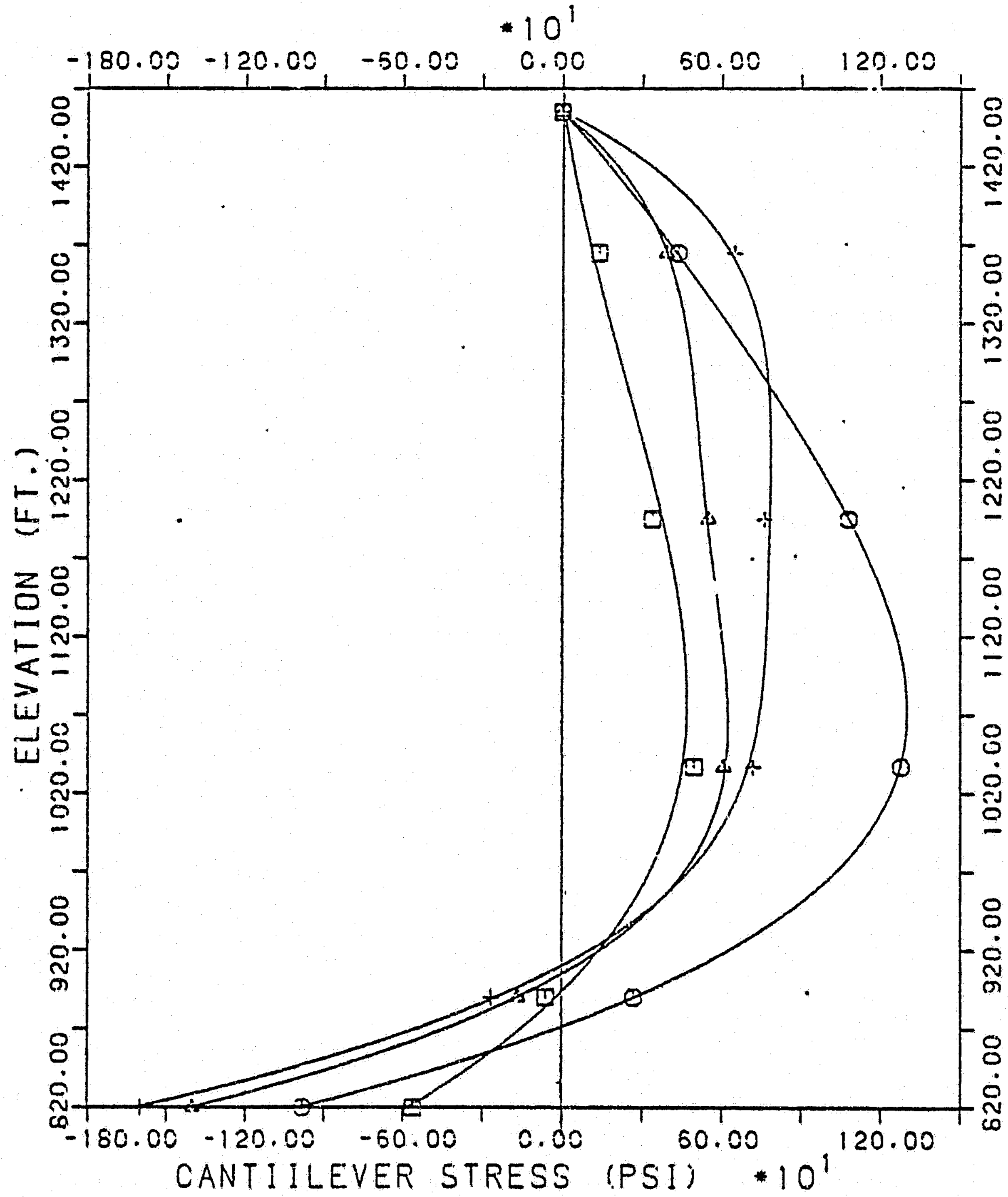
INTRADOS



ADAP RESULTS: SUSITNA THIN ARCH DAM

CROWN CANTILEVER STRESSES

EXTRADOS

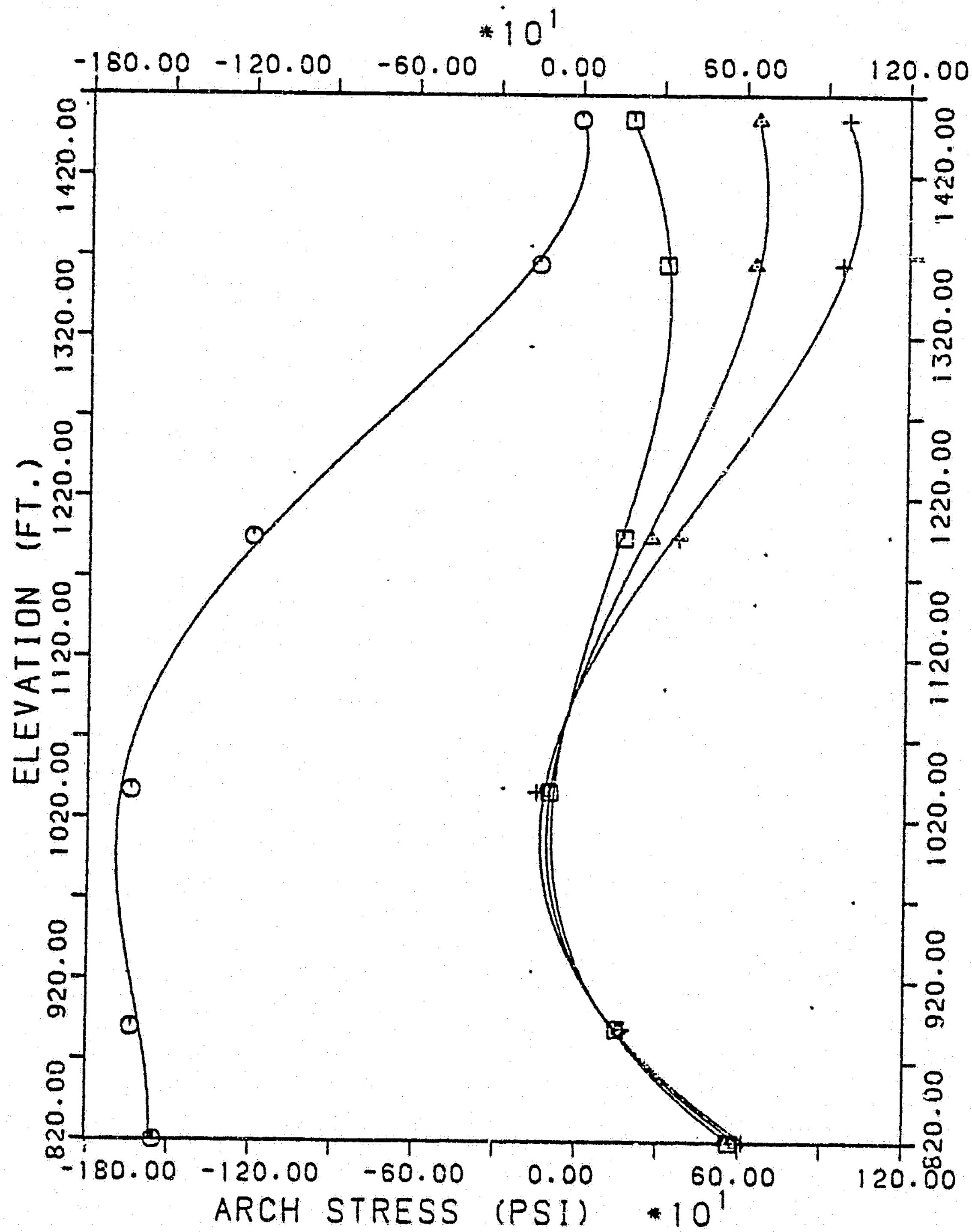


LEGEND:
- □ HYDRO.+GRAV.
- ○ HYDRO.+GRAV.+TEMP.
- △ HYD.+GRV.+EQ(0.25G)
- \+ HYD.+GRV.+EQ(0.50G)

ADAP RESULTS: SUSITNA THIN ARCH DAM

CROWN ARCH STRESSES

INTRADOS

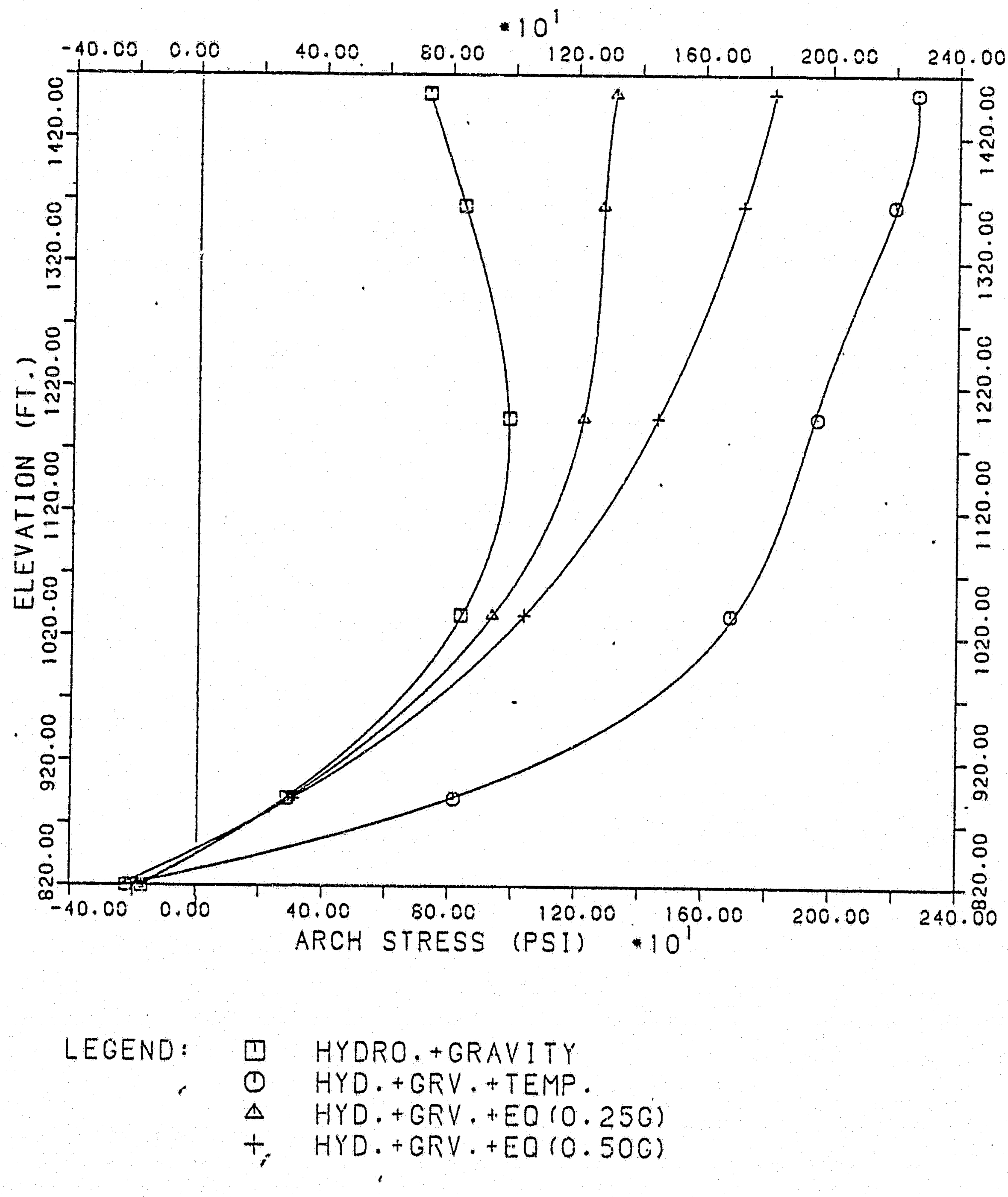


LEGEND:
- □ HYDRO.+GRAVITY
- ○ HYD.+GRV.+TEMP.
- △ HYD.+GRV.+EQ(0.25G)
- + HYD.+GRV.+EQ(0.50G)

ADAP RESULTS: SUSITNA THIN ARCH DAM

CROWN ARCH STRESSES

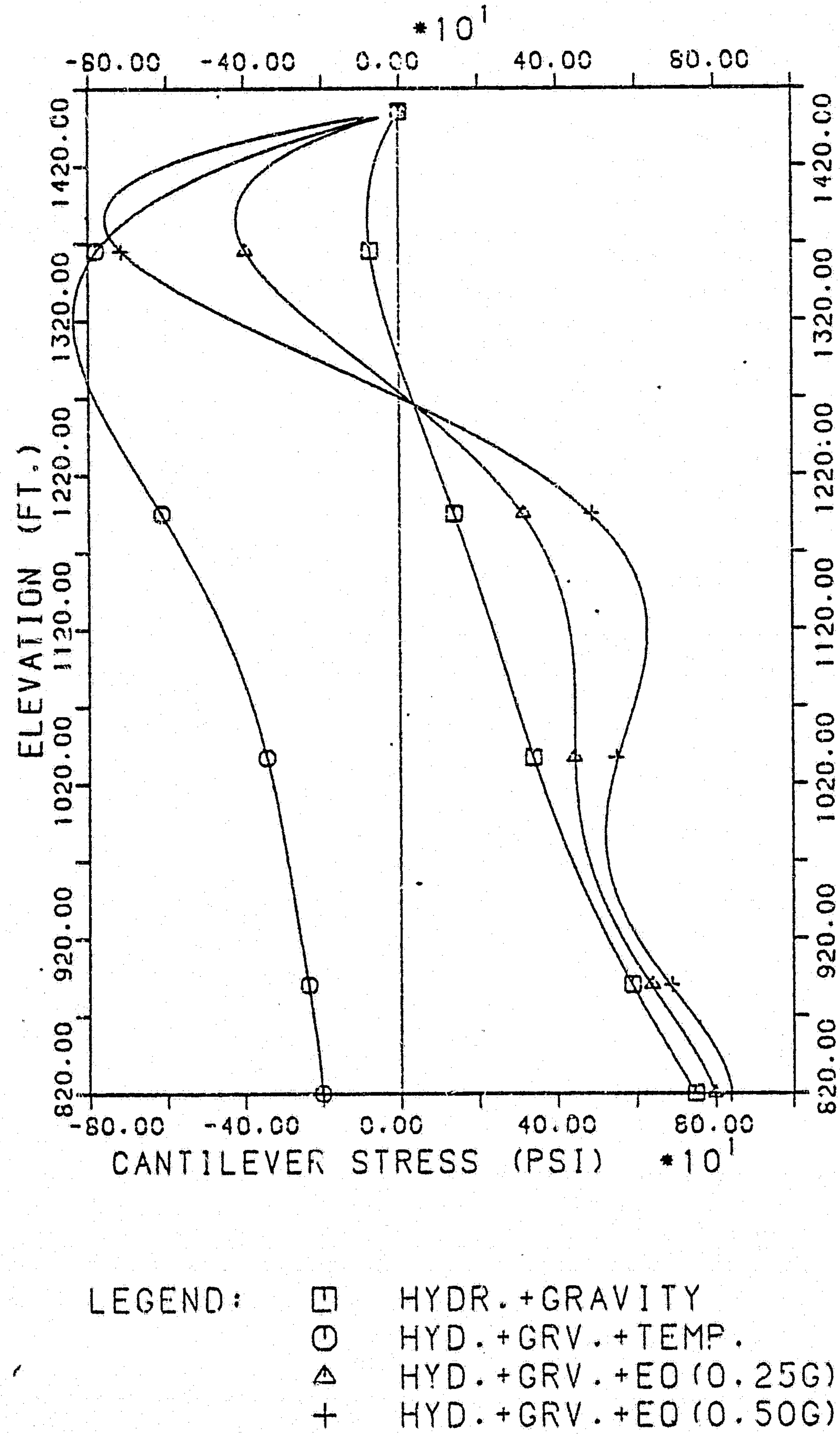
EXTRADOS



ADAP RESULTS: SUSITNA ARCH-GRAVITY DAM

CROWN CANTILEVER STRESSES

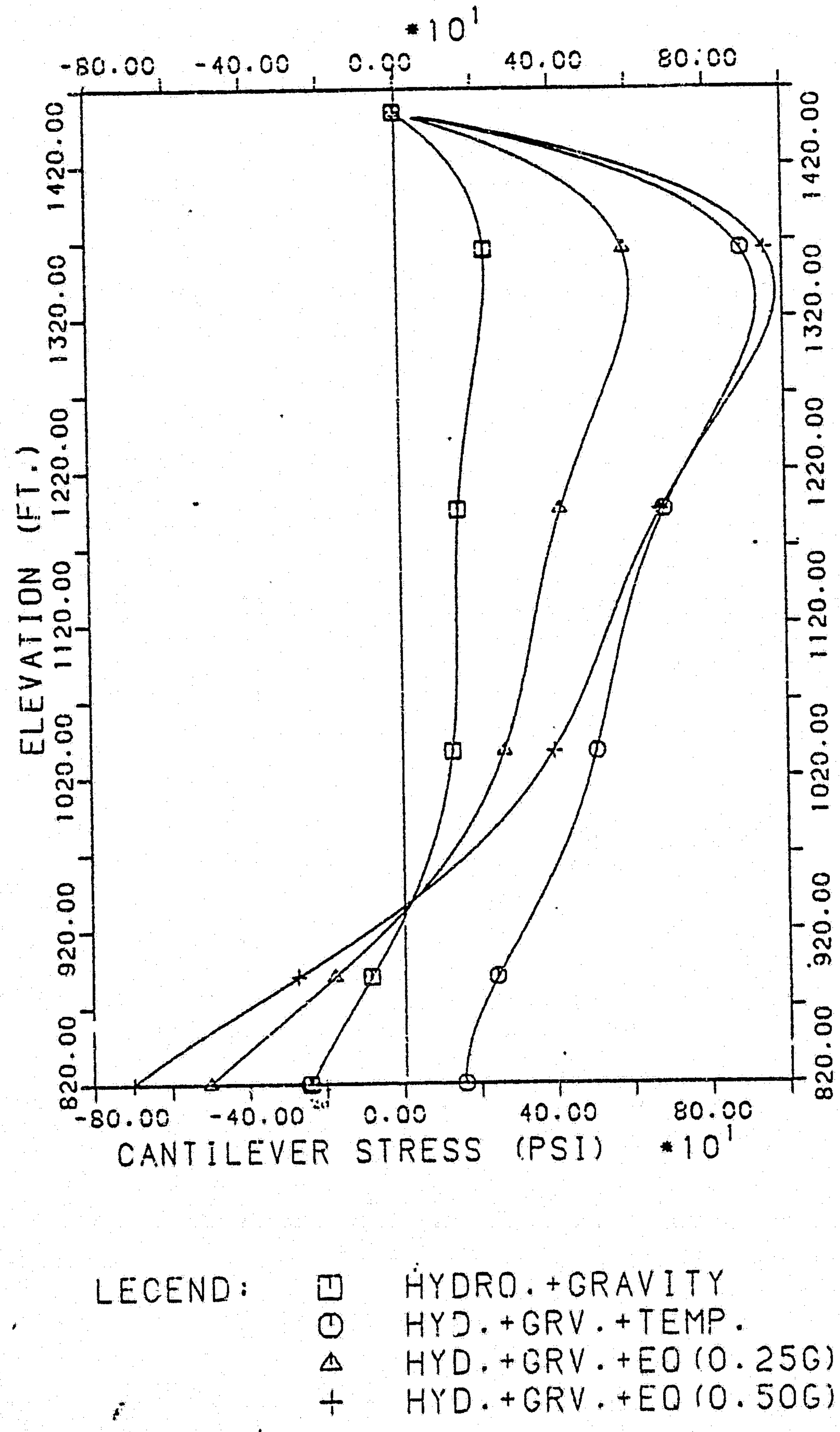
INTRADOS



ADAP RESULTS: SUSITNA ARCH-GRAVITY DAM

CROWN CANTILEVER STRESSES

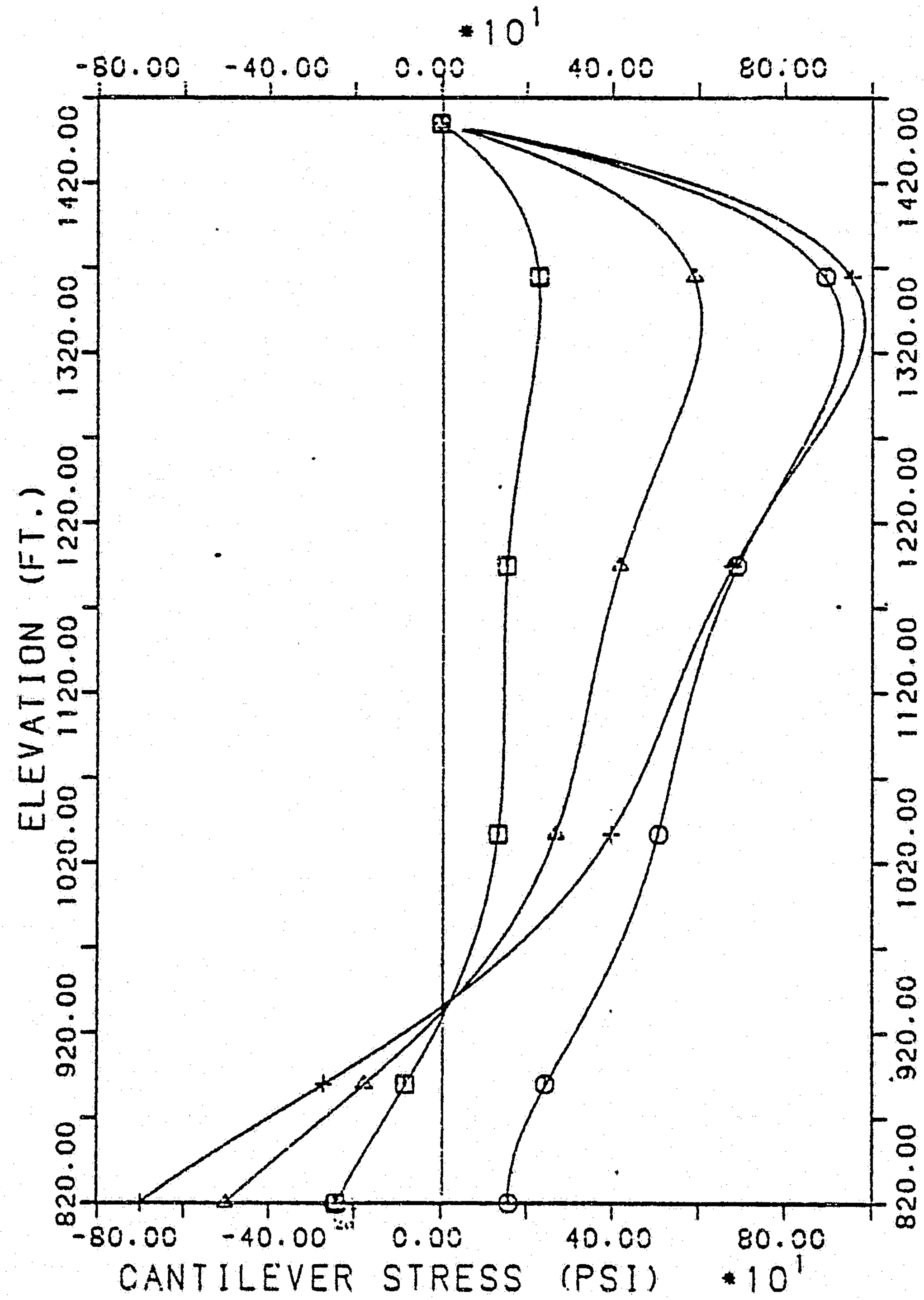
EXTRADOS



ADAP RESULTS: SUSITNA ARCH-GRAVITY DAM

CROWN CANTILEVER STRESSES

EXTRADOS

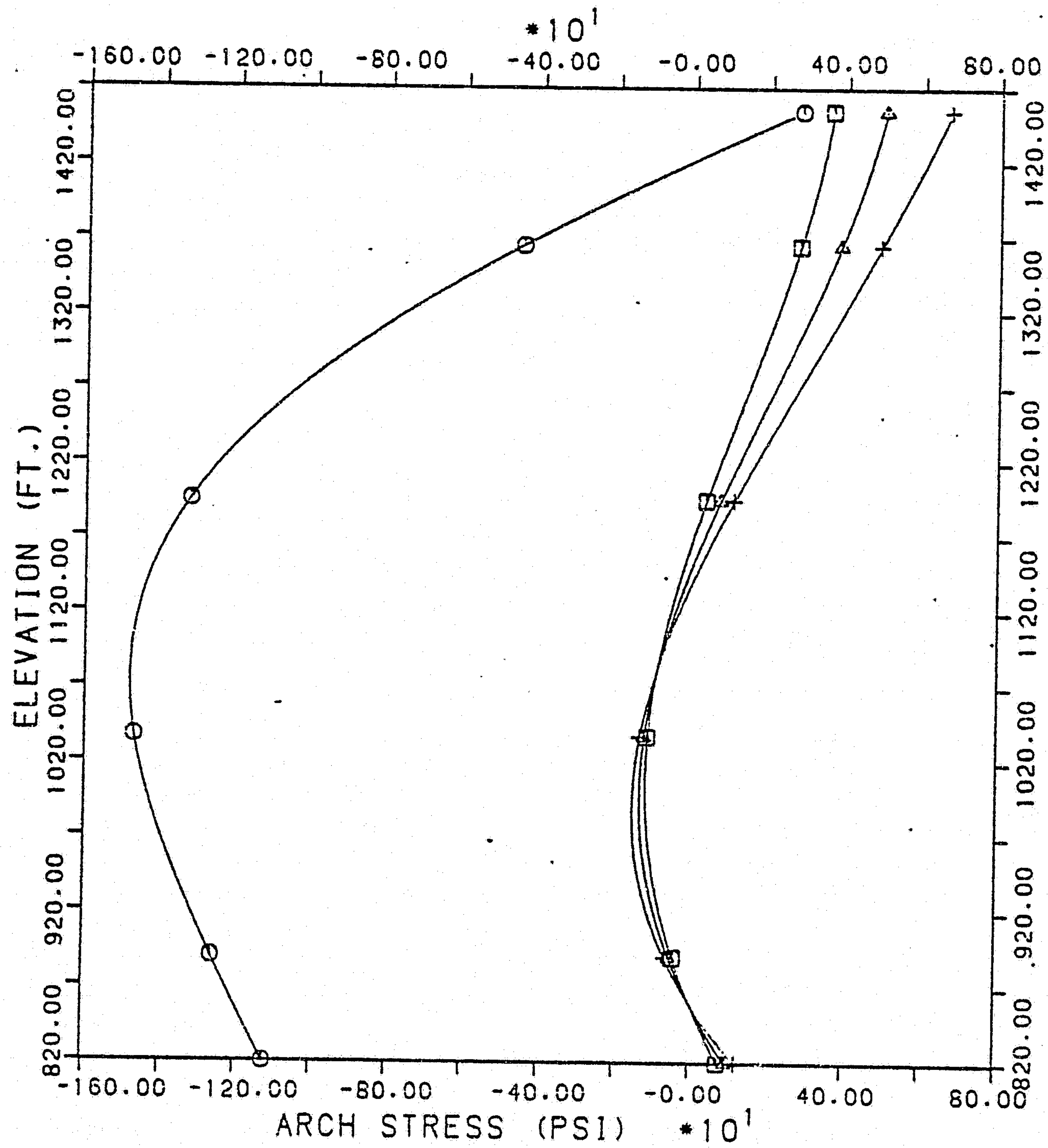


LEGEND:
- □ HYDRO.+GRAVITY
- ○ HYD.+GRV.+TEMP.
- △ HYD.+GRV.+EQ(0.25G)
- + HYD.+GRV.+EQ(0.50G)

ADAP RESULTS: SUSITNA ARCH-GRAVITY DAM

CROWN ARCH STRESSES

INTRADOS

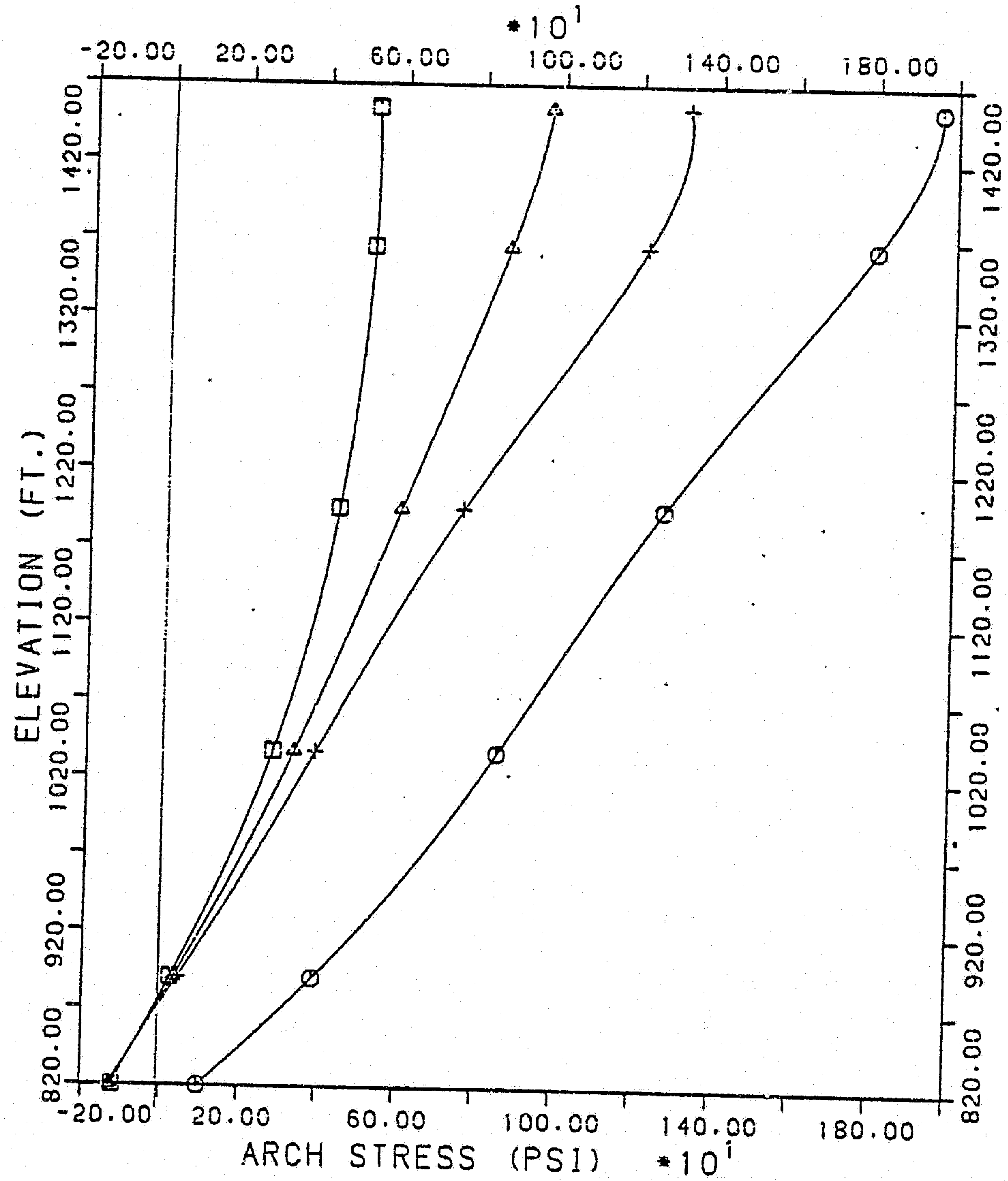


LEGEND:
- □ HYDRO.+GRAVITY
- ○ HYD.+GRV.+TEMP.
- △ HYD.+GRV.+EQ(0.25G)
- + HYD.+GRV.+EQ(0.50G)

ADAP RESULTS: SUSITNA ARCH-GRAVITY DAM

CROWN ARCH STRESSES

EXTRADOS

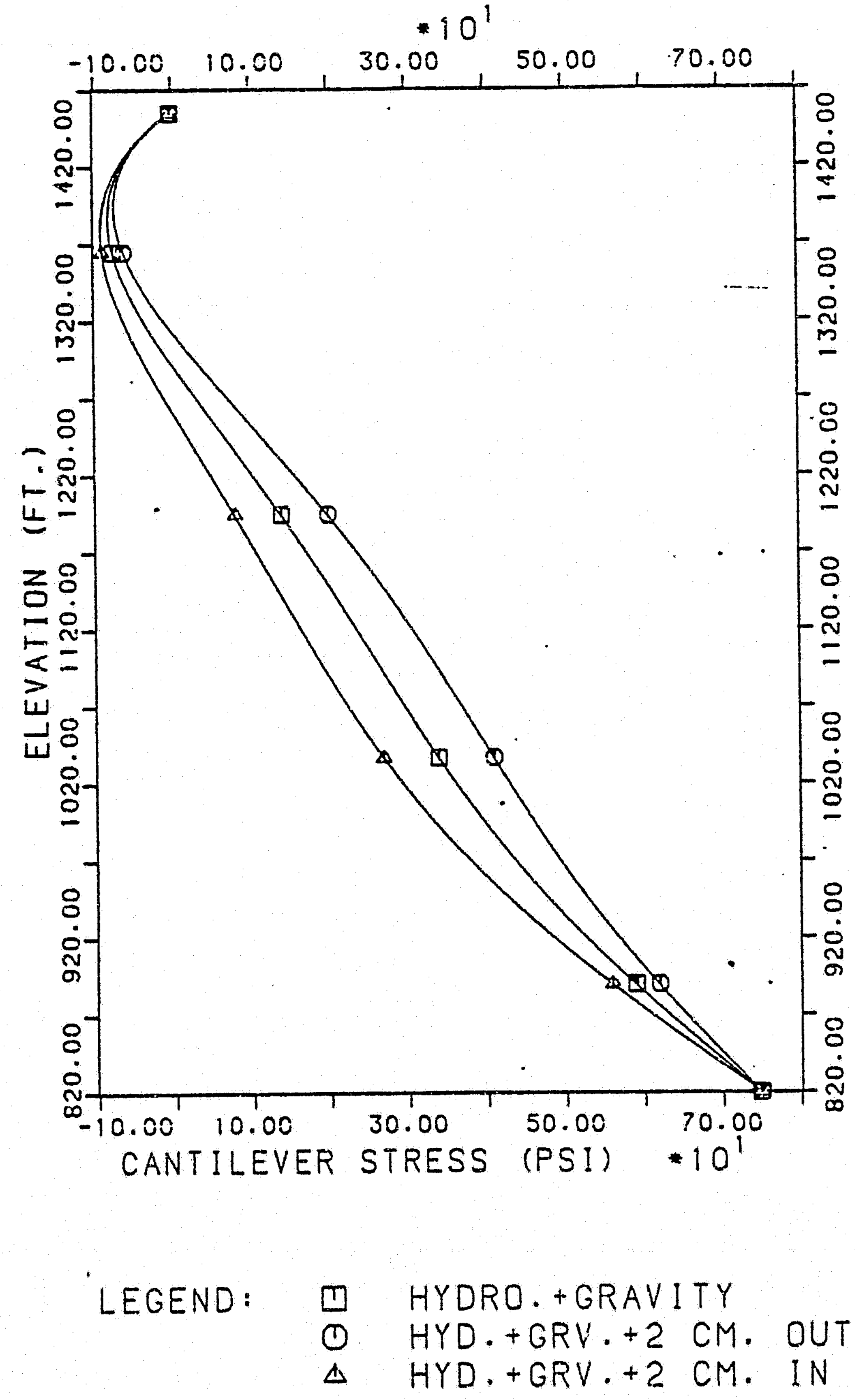


LEGEND:
- □ HYDRO.+GRAVITY
- ○ HYD.+GRV.+TEMP.
- △ HYD.+GRV.+EQ(0.25G)
- + HYD.+GRV.+EQ(0.50G)

AΦAP RESULTS: SUSITNA ARCH-GRAVITY DAM

VALLEY MOVEMENT STUDY: X DISPLACEMENT

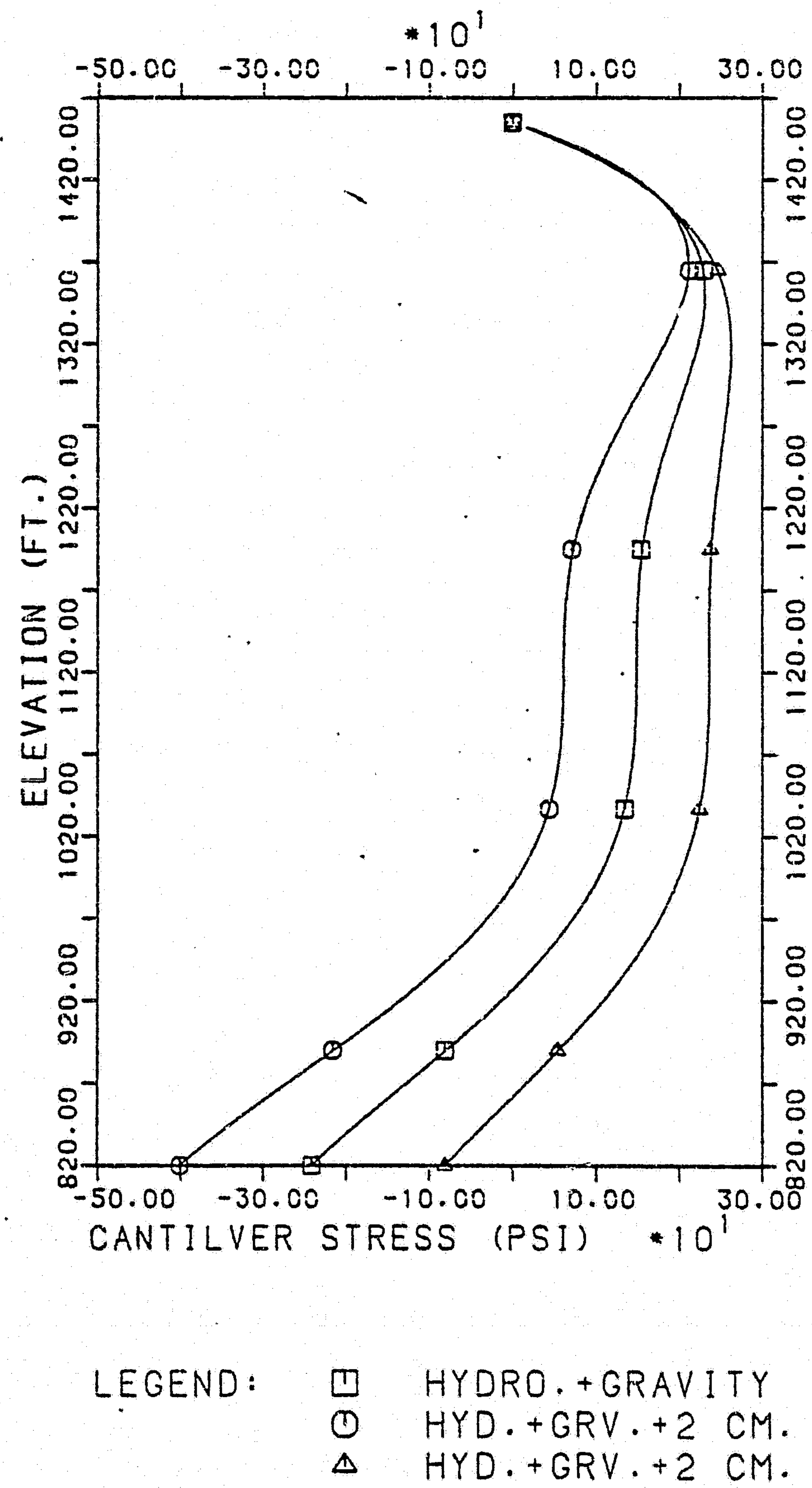
INTRADOS CROWN CANTILEVER STRESSES



AΦAP RESULTS: SUSITNA ARCH-GRAVITY DAM

VALLEY MOVEMENT STUDY: X DISPLACEMENT

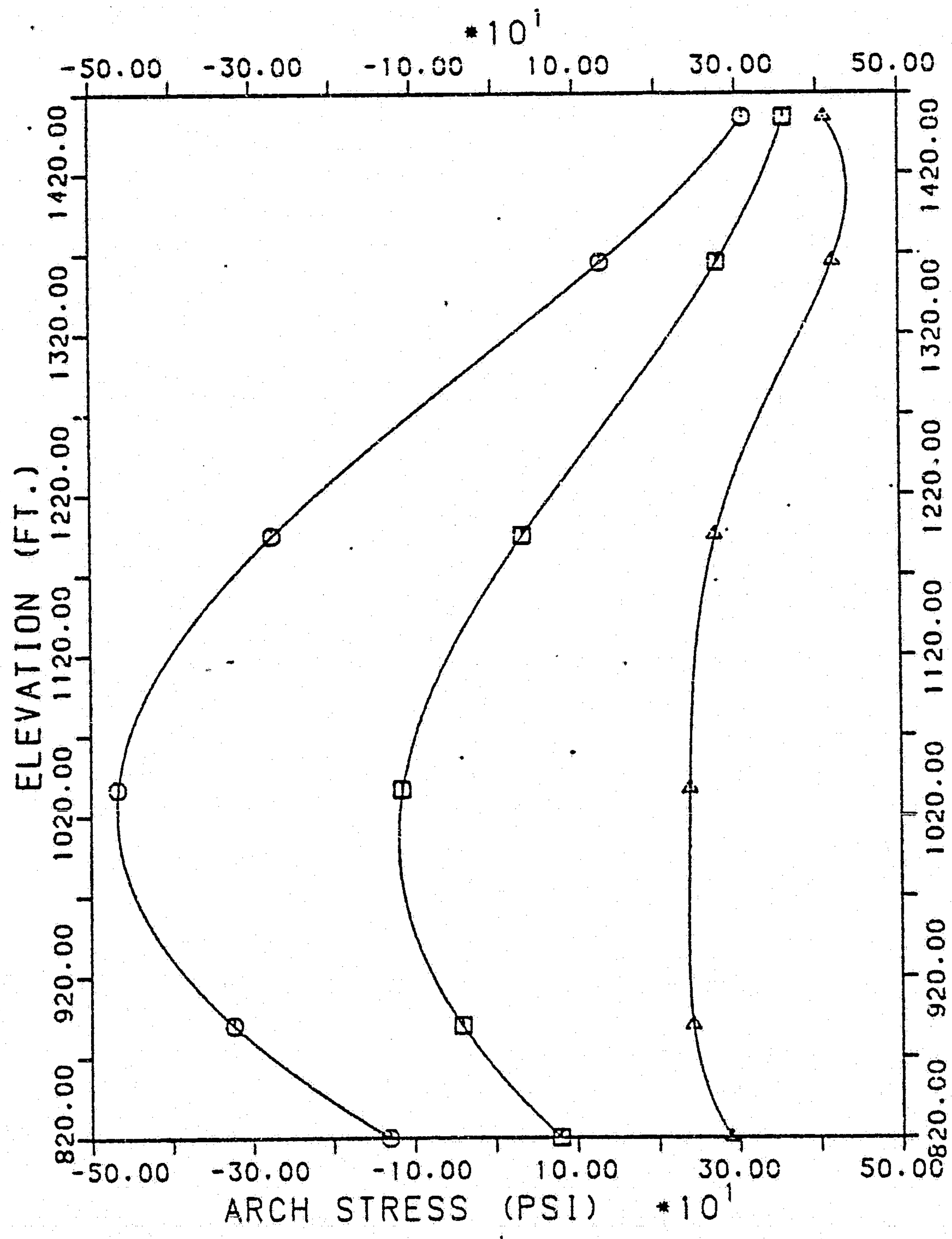
EXTRADOS CROWN CANTILEVER STRESSES



ADAP RESULTS: SUSITNA ARCH-GRAVITY DAM

VALLEY MOVEMENT STUDY: X DISPLACEMENT

INTRADOS CROWN ARCH STRESSES

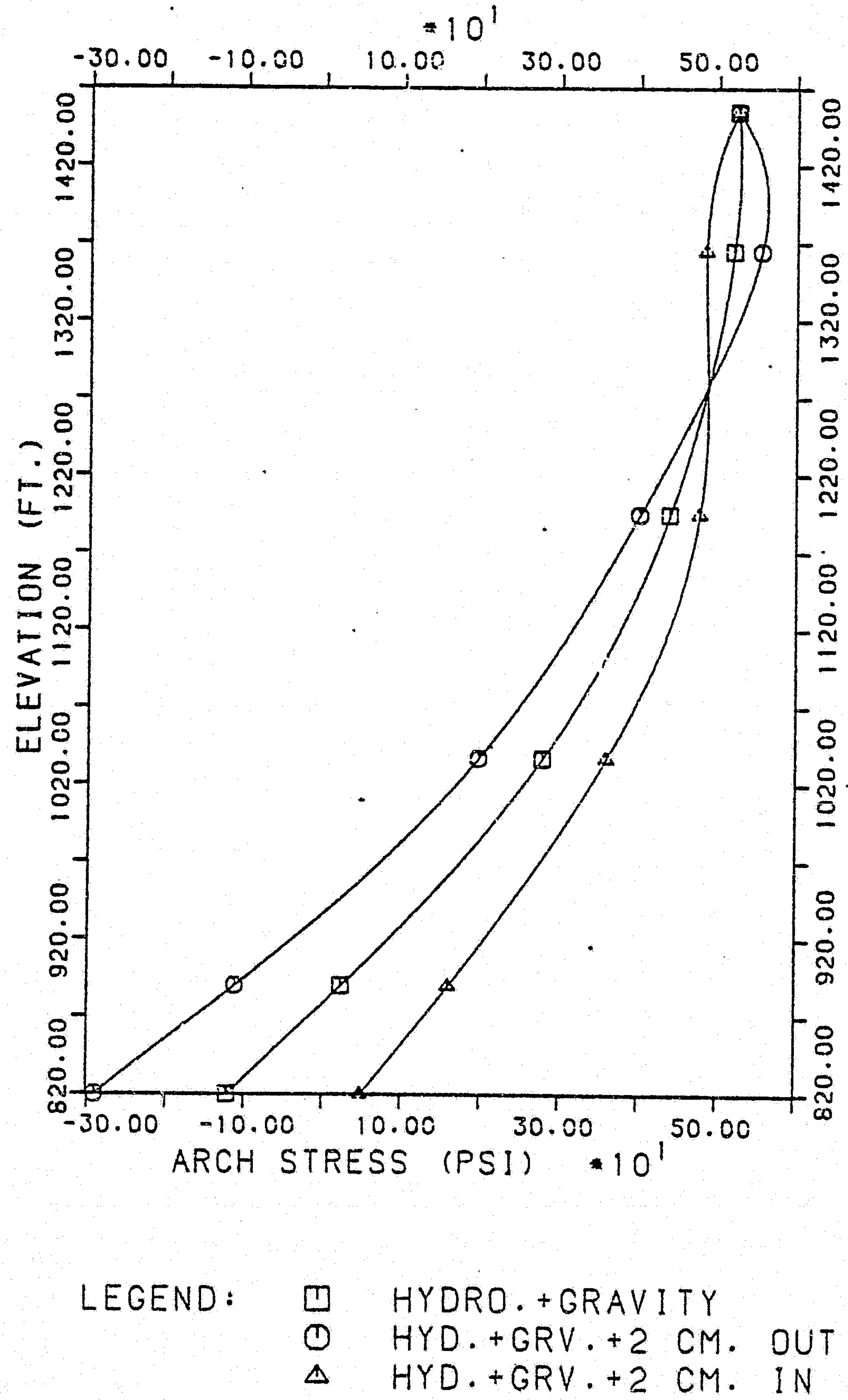


LEGEND: ⊡ HYDRO.+GRAVITY
⊙ HYD.+GRV.+2 CM. OUT
△ HYD.+GRV.+2 CM. IN

ADAP RESULTS: SUSITNA ARCH-GRAVITY DAM

VALLEY MOVEMENT STUDY: X DISPLACEMENT

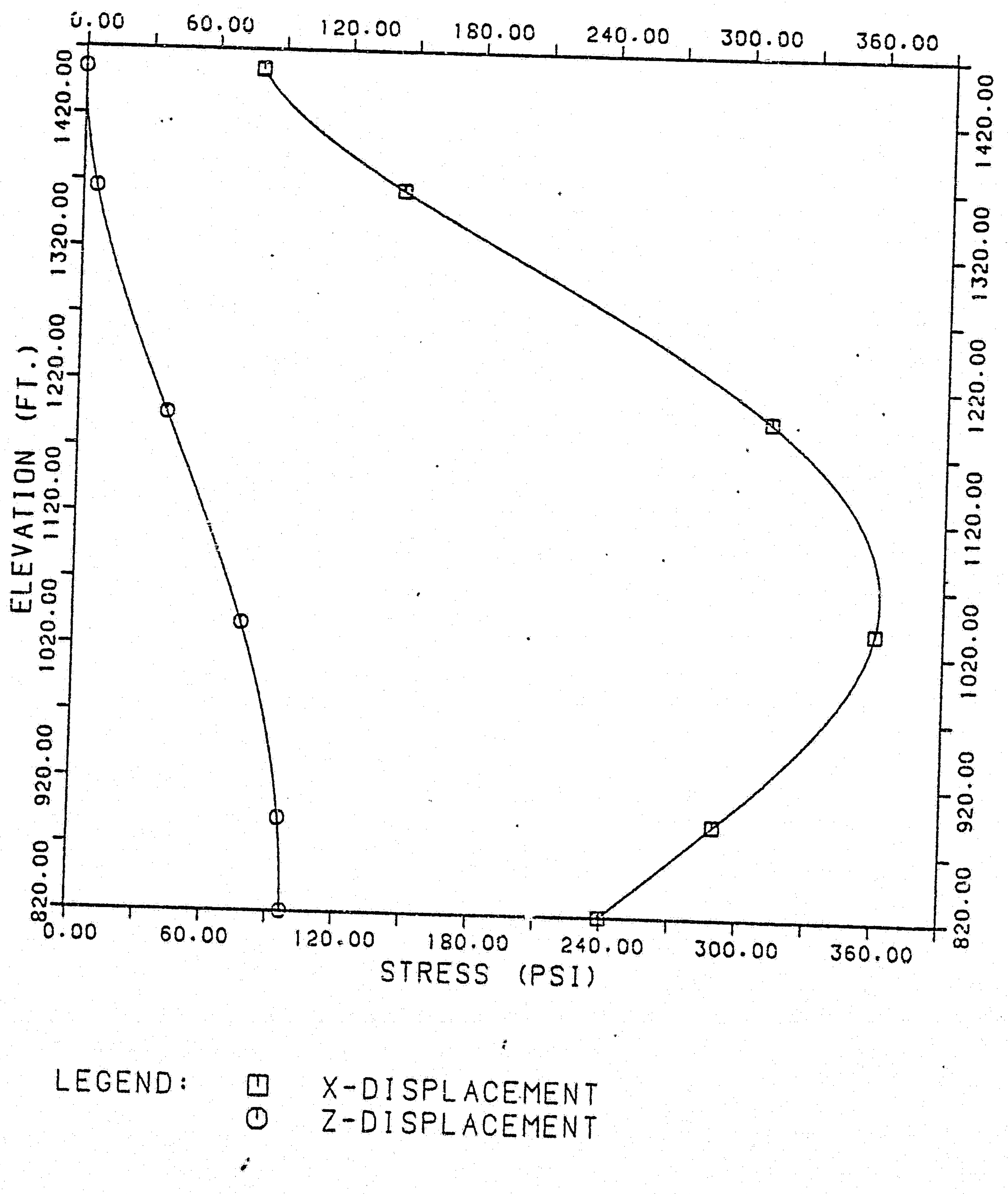
EXTRADOS CROWN ARCH STRESSES



ADAP RESULTS: SUSITNA ARCH-GRAVITY DAM

MAX. STRESSES

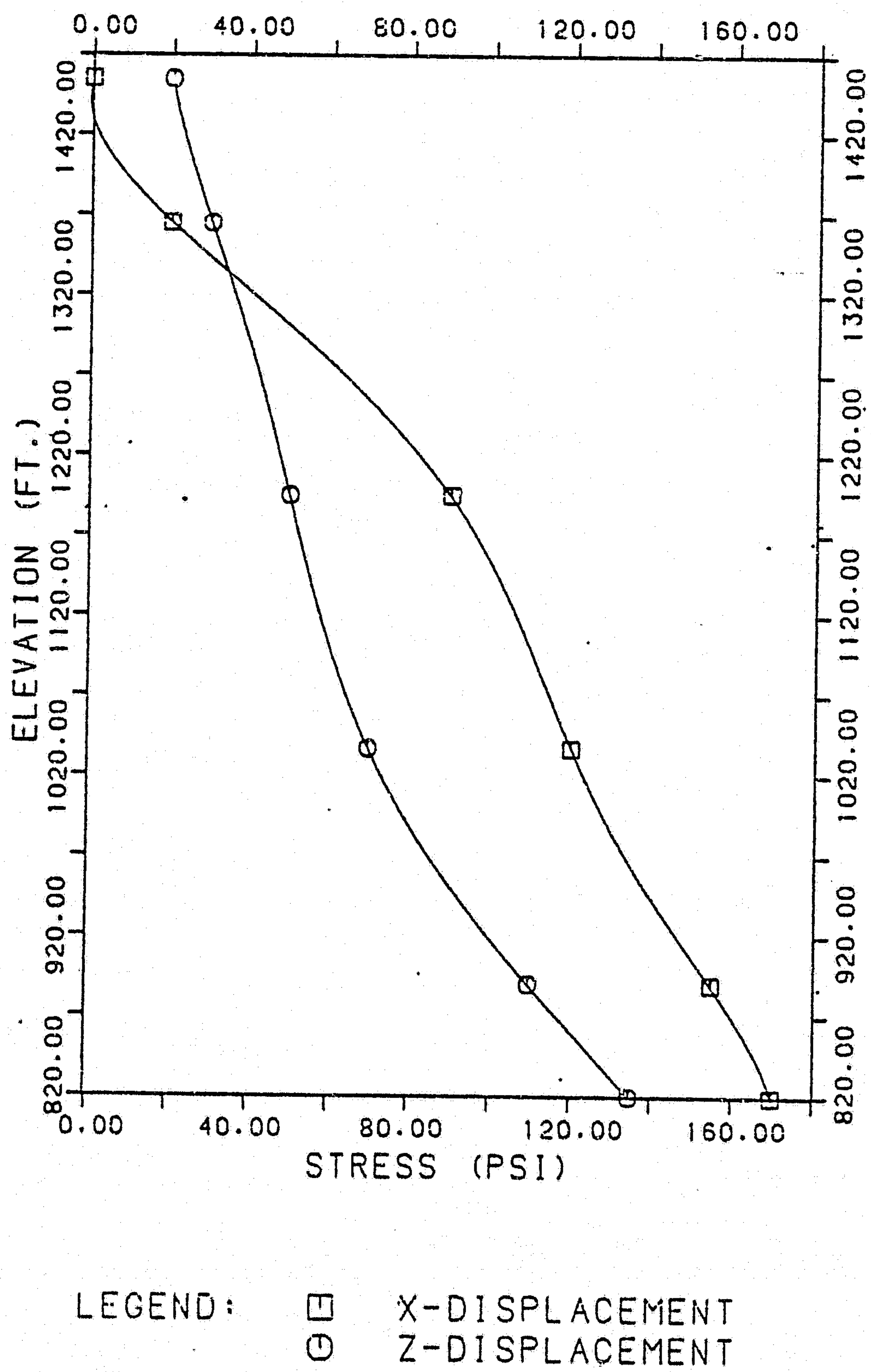
INTRADOS CROWN SECTION



ADAP RESULTS: SUSITNA ARCH-GRAVITY DAM

MAX. STRESSES

EXTRADOS CROWN SECTION



X. REPORT BY SPECIALIST CONSULTANTS PANEL

RECEIVED ... 1980

25 October 1980

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

Subject: Susitna Project
First Specialist Consultants Panel Meeting
October 20 through 24, 1980

Dear Mr. Lawrence:

Introduction

The undersigned members of the Panel visited the site on October 22, were briefed in the office of Acres American Incorporated on October 21 and 23, and had previously reviewed a package of information dated October 1980. This report presents our consensus of the information obtained and suggestions regarding future investigations on the project.

We consider the Susitna Project, as now conceived, to be viable and worthy of continued investigation.

General Geology and Seismology

The WCC presentation dealt with the well known features such as the Denali fault, the Castle Mountain fault, the Border fault and the Talkeetna fault; as well as the hypothesized "Susitna fault" and other linears defined in the WCC study to date. The Denali fault, Castle Mountain fault, and the Border fault are all well known, recent, active features that show evidence of displacing or offsetting Pleistocene features. The magnitude and minimum distances to the site of credible events on these structures are not controversial and design motions predicted from events on these structures are relatively straightforward. The possible influence of the Talkeetna fault and the Susitna linear on the design motions needs more study. The Talkeetna fault is a relatively old thrust fault which brings Triassic volcanics and Permian strata from the southeast over Cretaceous argillites on the northwest side of the fault. Although this feature does not appear to cut Pleistocene deposits, WCC has tentatively assigned to the feature a magnitude 7.5 to 7.9 event at a distance of 4 mi from Watana Dam. There is a good possibility that this is an old feature that may not be a "capable" structure. Thus it is of very high priority to perform detailed field work along this structure to investigate the age of overlying materials not displaced by this fault or to define the observed offsets of formations of known age that cross the fault. Observations in the Watana creek area may prove to be of great value since Tertiary deposits appear to cover both the Cretaceous argillites and the Triassic volcanics in this area.

Field studies also need to be conducted along the Susitna linear to establish if it is a real feature which has experienced offset and, if so, what is the evidence of the time of last movement and of the magnitude of the offset.

Other linears or possible faults close to Watana Dam should be investigated to such an extent that a statement can be made as to whether the feature is truncated by Pleistocene or older geologic formations.

If possible, a statement should be made regarding any possible structural explanation for the two clusters defined from the micro-earthquake observations.

Engineering Geology and Rock Engineering

The "fins" and "finger busters" in the Tertiary diorites as well as other rock ribs exposed in the canyon indicate that there are wide shear zones in the diorite intrusion. More exploration in the form of borings and possibly adits are necessary in the right abutment area to confirm that the rock quality is good enough to permit a reasonably accurate estimate of the cost of an underground powerhouse. Preliminary observations indicate that the construction of an underground powerhouse at Watana may be difficult or infeasible due to the wide shear zones. Reorientation of the powerhouse to minimize wall and roof instability may lead to unfavorable orientations for the penstocks.

Additional exploration of the relationship of the Tertiary clastic volcanics and andesites to the underlying diorite downstream of the dam on the right abutment is also necessary to evaluate the possible effects on the tailrace tunnels and on the possible long power tunnel. The andesites may fill an old buried valley in the diorite.

An estimate of the tunneling difficulty for the long power tunnel alternative can only be made after the various formations and the nature of the contacts between formations are mapped from Watana Dam to the downstream end of the tunnel. First priority should be assigned to this mapping for Scheme 3.

The argillite formation of Devil Canyon appears suitable for an underground powerhouse. More exploration is needed to delineate the rock quality and orientation of fractures and shears to permit an optimization of the orientation and to aid detailed roof and sidewall design.

The nature of the sheared and weathered zone of the bend in the river just upstream of the Devil Canyon site needs to be studied to determine the nature and possible origin of the feature.

<u>Watana Site</u>

<u>General</u>. Although an embankment dam with a height of about 800 ft would be comparable to the highest in North America and among the highest in the world, we consider the topography and available materials favorable to the construction of Watana Dam. The foundation and abutment conditions, although not yet fully explored, present no known unusual difficulties. We believe that further investigations of seismicity are most unlikely to indicate unfavorable features for which adequate provisions cannot be made in design. We believe that emphasis in the next exploratory phase should be placed on defining the boundaries of the pluton and the nature and effects of its contacts with the adjacent rocks in the general vicinity of the damsite.

<u>Spillway</u>. We concur that the spillway should not discharge into or through the buried valley to the right of the dam, and believe that a layout entirely in rock, closer to the dam, should be adopted. As the geologic situation becomes better defined, an upstream shift in the axis of the dam may prove advisable.

Reservoir Slides. Our overflight of the reservoir area for several miles upstream of the dam indicated to us that the topography and the nature of the materials near the reservoir rim are such that major landslides into the reservoir, such as to endanger the dam or control works, is remote even under seismic conditions. Therefore, we consider that special investigations of this possibility are not needed to establish the feasibility of the project.

Cross Section and Materials. We concur that a conventional embankment dam section with near-central core is appropriate. For estimates, the upstream and downstream slopes of 2.25:1 and 2:1 are reasonable. We would prefer that the downstream slope of the core be at least slightly positive to assure that settlement of the shells would induce compression in the core.

We consider that the riverbed alluvium should be removed beneath the core, filters, and transitions, and within a zone defined by lines extending from the outer edges of the crest downward at slopes of 1.5:1. For the feasibility studies we consider it advisable to assume that the material will be removed beneath the remainder of the embankment except where needed to support the cofferdams. Whether some of this material can remain can best be decided during the required excavation of the central portion.

We consider rounded gravels, cobbles, and boulders to be superior to rockfill for the shells of such a high dam and suggest that the upstream shell, in particular, should consist primarily of rounded material beneath a near-surface zone of rockfill that may serve as riprap. Such material, which does not suffer corner-breakage on saturation, reduces the likelihood of longitudinal cracking near the crest and tends to dilate under small strains. The latter property substantially increases the resistance during seismic shaking. Downstream of the core, use of rounded materials near the transitions is also advantageous, but compacted rockfill in a substantial portion further downstream will be satisfactory to accommodate suitable material from structural or other required excavation.

In our judgment, static and dynamic analyses can be deferred until the general quality and availability of borrow materials has been established. To this end the emphasis in the next exploratory phases should be placed on determining the character of the riverbed materials, particularly their grain-size, and on the extent and thickness of lodgment till deposits that might be suitable for core. Attention should be given to locating deposits of sufficient thickness to permit exploitation in near-vertical faces so that the moisture content will be increased as little as possible before and during excavation and transportation. The possibility of routinely processing all or most of the alluvium for optimum use in the dam should be considered.

Continuing investigations of the permafrost conditions in the south abutment are considered of high priority.

Devil Canyon Site

We have visited Devil Canyon Site and have examined the engineering and geologic data pertinent to it. We consider the site to be well suited for the construction of an arch dam.

Adits are not considered to be essential for further definition of foundation characteristics prior to a feasibility determination. Additional boring and laboratory investigations will be necessary to define the locations, directions and characteristics of joints and shears.

The possibility of surface rupture at the Devil Canyon Site must be resolved.

A more sophisticated arch dam design based on well formulated criteria should be prepared. Such a design should be supplemented by well documented and generally accepted analytical methods. This is considered to be necessary to establish the economic feasibility of the project.

Yours very sincerely,

Merlin D. Copen

Merlin D. Copen

Alfred J. Hendron Jr.

A. J. Hendron, Jr.

Ralph B. Peck

Ralph B. Peck

RBP/ajj