SUSITNA HYDROELECTRIC PROJECT

INTERNAL REVIEW BOARD MEETING #1

GEOTECHNICAL AND SEISMIC ASPECTS

JULY 23, 1980

NOTES ON MEETING

TABLE OF CONTENTS

KDC

SUSITNA HYDROELECTRIC PROJECT

AGENDA OF IST INTERNAL

BOARD REVIEW MEETING - GEOTECHNICAL

AND SEISMIC ASPECTS

Time & Location: Wednesday, July 23, 1980, 8:30 a.m. (all day)
Board Room, Niagara Falls Office
Ontario, Canada

In Attendance:

Project Team	Review Board
J. Lawrence	D. MacDonald
C. Debelius	J. MacPherson
J. Gill	L. Wolofski
I. Hutchison	D. Hepburn
V. Singh	H. Eichenbaum
S. Thompson	

Purpose: To review work plan for 1980 Task 4 (Seismic Studies) and Task 5 (Geotechnical Investigations) and preparation for External Review Board Meeting (tentatively scheduled for late August).

Moderator: John D. Lawrence

Agenda:

Time	Topic	Speaker
8:30 AM	Introduction	J. D. Lawrence
9:00 AM	Existing geologic, geotechnical & seismic data	S. Thompson & V. Singh
10:00 AM	Break	
10:15 AM	1980 Geotechnical Field Program	J. Gill
11:15 AM	Discussion	
12:00	Lunch	
1:00 PM	1980 Seismic Studies	V. Singh
2:00 PM	Discussion	
2:30 PM	Wrap-up & Summary of Board Views	
3:15 PM	Break	
3:30 PM	Scope and schedule of External Review Panel Meeting	

NOTE: Speakers are requested to hand out detailed agendas of their presentations during the meeting.

SUSITNA HYDROELECTRIC PROJECT

INTERNAL REVIEW BOARD MEETING #1, JULY 23, 1980

PRIMARY OBJECTIVES

1. Familiarization
2. Review of:
   - proposed dam locations and types (preliminary concepts only)
   - geotechnical exploration program scope and schedule
   - proposed seismic and reservoir induced seismicity programs
   - potential tunneling problems (preliminary concepts only)
3. Recommendations for scope of first external review panel meeting (late August)

SUSITNA HYDROELECTRIC PROJECT
INTERNAL REVIEW BOARD MEETING #1,
July 23, 1980
ACRES CONSULTING SERVICES OFFICE, CANADA
SUMMARY

August 4, 1980
P5700.13.10

In Attendance:

Project Team	Review Board
J. Lawrence	D. MacDonald
C. Debelius	J. MacPherson
J. Gill	L. Wolofsky
R. Henschel	
I. Hutchison	
V. Singh	
S. Thompson	
J. Hayden	

Introduction

John Lawrence began the meeting with introductions of all participants, followed by a brief summary of the agenda and speakers. A series of slides and talk was used to give general background on the Susitna Study Project, the various subcontractors forming the study team, and their role in overall project. This portion was concluded with slides taken along the Susitna River Valley, starting in glacial headwaters and progressing into the lower river basin. John Hayden gave a brief summary of the current status on all the various subtasks, with the exception of Tasks 4 and 5 which were discussed later in detail.

Existing Geologic, Geotechnical and Seismic Data

Virendra Singh summarized the geotechnical data currently available for the four sites of interest; i.e., Denali, Vee, Devil Canyon and Watana. This data includes a summary of investigation completed by others at each site, significant features identified and conclusions about each site. (see attached copies of view graphs.) Some additional data had only recently been received and review and compilation (subtask 5.01) had been consequently delayed.

Stewart Thompson gave a brief review of the regional and site specific geology for both proposed damsites. The geologic history is very complex and not well understood. Information at both sites is somewhat limited due to poor rock exposures. Field mapping program of damsites and reservoirs is currently planned but access is very difficult. A series of slides were presented showing general conditions and geology. At Devil Canyon there is believed to be a relict channel and possible shear zone on the left abutment which needs further investigation as it may have serious impact on site suitability or type of dam. Also, possible stress relief features (open fractures) exist in the left abutment which need to be drilled and verified. It was recommended that in order to prove the abutment suitable for an arch dam it may be necessary to excavate adits in due course. Slope stability in the reservoir also needs to be investigated. Permafrost conditions, thick overburden and steep slopes combined with thawing and wave action produced by reservoir can potentially result in localized beaching, slides and slope failures. There is a need to identify potential problem areas and evaluate effects of such failures. It was suggested that such slides will most probably occur and the effort in the study should be directed towards a means of handling the problem. The large waves created by earthquakes or landslides was discussed. Adequate freeboard would have to be maintained in the reservoir to handle such cases.

1980 Geotechnical Field Program

Jim Gill reviewed the geotechnical program as originally developed for the Plan of Study and the permitting requirements for the program. BLM is lead agency, however, most activities are located on native lands. There is presently a problem with the Chickaloon Village lawsuit over disputed

land claims which is interfering with field programs. We are not allowed to work on disputed lands until the matter is settled. The major area affected is borrow area G at Devil Canyon (see map). Based on a review of existing data, budget and logistics, the original program as developed in the Plan of Study was revised for 1980 with the intention of providing an increased amount of diamond drilling this year with sufficient work in borrow areas to confirm materials and overlap next years program. The revised program as shown in Figs. 1 thru 5, and detailed in Tables 1 thru 4 was discussed.

Following the recent site visit by S. Thompson, L. Wolofsky and P. Morris, the program was reviewed and revised somewhat further. Based on their recommendations the total number of diamond drill holes to be completed this year was revised to 3 at each site. (Watana BH-6, 2 & 8; Devil Canyon-BH 1, 2, & 4.) The philosophy behind this change was to reduce the expenditures during 1980 while still maximizing the data obtained, and leaving enough flexibility to allow for changes in layout which may result from Task 6 studies and which would then be investigated in 1981. Presently BH-6 at Watana is complete and BH-2 is underway. The auger drilling program is complete, but had some difficulties as the materials generally contained boulders, particularly in borrow area E, and it was not possible to get holes as deep as originally planned. This results in need for deep test pits (probably in fall/winter) to obtain samples for lab testing.

Other areas which require some further discussion and development include:

- application of SLAR and low sun angle photos for identification of permafrost
- high moisture contents (>7%) from thawing frozen materials in borrow areas will make handling and suitability of materials very questionable.

-intrumentation consisting of thermal probe and piezometers has to be evaluated further and the type and means of installation resolved.

- existing piezometers installed by the Corps of Engineers should be reinstated and read if possible. Interpretation of readings is currently difficult as riser pipes are filled with diesel fuel.
- possibility of using technical climbers at Devil Canyon for mapping.

Discussion: A general discussion of the morning's topics raised the following points:

- at Devil Canyon there is a need to look at earth/rockfill dam alternatives and possible borrow sources for construction materials.
- all available geotechnical data pertaining to Devil Canyon is to be reviewed in Buffalo and commented on by the end of September.
- methods of sampling permafrost in rock and the significance to design need to be reviewed. Past projects have used "chiller" set-up with good results.

  There is a question of what temperature to use for solution to prevent formation of ice during drilling.
- spillway designs and locations need to be determined at both sites.
- it is desirable to minimize 1980 program and keep enough money and flexibility to allow for layout changes in structures. Emphasize features this year which will have a major impact on site suitability.
- there is a need to advance layout studies to late 1980 to allow sufficient time for design of 1981 investigation program.
- tunnel alternative layouts are underway. Any investigation (for tunnel) will be done in 1981, but will be a major change to the original Plan of Study.
- there is a need to resolve which load growth forecast the dam designs

are to be based on. It is possible to have range of schemes for various forecasts.

- the earthquake factor to be used in design has to be established so preliminary work can start. A figure of 0.68 mentioned in previous Corps reports is a peak acceleration for 1 cycle and not for periods of strong ground motion which is likely to be 1/2 to 2/3 of this. An acceleration of 0.5 g is considered adequate for preliminary design. The impact of such a factor on dam design should be evaluated as soon as possible.

1980 Sesmic Studies;

Virendra Singh summarized the seismological studies presently being performed by Woodward-Clyde Consultants, which include installation of a micro seismic monitoring network and identification and evaluation of potential activity of faults within the project area. The primary objective of these studies is to define the maximum probable earthquake distance from sites and attenuation at the sites such that an appropriate earthquake factor and gound motion can be selected for design. WCC is also supposed to evaluate potential for reservoir induced seismicity. It is expected that a site meeting in late August will be held by WCC with a preliminary report in October and a final report in November (see viewgraphs).

Discussion

There was some discussion about reservoir induced seismicity (RIS). WCC Preliminary evaluation of historical data indicates about a 90% probability of reservoir induced seismicity for Watana and a 50% probability for Devil Canyon. General consensus was that (RIS) would occur, but that magnitude of resultant earthquake would be less than the maximum probable design earthquake and should therefore not have any significant affect on design.

WCC studies are geared toward developing the maximum probable earthquake in project area and attenuation curves to each site. Acres is to select design earthquake. It is considered that three months of monitoring of the micro-seismic network would be sufficient this season, and that it is not necessary to monitor all winter. Reservoir induced seismicity is a potential psychological problem to people rather than a design problem. There is some concern over the Susitna fault as to whether or not it really is a fault, and if so, whether it is active. The location is within about 2-3 miles of Watana damsite.

There was considerable discussion over what earthquake factor to use in preliminary design. Previous reports give values up to 0.68g, which is greater than any known values used for existing dam designs. It was felt that this value is the maximum peak acceleration for one cycle and not the value for the period of strong ground motions of significant duration which would be used for design. Normally the value for design would be 2/3 to 1/2 of the peak. It was suggested that value for preliminary design should be 0.5g and it would be worthwhile to examine literature on existing dams in high seismic areas to get a feel for what effect it will have on the design of Watana or Devil Canyon. After reviewing the problem in-house the next step would be to consult outside expertise via the proposed review panel. A recent ICOLD report has case histories of large dam failures in China due to earthquake. It includes very detailed analysis of failure mechanisms which might prove useful.

There is a need to develop approximate layouts of both developments by early '81 so that investigation programs can be developed. It was generally considered better to spend extra time in the office now (earlier than originally scheduled) developing layouts based on assumptions rather

than having to potentially waste time in the field on exploration of non-feasible schemes.

Conclusions

Wrap-Up - Some of the key points which came out of the meeting were:

1) The schedule for layout studies must be re-examined and accelerated, such that preliminary layouts are available in early '81. This will allow for flexibility in the design of the '81 drilling program.

2) The type, layout and discharge channels for spillways must be examined.

3) Earthquake factor to be used in preliminary design must be deter mined.

   Very little precedence exists for such high seismic regions. It was suggested that we assume 0.5g until more data from WCC becomes available in the near future. Acres should review current designs for dams in highly seismic areas with the possibility of requesting outside opinions/expertise.

4) Devil Canyon will require adits to verify abutments for an arch dam prior to design. In the original POS it had not been planned to use adits until Phase II work. It will be possible to use borehole data and down-hole camera, geophysical logging and instrumentation both to verify that the site appears suitable and that adits should subse- quently be used to confirm this.

5) To apply for the FERC license there has to be sufficient data for a specific dam layout at a specific site to prove feasibility. Some flexibility may be allowed for relatively minor changes after licens ing, but a major change such as type of dam, or location may not be acceptable to FERC. It presently appears that it is not possible to

prove suitability of Devil Canyon site for arch dam by mid 1982 in view of the need for adits not currently scheduled. Therefore it will probably be necessary to submit a license application for both dams with a type of dam other than an arch at Devil Canyon, or submit separate applications as data becomes available. It remains to be determined if there is any way to delay submission of Devil Canyon section of license application to allow sufficient time to satisfactorily prove the suitability of the Devil Canyon site for an arch dam or other dam type. There is also a problem with licensing if investigations prove that one of the sites is not suitable, and a new site has to be investigated. Data must be reviewed as it becomes available and discussions held with FERC people has been very cooperative in this respect thus far.

6) The question of reservoir slope stability and how we are going to handle it needs to be addressed further. From preliminary site reconnaissance it is obvious that beaching, thawing and slope instability will occur with reservoir filling. There is a need to identify those area which are likely to present problems, and to determine what effects they will have on the reservoir and what measures, if any, have to be taken. This problem will be aggravated by the proposed 100-150 foot annual fluctuation in reservoir levels at Watana. Aesthetically it could be a problem but should not have serious engineering impacts on operation of the reservoirs. It was proposed that an in-house review be made of reports for similar projects to determine what alternatives have been used.

External Review Panel

At present the status of the External Review Panel, originally scheduled for late August, is unclear. A five member review panel was recommended to APA by Acres. These recommendations are currently being reviewed by the APA Board of Directors. The last word was that APA may appoint another firm to interface with the panel. It is likely that this firm would then have Acres make a presentation to the panel and then make its own recommendations to APA based on finds by the review panel. Scheduling of all this is still undecided as the other firm has not been selected yet. It was suggested that earliest possible meeting might be in late September. In light of this situation it was suggested that we (Acres) should recommend to APA a separate meeting of a smaller panel of outside consultants (possibly members scheduled for the APA review panel) in the near future to review our programs, since the external APA review panel may be too late to accomplish anything useful. This matter was to be looked into further by John Lawrence.

Closing

Another meeting of the Internal Review Panel and Project Team was tentatively scheduled for later this year to review the completed field data and earthquake data from Woodward-Clyde.

If possible, site visits for review panel member will be arranged at convenient times in the summer program, with possible on-site meetings.

Reported by Robert Henschel
Robert Henschel

ATTACHMENT

A

EXISTING GEOTECHNICAL & SEISMIC DATA

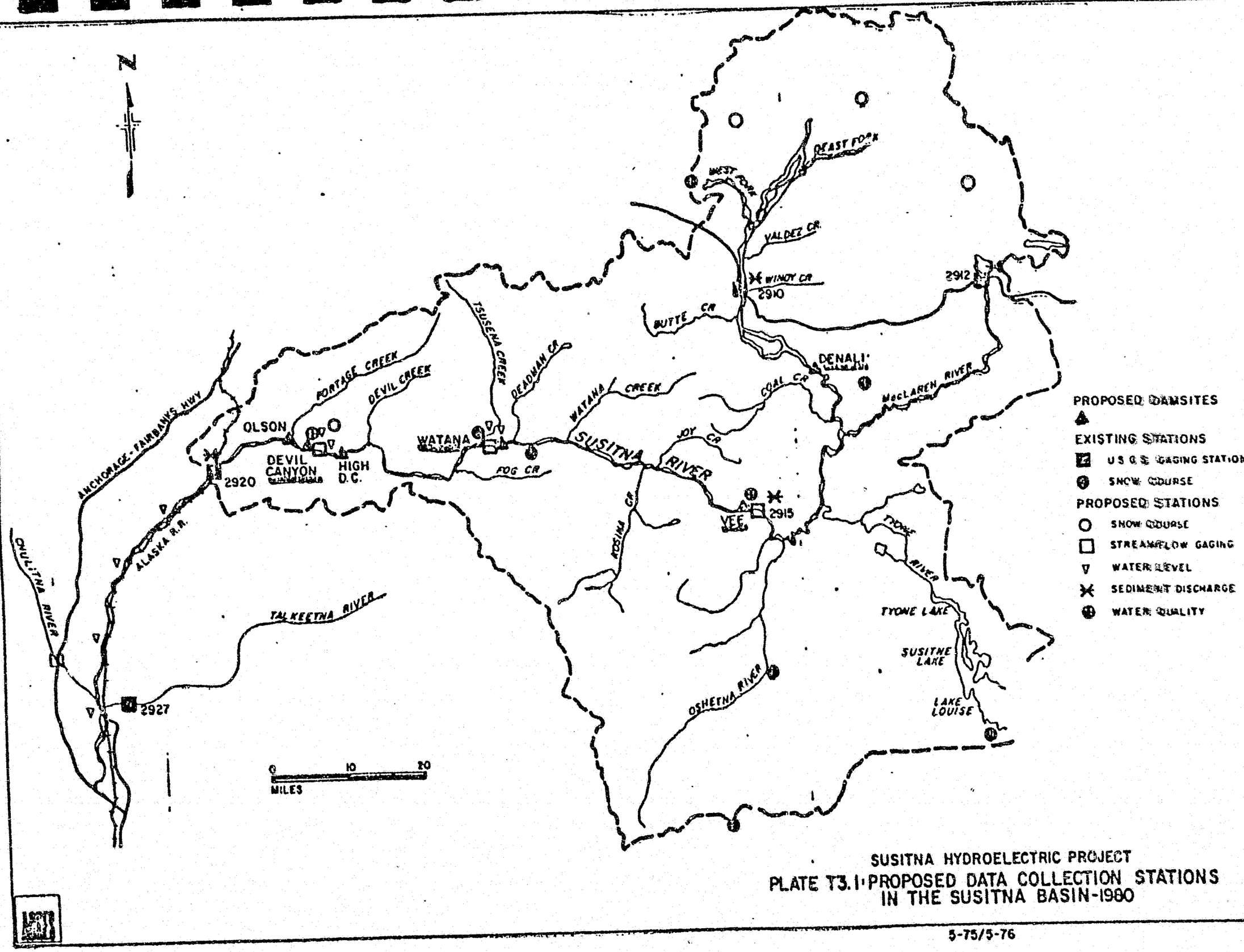
I. GENERAL

- A. Geology and Seismic Reports
- B. Site Specific Data

II. SITE SPECIFIC DATA - GEOTECHNICAL

- A. Denali Site
- B. Vee Canyon
- C. Devil Canyon
  - Investigations
  - Significant Features
  - Summary and Conclusions
- D. Watana
  - Investigations
  - Significant Features
  - Summary and Conclusions

III. DISCUSSIONS



SUSITNA HYDROELECTRIC PROJECT

PLATE T3.1 PROPOSED DATA COLLECTION STATIONS IN THE SUSITNA BASIN-1980

5-75/5-76

DENALI

STRUCTURE: 235' HIGH EARTH DAM

INVESTIGATION:

1958-'59 USBR

- 5 BOREHOLES ~ 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.

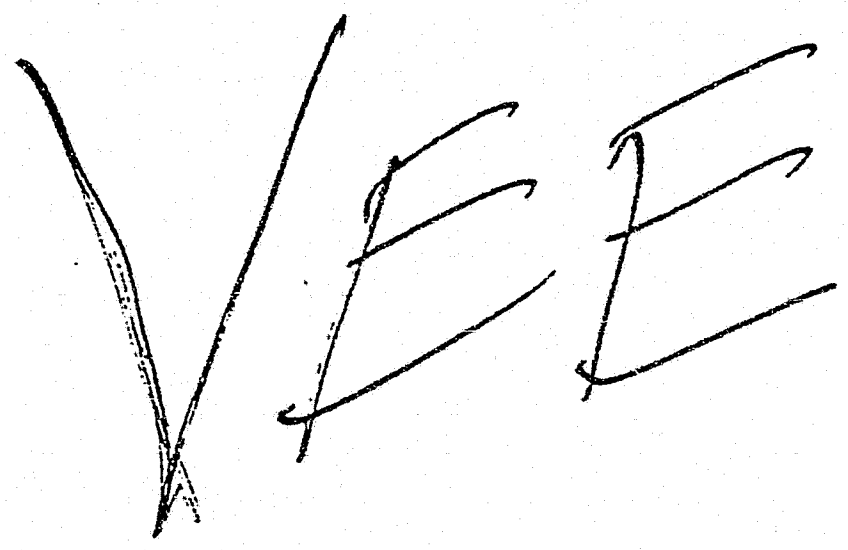
DEEP CUTOFF

LIQUIFACTION

SUMMARY:

MOVE SITE 8000' D/S

EXTENSIVE FIELD INVESTIGATIONS
REQUIRED



VEE CANYON

STRUCTURE: 470' HIGH EARTH DAM

INVESTIGATION:

1960-'62 USBR

13 BOREHOLES, 1646 LF, 180' MAX.

16 DOZER TRENCHES

SIGNIFICANT FEATURES:

VERY STEEP CANYON (800')

125' OVER BURDEN

POOR QUALITY ROCK

SADDLE DAM

400' OVERBURDEN

PERMAFROST TO >60'

ROCKLINE BELOW EXISTING RIVER EL.

MATERIAL SOURCES:

NOT DELINEATED

GLACIO-FLUVIAL FOR EMBANKMENT

RIVER CHANNEL FOR AGG.

VEE

PROBLEMS:

ROCK SLOPE STABILITY - EXCAVATION

LEFT ABUT - HEAVY TALUS

PERMAFROST

POOR ROCK QUALITY - HEAVY TUNNEL SUPPORTS

400' OVERBURDEN UNDER SADDLE DAM

SUMMARY:

ADDITIONAL EXPLORATION REQ'D.

SITE UNSUITABLE FOR CONCRETE DAM

DEVIL

DEVIL CANYON

STRUCTURE: 635' HIGH CONCRETE GRAVITY-ARCH DAM

INVESTIGATION:

USBR 1957-'58; COE 1978

- 22 BOREHOLES 30' - 150' DEEP
- 19 TRENCHES AND TEST PITS
- 3300 LF SEISMIC

LAB TESTS

- PETROGRAPHIC
- ELASTIC PROPERTIES
- UNCONFINED COMPRESSIVE STRENGTH

SIGNIFICANT FEATURES:

- 35'± ALLUVIUM OVER BED ROCK
- SHEAR ZONES AND FAULTS - BOTH ABUTS.
- 3 JOINT SETS (FROM N25°W)
- BEDDING DIPS SOUTH
- 35' - 50' WEATHERED ROCK
- 8.5 AT 40 MI. OR 7.0 AT 10 MI. EARTH QUAKE

MATERIAL SOURCES:

CONCRETE AGG. AND EMBANKMENT MTLS. READILY AVAILABLE 1000' U/S

MARGINAL FREEZE/THAW RESISTANCE

IMPERVIOUS - PROCESSED

PROBLEMS:

LEFT ABUT.

SOUTHERLY DIPPING BEDS REQUIRE EXTENSIVE DENTAL WORK

ROCK SUPPORT REQUIRED

THRUST BLOCK - ANCHOR (DEEP)

RIGHT ABUT.

BEDDING DIPS ~ 60° SE (UNFAVORABLE)

SHEAR ZONES - 1' ± to the river

SADDLE DAM

E-W TRENDING BURIED CHANNEL

90' OVER BURDEN

PERMA FROST

DEEP CUTOFF

POSSIBLE SHEAR ZONE

UNDERGROUND STRUCTURES:

ROCK IMPROVES WITH DEPTH

DIVERSION TUNNEL LINING REQ'D

DEVIL CANYO

Summary:

EXTENSIVE GROUTING

DETAILED FOUNDATION AND ABUTMENT EXPLORATION REQUIRED

PILOT TUNNELS RECOMMENDED

AMPLE AGGREGATE AVAILABLE, PROCESSING REQ'D.

WATANA

STRUCTURE: 810' HIGH EARTH DAM

INVESTIGATION:

1950-'53, USBR, RECONNAISSANCE
1975, COE, "
D+M, 22500 LF SEISMIC
1978 COE 28 BOREHOLES
30' TO 600' DEEP
27 TEST PITS
18 AUGER HOLES

S+W 47665 LF 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"

MATERIALS:

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

CORE - BORROW AREA "D"

FILTER / AGG. - BORROW AREA "D"

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?

ATTACHMENT

B

SUSITNA HYDROELECTRIC PROJECT

TASK 4 & 5
INTERNAL REVIEW MEETING
JULY 23, 1980
1980 GEOTECHNICAL PROGRAM

1. Scope of Geotechnical Work Contained in the Acres Plan of Study.

2. Scope of 1980 Geotechnical Investigations Under Bureau of Land Management Permit No. AK-017-0096.

3. Spring 1980 Revised Program.

4. Current 1980 Geotechnical Program.

ACRES AMERICAN INCORPORATED
Consulting Engineers
2207 Spenard Road
Anchorage, Alaska 99503
Telephone 907 276-4888 Telex 91-6423 ACRES BUF
Other Offices: Columbia, MD: Pittsburgh, PA: Raleigh, NC: Washington, DC: Buffalo, NY

under 4 methods

Gold Creek

Canyon

SUSITNA RIVER

Fog Lakes

Creek

TALKEETNA

Talkeetna

1 HOLE 1

WATANA DAMSITE

PROPOSED DRILLING PROGRAM

HOLE NO.	LOCATION	APPROX. ELEV.	AZIMUTH	INCL.	HOLE LENGTH	PRIMARY OBJECTIVES	SPECIAL TESTING
BH-1	RT. ABUT.		225°	60°	250-300'	GEOLOGIC STRUCTURE, VELOCITY DISCONTINUITY	PERMEABILITY
BH-2	RT. ABUT.		45°	55°	200-500'	GEOLOGIC STRUCTURE, GRADATIONAL CONTACT, VELOCITY DISCONTINUITY, BURIED CHANNEL?	PERMEABILITY, CAMERA, IN-HOLE GEOPHYSICS
BH-3	RT. ABUT.		—	VERT.	50-100'	OVERBURDEN THICKNESS, CORRELATE W/ SEISMIC	
BH-4	RT. ABUT.		—	VERT.	200-300'	OVERBURDEN THICKNESS, CORRELATE W/SEISMIC	
BH-5	RT. ABUT.		—	VERT	100-200'	OVERBURDEN THICKNESS, CORRELATE W/SEISMIC	
BH-6	RT. ABUT.		225°	60°	740'	GEOLOGIC STRUCTURE (FAULT IN RIVER CHANNEL?)	PERM, CAMERA, GEOPHYSICS, THERMISTOR/PIEZOMETER
BH-7	LT. ABUT		—	VERT	100-150'	OVERBURDEN THICKNESS, GEOLOGY AND STRUCTURE	PERM, THERMISTOR, SLOPE INDICATOR
BH-8	LT ABUT		60°	60°	600-750'	GEOLOGIC STRUCTURE (POWERHOUSE)	PERM, CAMERA, GEOPHYSICS, THERMISTORS
BH-9	RIVER U/S		—	VERT	100-150'	OVERBURDEN THICKNESS, FOUNDATION AND PERM. FOR COFFERDAM	PERMEABILITY
BH-10	RIVER D/S		—	VERT	100-150'	OVERBURDEN THICKNESS, FOUNDATION AND PERM. FOR COFFERDAM	PERMEABILITY

TABLE [redacted]

WATANA DAM SITE

SEISMIC REFRACTION SURVEY

SEISMIC LINE	LOCATION	APPROX. LENGTH	PRIMARY OBTECTIVES	REMARKS
SL-1	RT. ABUT.	6600'	INVESTIGATE BURIED CHANNEL, OVERBURDEN THICKNESS, VELOCITY ANOMALY, ALT. SPILLWAY RTE	
SL-2	RT ABUT.	4400'	INVESTIGATE BURIED CHANNEL, OVERBURDEN THICKNESS, VELOCITY ANOMALY, ALT. SPILLWAY RTE.	
SL-3	RIVER	2200'	INVESTIGATE OVERBURDEN THICKNESS, ROCK QUALITY (INTAKE, ACCES/DIVERSION TUNNELS, RIVER CHANNEL	
SL-4	RIVER	1100'	OVERBURDEN THICKNESS (CORE ZONE) CHANNEL SHAPE	SHOOT IN WINTER OFF RIVER ICE
SL-5	RIVER	1100'	OVERBURDEN THICKNESS, CHANNEL SHAPE	SHOOT IN WINTER OFF RIVER ICE

DEVIL CANYON DAMSITE

PROPOSED DRILLING PROGRAM

HOLE NO.	LOCATION	APPROX. ELEV.	AZIMUTH	INCL.	HOLE LENGTH	PRIMARY OBJECTIVES	SPECIAL TESTING
BH-1	RT. ABUT.		225°	60°	500-600'	GEOLOGIC STRUCTURE, ROCK QUALITY (POWERHOUSE)	PERM, CAMERA, GEO-PHYSICS, THERMISTORS
BH-2	RT. ABUT.		240°	65-75°	350-450'	GEOLOGIC STRUCTURE, ROCK QUALITY (DAM FOUNDATION)	PERM, CAMERA, GEO-PHYSICS, THERMISTOR, PIEZ.
BH-3	LT. ABUT.		45°	70°	500-600'	GEOLOGIC STRUCTURE, ROCK QUALITY (DAM FOUNDATION, DIVERSION TUNNEL	PERM, CAMERA
BH-4	LT. ABUT.		150°	60°	400-600'	GEOLOGIC STRUCTURE (SHEAR ZONE/OLD CHANNEL) CORRELATE W/SEISMIC	PERM, CAMERA, GEO-PHYSICS
BH-5	RIVER - RT.		225°	70°	400-500'	OVERBURDEN THICKNESS, POSSIBLE FAULTING IN RIVER CHANNEL	PERM, CAMERA
BH-6	RIVER - LT.		—	VERT	100-150'	OVERBURDEN THICKNESS, FOUNDATION AND PERMEABILITY FOR COFFERDAM	PERMEABILITY
BH-7	RIVER - LT.		—	VERT	100-150'	OVERBURDEN THICKNESS, GEOLOGIC STRUCTURE (MAY BE INCLINED IF NECESSARY)	PERM, CAMERA
BH-8	RIVER - RT.		45°	60°	100-150'	OVERBURDEN THICKNESS, GEOLOGIC STRUCTURE, ROCK QUALITY (DRAFT TUBES)	PERM, CAMERA
BH-9	RIVER - LT.		—	VERT	100-150'	OVERBURDEN THICKNESS, FOUNDATION AND PERMEABILITY FOR COFFERDAM	PERMEABILITY

TABLE 4

DEVIL CANYON DAMSITE

SEISMIC REFRACTION SURVEY

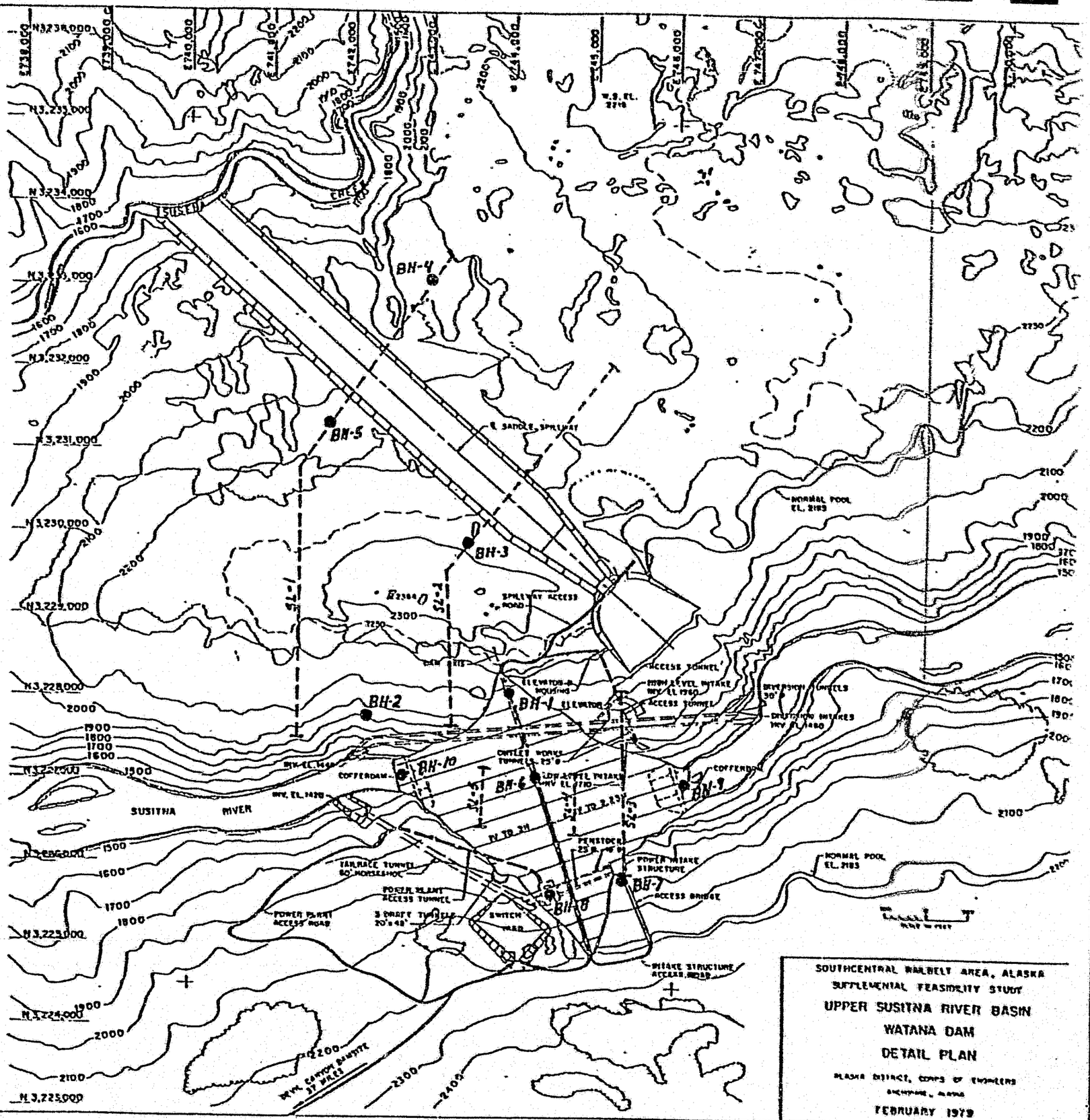
SEISMIC LINE	LOCATION	APPROX. LENGTH	PRIMARY OBJECTIVES	REMARKS
SL-1	LT. ABUT.	900'	INVESTIGATE OVERBURDEN THICKNESS, RELICT CHANNEL, POSSIBLE SHEAR ZONE (SADDLE DAM)	
SL-2	LT. ABUT.	900'	INVESTIGATE OVERBURDEN THICKNESS, RELICT CHANEL, POSSIBLE SHEAR ZONE (SADDLE DAM)	
SL-3	RIVER	300'	INVESTIGATE OVERBURDEN THICKNESS, CHANNEL SHAPE (COFFERDAM)	SHOOT IN WINTER OFF RIVER ICE
SL-4	RIVER	300'	INVESTIGATE OVERBURDEN THICKNESS, CHANNEL SHAPE (DAM FOUNDATION)	SHOOT IN WINTER OFF RIVER ICE
SL-5	RIVER	300'	INVESTIGATE OVERBURDEN THICKNESS, CHANNEL SHAPE (COFFERDAM)	SHOOT IN WINTER OFF RIVER ICE

NOTES

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

● BH-1 BOREHOLE LOCATION

SL-3 SEISMIC LINE



SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAM
DETAIL PLAN
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
FEBRUARY 1979

FIGURE 1

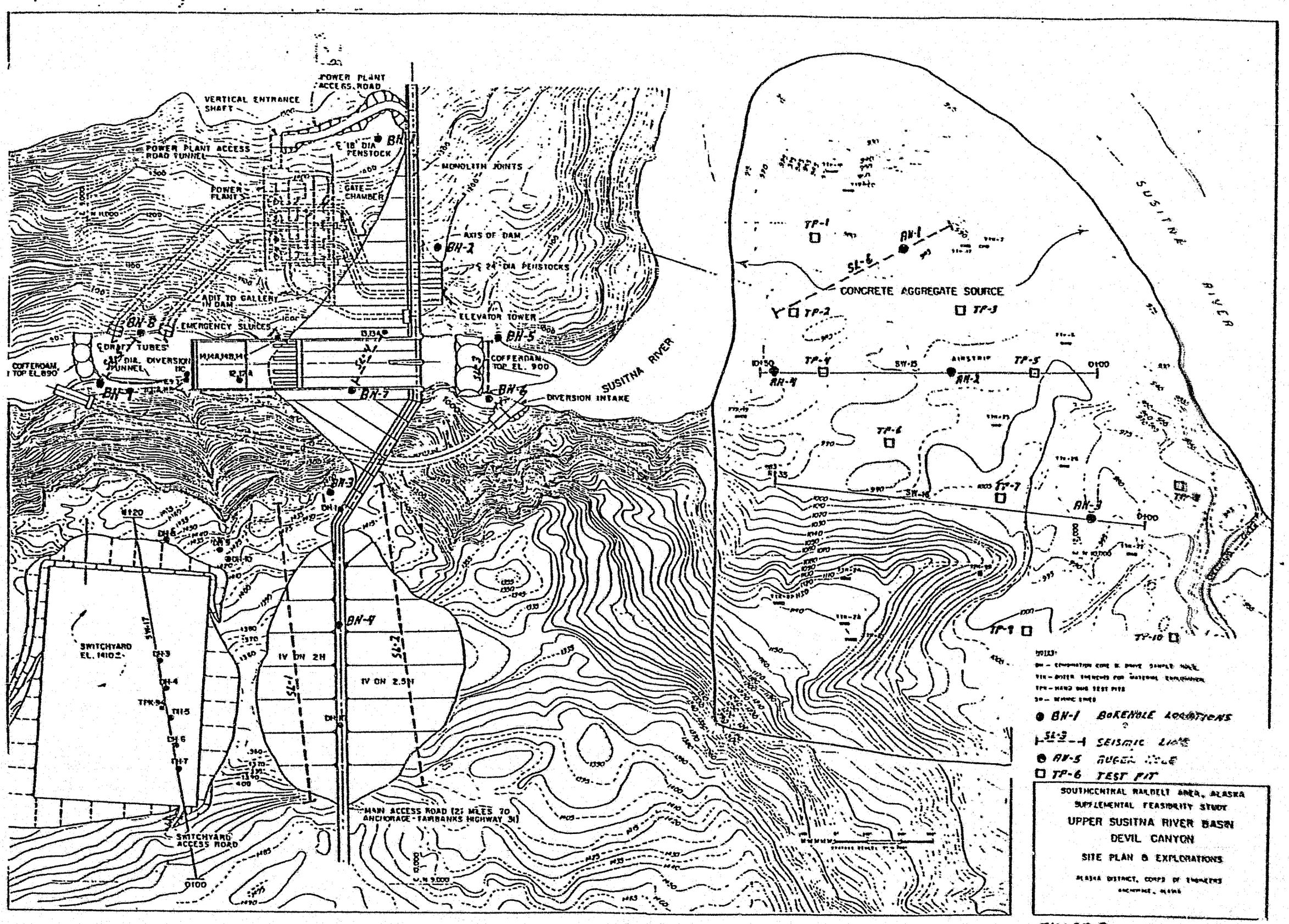
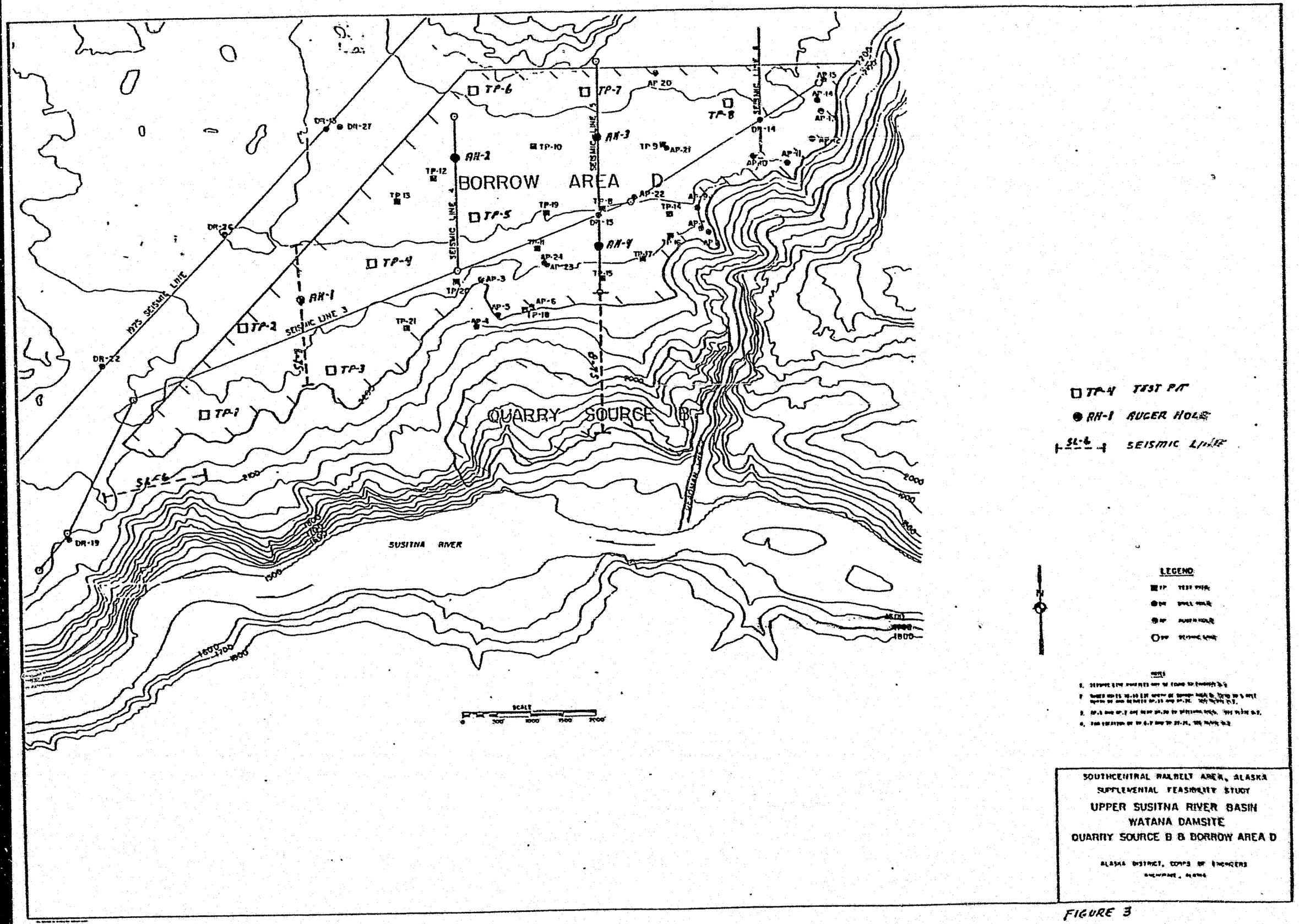

POWER PLANT ACCESS ROAD
VERTICAL ENTRANCE SHAFT
POWER PLANT ACCESS ROAD TUNNEL
POWER PLANT
18' DIA PENSTOCK
GATE CHAMBER
MONOLITH JOINTS
AXIS OF DAM
24' DIA PENSTOCKS
ADIT TO GALLERY IN DAM
EMERGENCY SLUICES
ELEVATOR TOWER
DRAFT TUBES
COFFERDAM TOP EL. 890
COFFERDAM TOP EL. 900
DIVERSION INTAKE
SUSITNA RIVER
BN-1
BN-2
BN-3
BN-4
BN-5
BN-6
BN-7
BN-8
SWITCHYARD EL. 1410±
IV ON 2H
IV ON 2.5H
MAIN ACCESS ROAD (27 MILES TO ANCHORAGE-FAIRBANKS HIGHWAY 3)
SWITCHYARD ACCESS ROAD
CONCRETE AGGREGATE SOURCE
AIRSTRIP
TP-1
TP-2
TP-3
TP-4
TP-5
TP-6
TP-7
TP-8
TP-9
TP-10
AR-1
AR-2
AR-3
AR-4
SW-15
SW-16
SL-1
SL-2
SL-3
SL-4
SL-5
SL-6
BN - EXPLORATION CORE & DRIVE SAMPLE HOLE
TH - OTHER BOREHOLES FOR MATERIAL EXPLORATION
TP - HAND DUG TEST PITS
SW - SEISMIC LINES
BN-1 BOREHOLE LOCATIONS
SL-3 SEISMIC LINE
AR-5 AUGER HOLE
TP-6 TEST PIT
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
DEVIL CANYON
SITE PLAN & EXPLORATIONS
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

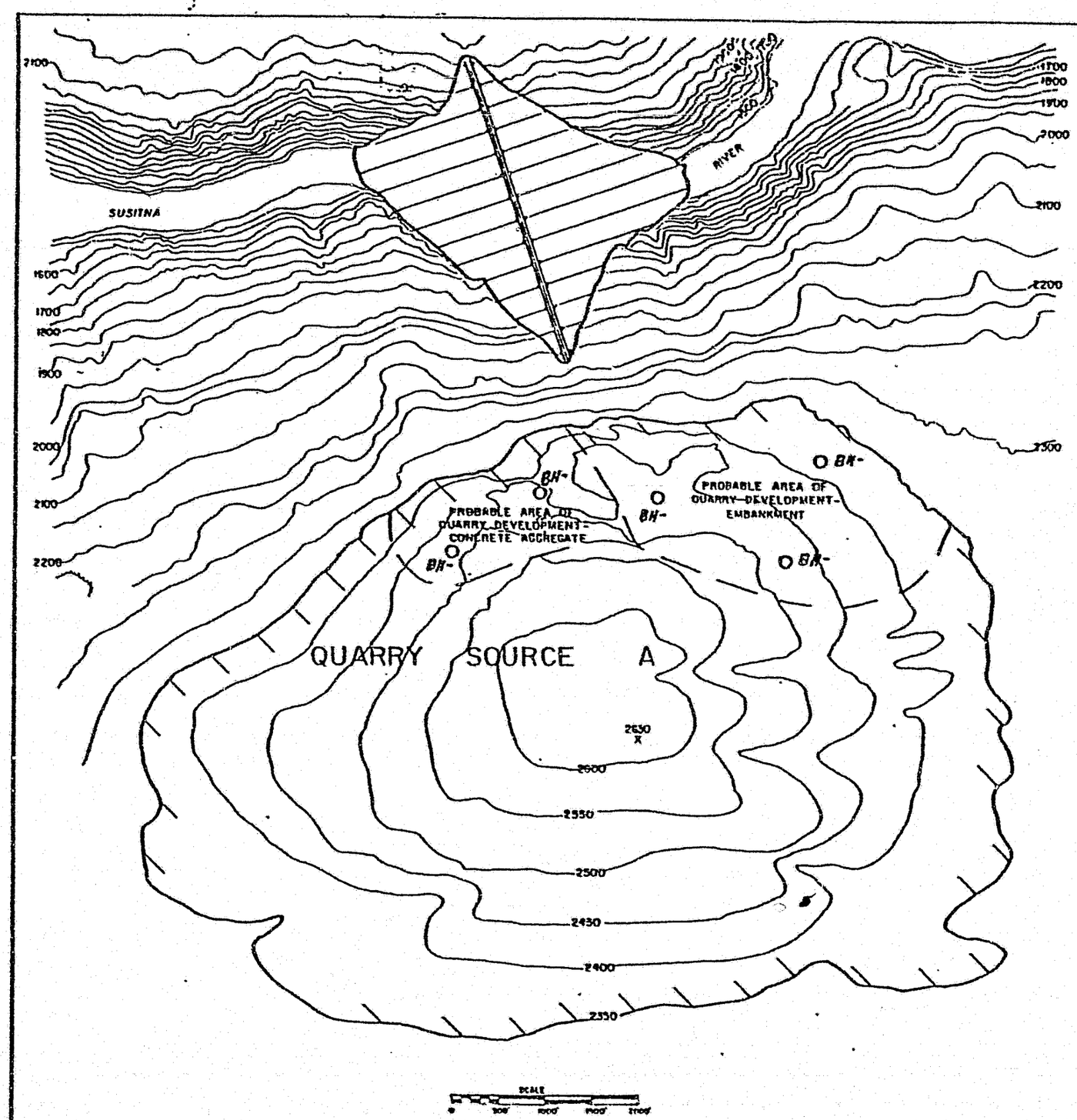
FIGURE 2



SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
QUARRY SOURCE B & BORROW AREA D

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

FIGURE 3



O BH- TENTATIVE BOREHOLE LOCATION

N

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
QUARRY SOURCE A

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

FIGURE 5

ATTACHMENT

C

1980 SEISMIC STUDIES

I. GENERAL

- WCC Project Team
- Status of 1980 Activities
- Monitoring of Program

II. SUSITNA VALLEY SEISMIC SETTING

- Seismotectonic Setting
- Available Historical & Instrumented Records
- Limitations of the Record Data

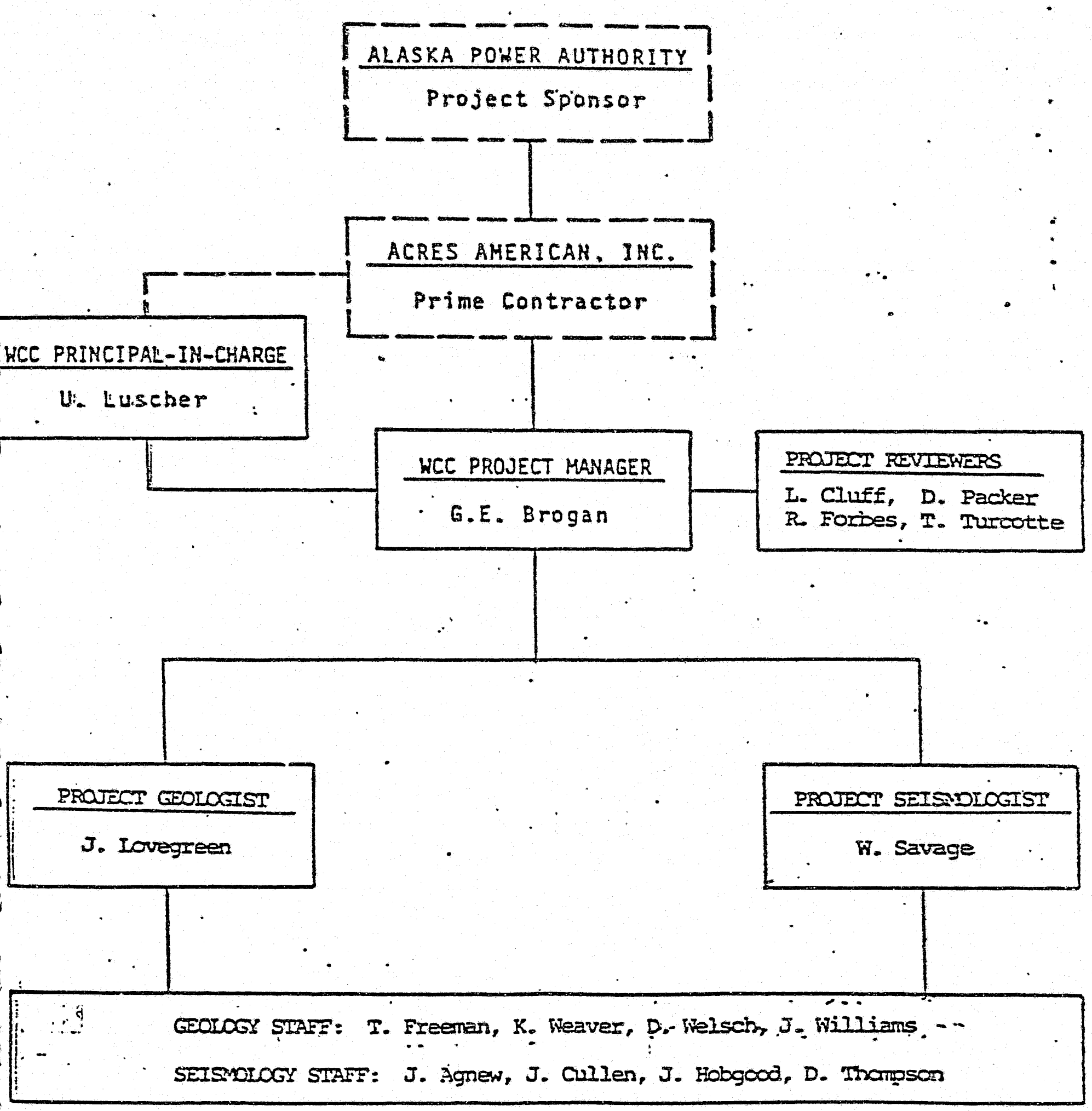
III. PURPOSE OF THE PROGRAM

- Definition of Seismic Event
- Source of Seismic Event
- Surface Rupture Potential

IV. STATUS OF PROGRAM

- Office Studies
- Field Studies
- Microseismic Network

V. DISCUSSIONS



WOODWARD-CLYDE CONSULTANTS PROJECT ORGANIZATION

STATUS OF 1980 ACTIVITIES

4.01 REVIEW OF AVAILABLE DATA — C

4.02 SHORT TERM SEISMOLOGIC MONITORING — U

4.03 PRELIMINARY R. I. S. — C

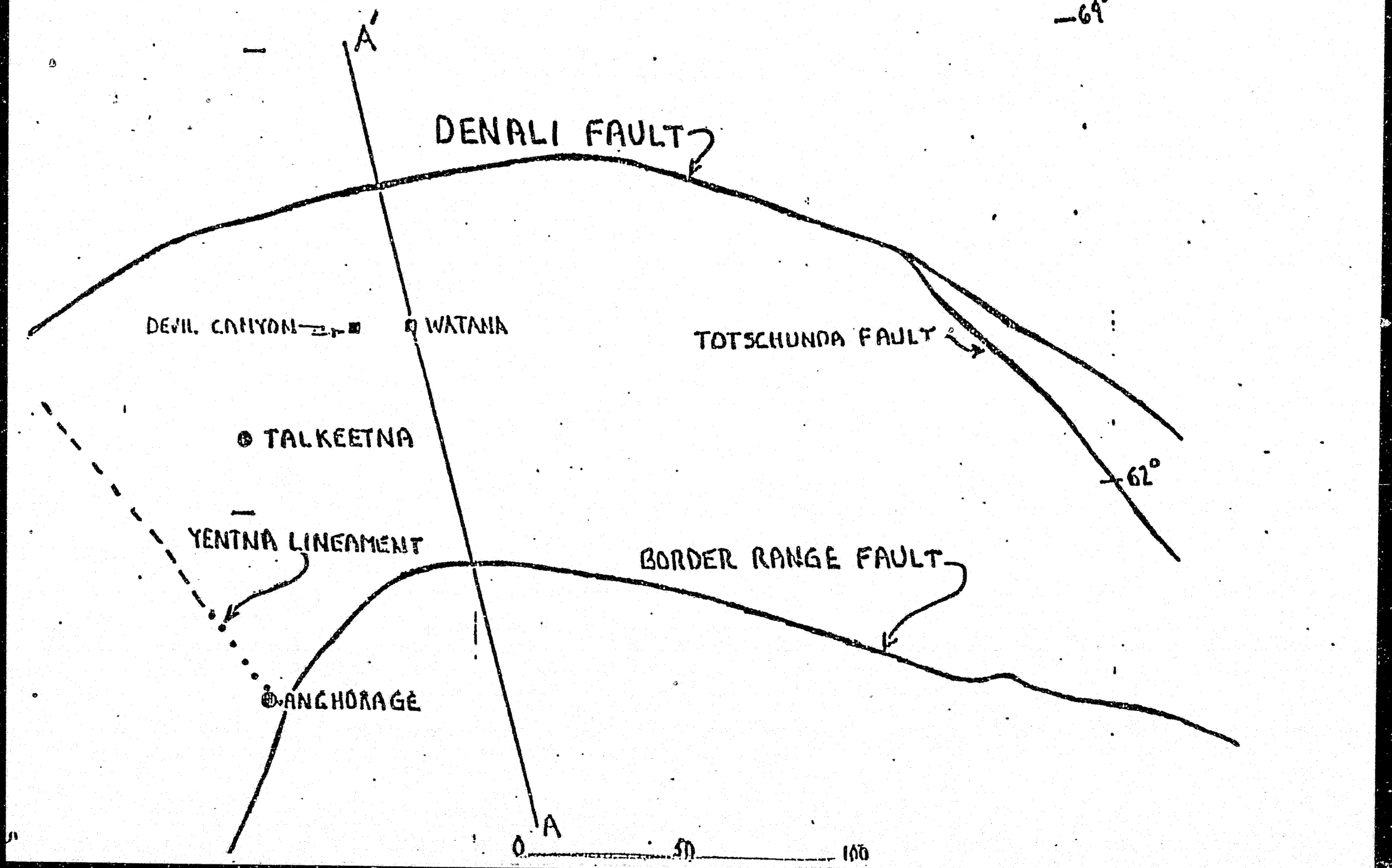
4.04 REMOTE SENSING IMAGE ANALYSIS - F

4.05 SEISMIC GEOLOGY RECONNAISSANCE - U

4.07 PREM. GROUND MOTION STUDIES

MONITORING — FIELD ACTIVITIES ANCHORAGE

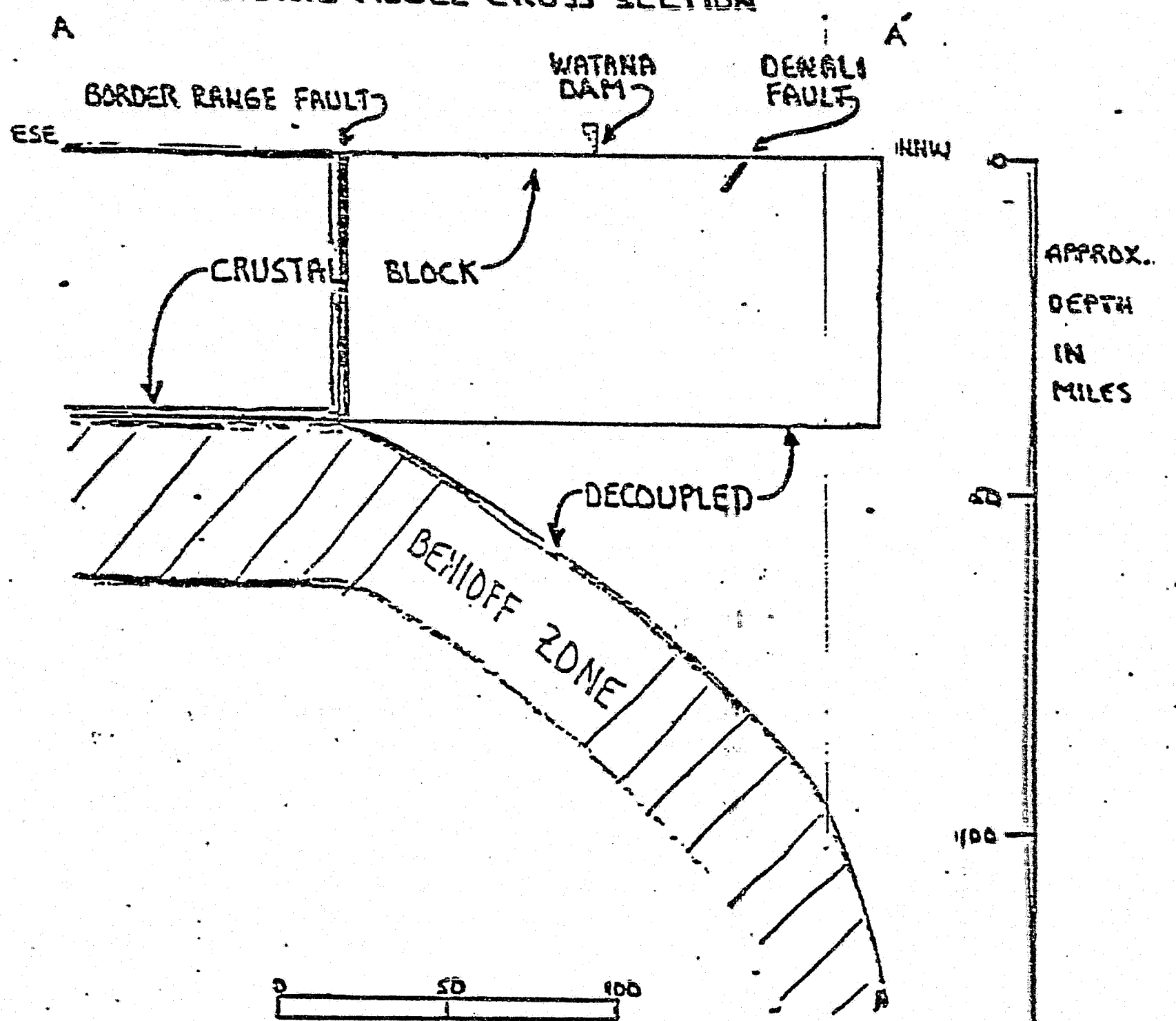
— TECHNICAL PART INCL PLAN OF STUDY BUFFALO


A'
DENALI FAULT?
DEVIL CANYON
WATANA
TOTSCHUNDA FAULT
TALKEETNA
YENTNA LINEAMENT
BORDER RANGE FAULT
ANCHORAGE
A
0
50
100
-69°
-62°

3 - TYPES OF EARTHQUAKES

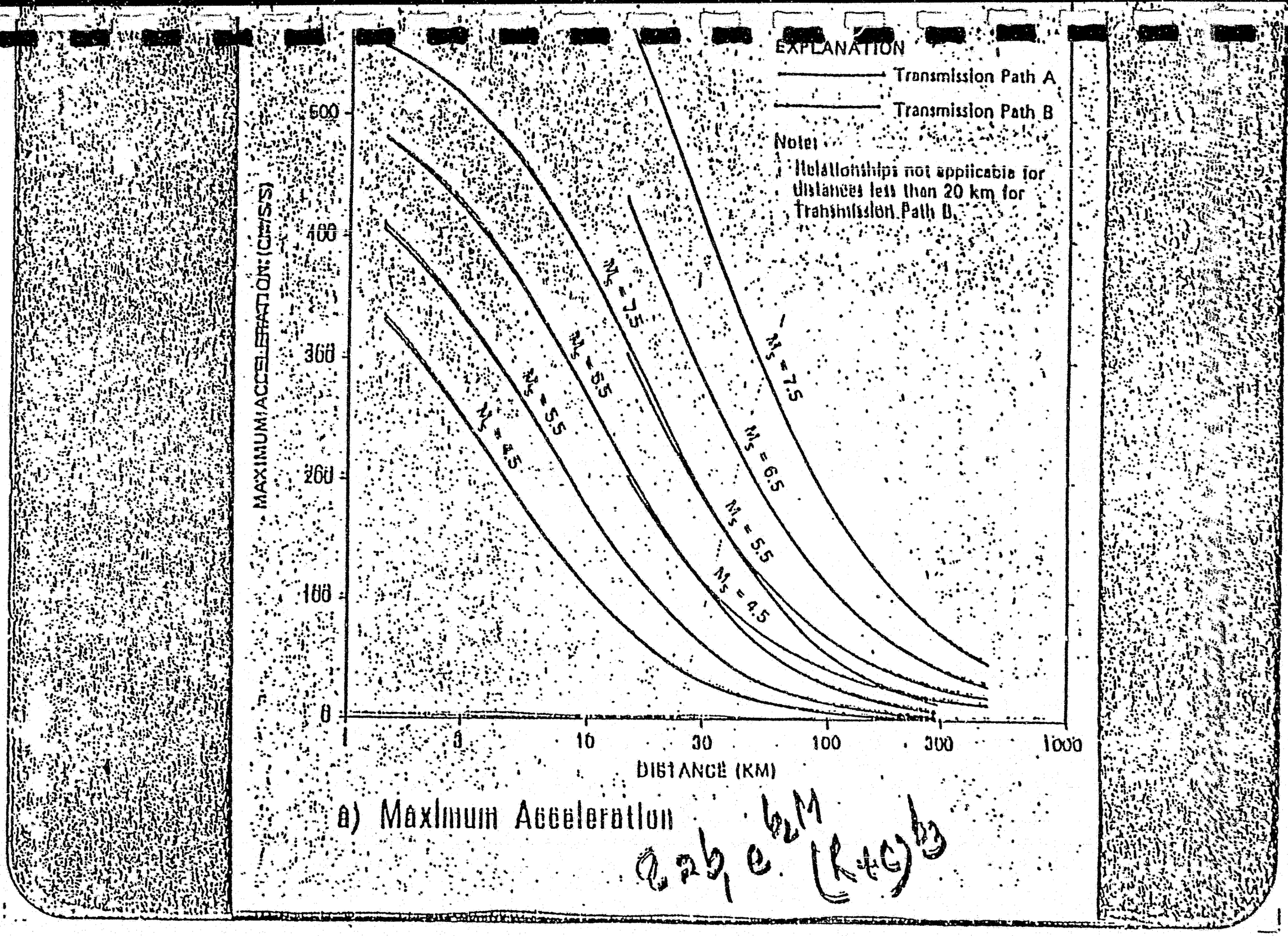
- SHALLOW EARTHQUAKE
  N.A. | PACIFIC PLATE CONTACT
- SHALLOW WITHIN N.A. PLATE CRUST
- DEEP - ORIGINATING IN BENIOFF ZONE

TECTONIC MODEL CROSS SECTION



146581-4006

10 JUNE 80



a) Maximum Acceleration

Table (1.6)

AVAILABLE HISTORIC & INSTRUMENTED DATA IS - LIMITED

Recorded History is about less than 100 YRS

DATA DOES NOT CLEARLY INDICATE DECOUPLING

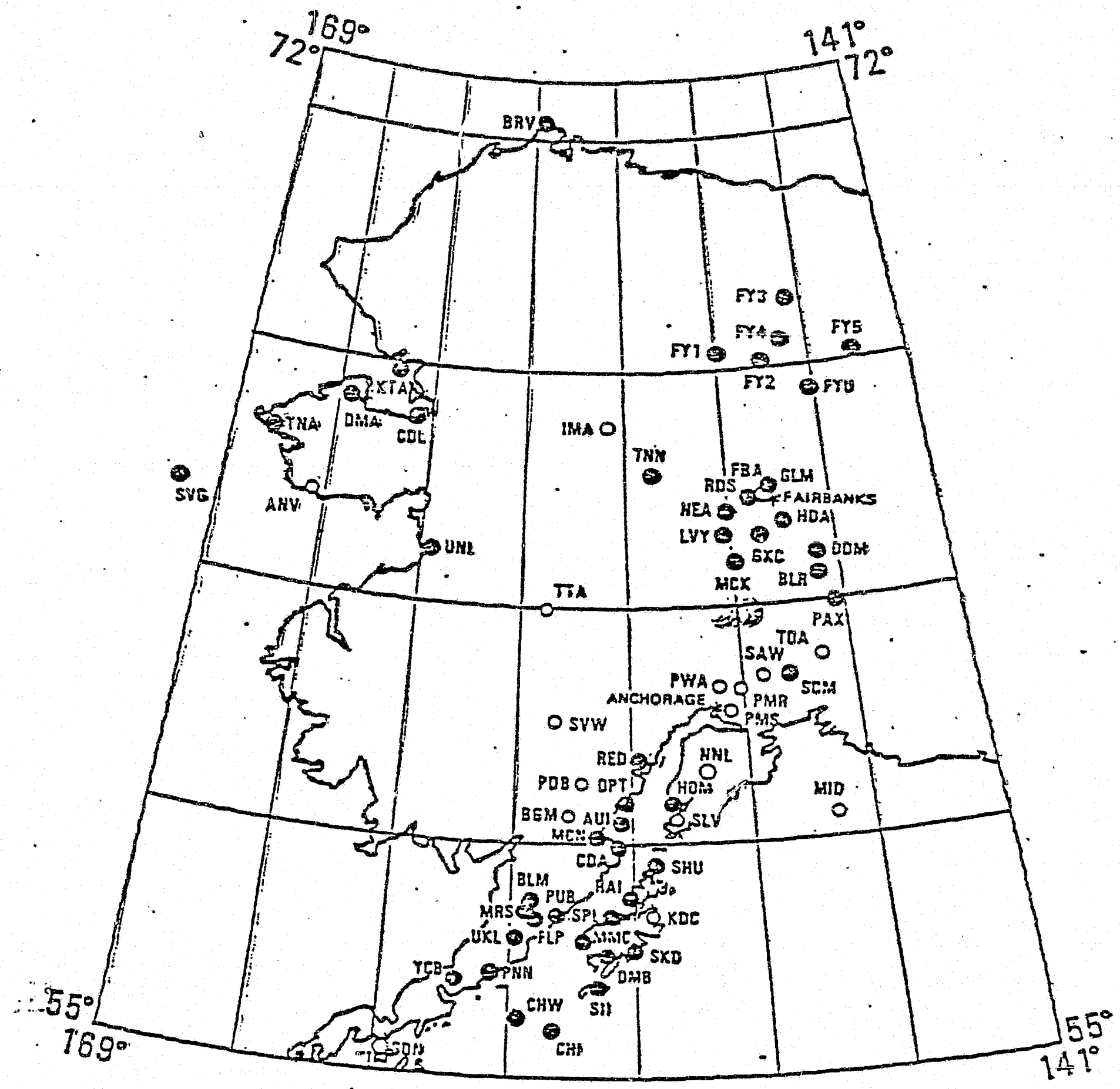
PURPOSE →

EVALUATION OF EARTHQUAKE SOURCES

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

MICROEARTHQUAKE STUDY OBJECTIVES

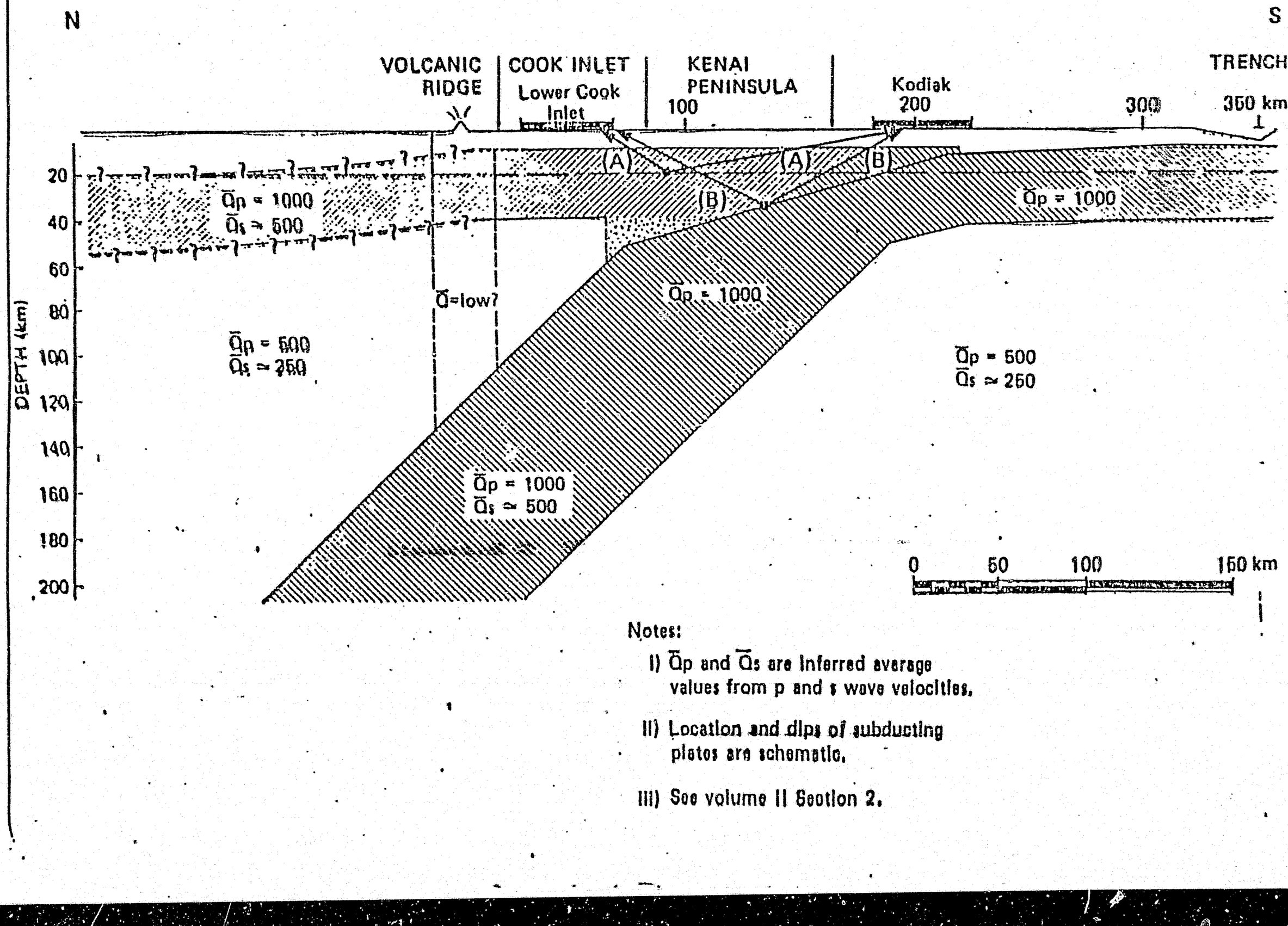
- LOCATIONS AND FOCAL DEPTHS OF MICROEARTHQUAKES.
- STYLE OF FAULTING.
- STRESS ORIENTATION.
- GEOLOGIC ASSOCIATIONS OF MICROEARTHQUAKES.
- SOURCE AND WAVE PROPAGATION CHARACTERISTICS.



GEOGRAPHIC LOCATIONS OF SEISMIC STATIONS

14658A-400D

10 JUNE 1980

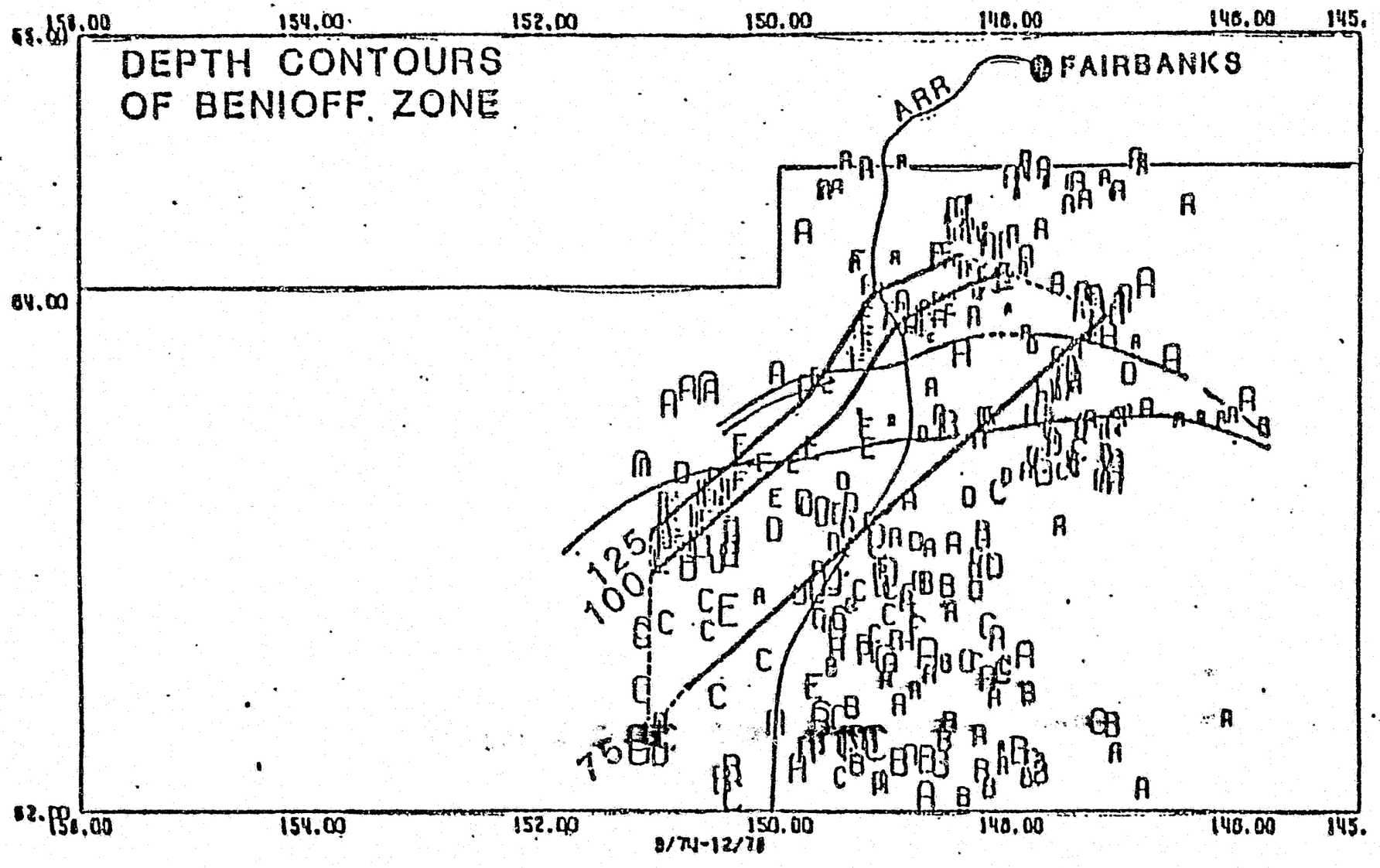


Notes:

I) $\bar{Q}p$ and $\bar{Q}s$ are inferred average values from p and s wave velocities.

II) Location and dips of subducting plates are schematic.

III) See volume II Section 2.



◎ DAM SITES

10 JUNE 1980

14658A-4000

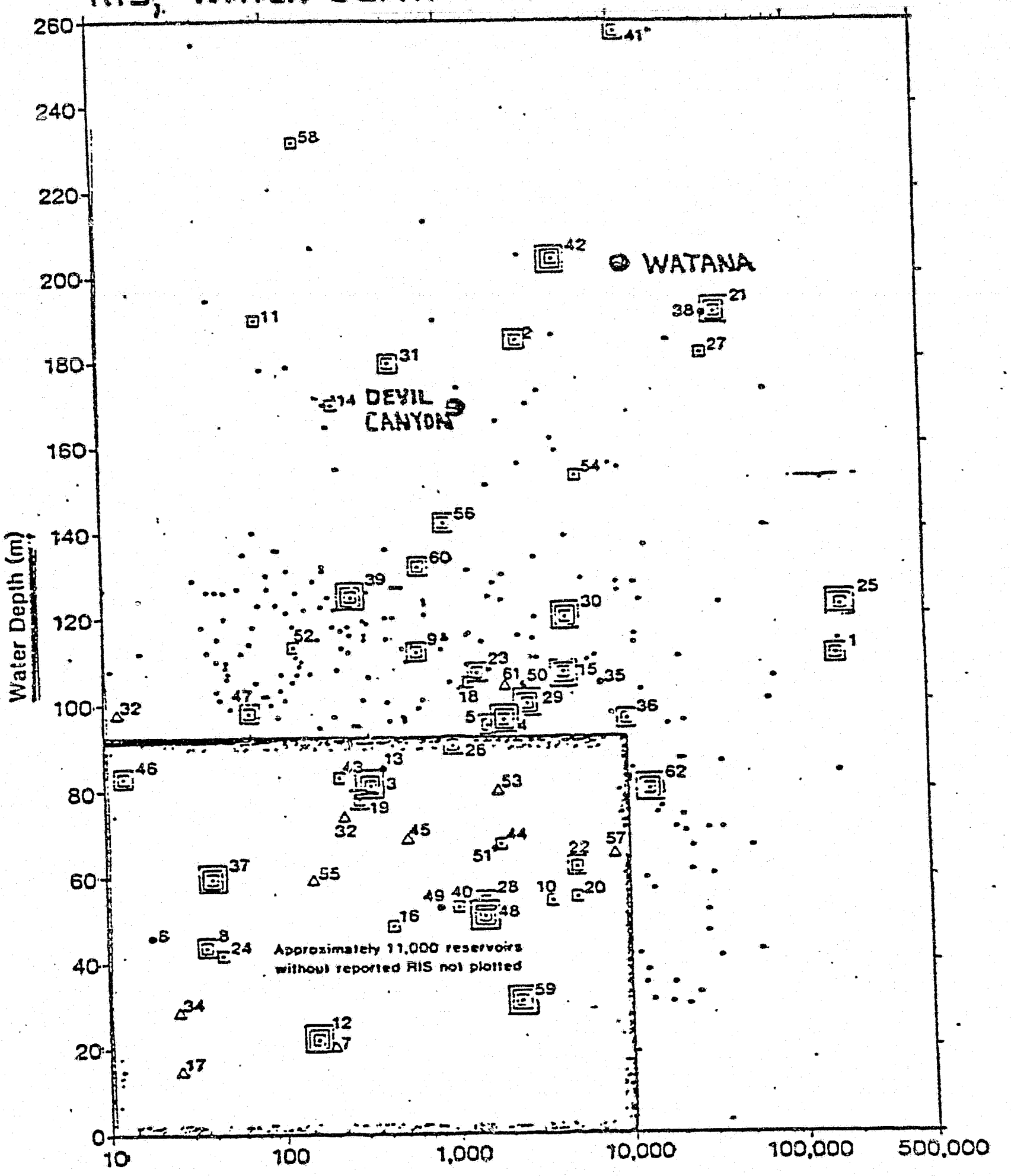
RESERVOIR INDUCED SEISMICITY

REVIEW OF

1980 FIELD PROGRAM

RESULTS

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