043 .

The Light company Houston Lighting & Power P.O. Box 1700 Houston, Texas 77001 (713) 228-9211

October 31, 1985
ST-HL-AE-1499
File No.: G9.17

Mr. George W. Knighton, Chief
Licensing Branch No. 3
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, DC 20555

South Texas Project
Units 1 and 2
Docket Nos. STN 50-498, STN 50-499
Responses to DSER/FSAR Items
Geology

Dear Mr. Knighton:

The attachments provide STP's response to Draft Safety Evaluation Report (DSER) or Final Safety Analysis Report (FSAR) items.

The item numbers listed below correspond to those assigned on STP's internal list of items for completion which includes open and confirmatory DSER items, STP FSAR open items, and open NRC questions. This list was given to your Mr. N. Prasad Kadambi on October 8, 1985 by our Mr. M. E. Powell.

Some of the attachments include mark-ups of FSAR pages which will be incorporated in a future amendment. Others are stand alone writeups portions of which may be incorporated into the FSAR.

Attachment	Item No.*	Subject
1	----	Information Requested During 10/23/85 Meeting with NRC and STP Personnel
2	D 2.5-4	Harding Lawson Associates report dated October 30, 1985 "Interpretation of Geophysical Data - South Texas Project"
3	D 2.5-4	Summary Statement of Geologic Structures and Significance

* Legend
D - DSER Open Item C - DSER Confirmatory Item
F - FSAR Open Item Q - FSAR Question Response Item

L1/DSER/a10

Attachment	Item No.*	Subject
4	D 2.5-3	Postulated Surface Projection of Growth Faults Identified in Upper 1,000 feet; Revised FSAR text Section 2.5.1.2.5.6
5	D 2.5-3 Q 231.19N-1	The post-CP stage Lineament Study; Response to NRC Question 231.19N and revised FSAR text Section 2.5.1.2.5.5
6	D 2.5-1 D 2.5-2	Salt Hypothesis write-up
7	D 2.5-5	Depth-Age Relationship; revised FSAR text Section 2.5.1.1.5.4.2
8	D 2.5-2 D 2.5-6	Assessment of Potential Ground Motion Associated with Growth Faults
9	D 2.5-6	Reservoir Induced Seismicity

If you should have any questions concerning this matter, please contact Mr. Powell at (713) 993-1328.

Very truly yours,

M. R. Wisenburg
Manager, Nuclear Licensing

MEP/bl

Attachments: See above

* Legend
D - DSER Open Item
F - FSAR Open Item
C - DSER Confirmatory Item
Q - FSAR Question Response Item

L1/DSER/a10

cc:

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Revised 9/25/85

*All attachments, all others without attachment #2

L1/DSER/a10

Attachment 1

INFORMATION REQUESTED DURING 10/23/85 MEETING WITH NRC AND STP PERSONNEL	DATE	NATURE OF RESP.	ATTACHMENT TO ST-HL-AE-1499 WHICH ADDRESSES THIS ITEM
(1) HLP to state fault's A&I are not unique	10/28 *	Not unique and why	2 and 3
(2) Likelihood of earthquakes attributed to filling of MCR	11/1	Fault capability is limiting (FSAR)	9
(3) HLP to submit HLA report	10/28 *	Updated	2
(4) HLP to correlate depth to seconds by 10/24	10/24 *	Updated, part of 3	2
(5) HLP to provide geological information obtained from relocated Little. Rob. Slough excavation	10/28 *	Geological Map	4
(6) Displacement data at shallowest pick on faults A, I, J	10/28 *	-	2
(7) HLP to provide consolidated Fault Map	12/1	-	TO BE PROVIDED LATER
(8) Discuss eastern extent of Fault I	10/28 *	-	2
(9) HLP to provide formal commitment to Geotechnical Monitoring Program; Tech. Spec. or OP Proc.	12/1	-	TO BE PROVIDED LATER
(10) Age depth correlation to be modified	10/30	-	7
(11) Sect. 2.5.1 - Lineament & fault have no correlation including well casement evaluation	10/28 *	Similar to 5, rewrite	4

* Note: Draft of information previously made available to NRC

Attachment 2

A Report Prepared for

Bechtel, Incorporated
50 Beale Street
San Francisco, California 94105

INTERPRETATION OF GEOPHYSICAL DATA
SOUTH TEXAS PROJECT
HOUSTON LIGHTING AND POWER

HLA Job No. 3854,092.09

by

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October 30, 1985

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I SUMMARY

Seismic reflection data and well logs have been examined for the South Texas Project. Ten faults comprised of eight growth faults and two antithetic faults exist in the study area. The faults are designated A through J; A-F, I, and J are growth faults whereas G and H are antithetic faults.

Three of the ten faults rise closer than 5000 feet to the ground surface: Faults A, I, and J. The shallowest seismic evidence of south-dipping Fault A is 490 feet below the surface approximately 3.4 miles north of the plant site. There is well log evidence of 440 feet of offset along the fault between 7000 and 8000 feet below the surface, and one of four seismic reflectors traced around the project area is offset about 100 feet at 2500 feet below the surface. The fault trends approximately west-northwest.

Fault I was traced to within 800 feet of the surface approximately 4.5 miles southwest of the plant site. Seismic reflectors show about 40 feet of offset on this south-dipping fault at that depth. Fault I trends approximately east-west.

Fault J was traceable to within 3850 feet of the surface on one seismic reflection profile. The shallowest point on Fault J is approximately 5.7 miles south of the plant site. No trend could be established as the fault was found on one seismic profile only.

II INTRODUCTION

A. Purpose

This report presents a review and evaluation of pertinent portions of available geophysical data for the South Texas Project (STP). Interpretations of the geophysical data by others for both pre-construction permit (CP) and post-CP phases are currently under review by the Nuclear Regulatory Commission (NRC) geotechnical staff. It is the purpose of our review and evaluation to provide an independent view of the geologic structure beneath the South Texas Project based on available seismic reflection data and geophysical well logs (E-logs and spontaneous potential [SP]). Of primary concern in this interpretation are the location and limits of growth faults.

Our initial effort was directed toward review of data north of the plant site and concerned the near-surface extension of growth faults (primarily Fault A), and possible evidence for a shallow capping reflector as reported on September 18, 1985 in a letter to C. R. McClure, Manager of Engineering Geology, Bechtel, Inc. The results of this initial evaluation have been incorporated into this report. Weekly progress reports have also been transmitted to Bechtel, Inc.

B. Site Description

The South Texas Project is located approximately 75 miles south-southwest from Houston, Texas, near Bay City, Texas, and about 10 miles from Matagorda Bay on the Gulf of Mexico. As described in the Final Safety Analysis Report

(FSAR), it lies on the flat coastal plain of the Texas gulf region and consists of plant site, essential cooling pond, and main cooling reservoir (approximately 14 square miles for the entire project area). The site has been explored using the seismic reflection method by at least five geophysical companies, primarily for oil and gas. Most of the data are concentrated in the area at and to the north of the plant site, but line coverage also extends to the south into the main cooling reservoir area.

III SCOPE OF SERVICES

The scope of services includes the interpretation of 98.5 miles of existing reflection records and a number of geophysical well logs. Based on this interpretation, eight seismic stratigraphic cross sections have been prepared that identify growth faults and prominent horizontal seismic reflectors. Contour maps of each fault plane are presented. Some of the fault designations vary from previous interpretations but in most cases indicate a similar structural picture. The following sections of this report discuss the results of the interpretation covering depth and location of the faults, seismic reflectors, and structural cross sections. The report discusses the rationale and criteria used in identification of faults.

IV AVAILABLE DATA

A. Geophysical

1. Seismic Reflection

Our structural interpretation is based on seismic reflection records obtained by five geophysical companies both prior to and after the STP-CP date. The 98.5 miles of seismic data were obtained from the following sources:

a. JAECON Lines 2M, 4M	24 miles
b. TXO Lines 1, 2	7 miles
c. CONOCO Lines 1, 2, and 3	24 miles
d. PETTY RAY Lines 73-1 to 73-6	26 miles
e. GUS Lines A, B, C (original) Lines A and C (reprocessed)	17.5 miles

The exisiting shot point location maps were made available and these have been reproduced as Plate 1.

JAECON LINES 2M and 4M provide excellent data showing essentially the "type" record for growth fault identification. Identification and tracing of the same reflections can be done because of the well defined patterns on opposite sides of the fault. Features occurring on these records that are typical of growth faults are: 1) the vertical intervals between reflection horizons thicken on the downthrown side of the fault indicating thickening sedimentary layers; 2) displacements along the fault plane are seen to increase with depth; and 3) the steepness of the fault plane

decreases with depth. A. W. Bally et al. (see Bibliography) show very similar records in their discussion of the structural styles of the Texas Gulf coastal area. A limiting factor for these lines was the information above 0.3 second where record quality deteriorated restricting the interpretation of the near-surface reflectors. However, Line 2M, the main north-south line provided the clearest information on Faults A, B, and C and related adjustment faults (antithetic) and best depicts the formation of growth faulting. Additional information may be gained in the near-surface by reprocessing, as the original field data were recorded at a 2-millisecond (ms) sample rate. The records were processed with the sampling rate at 4 ms eliminating the high-frequency reflections necessary for resolving near-surface layering.

TXO LINES 1 and 2, basically north-south lines northwest of the plant site were of good quality, but of limited extent (approximately 7 miles).

CONOCO LINES 1, 2, and 3 are the oldest data and therefore relative to Jaecon data they are not state-of-the-art. They are of fair quality for deep information but we were not able to see, with any clarity, faulting above 1.0 second due to the overriding effect of ground roll. Ground roll is surface wave energy that travels along or near the surface of the ground, usually characterized by relatively low velocity and low frequency, but high amplitude. Ground roll tends to mask desired signals (Sheriff, 1984).

PETTY RAY LINES 73-1 to 73-6 were originally shot for STP in 1974 for deep information. They are fair to poor quality records showing some

near-surface data, but they are basically noisy and contain multiples because they were obtained with low-fold (3-, 4-, and 5-fold) and they lack resolution of structural information.

GUS LINES A, B, C (original records) provide good shallow information. Portions of these lines were reprocessed with a strong coherency filter. This processing method forces any data to line up across the record forming a series of apparently flat-lying continuous reflectors. The results are that the detailed information on the original records is obscured. The interpretation for these lines is based on the original records.

2. Geophysical Well Logs

Geophysical logs for wells in the vicinity of the STP were made available for the interpretation. These logs were reviewed and those used in the interpretation (listed below) were selected based upon their proximity to the seismic reflection lines in the plant site area and where they could provide significant structural information. The logs were used to verify or extrapolate the data as seen on the reflection records. The E-log and SP curves provide clear indications of sands and clays which serve as marker horizons that can be correlated with the seismic reflections. This use, in a sense, provides "ground truth" information for the interpretation.

Well Number	Name	Nearest Line Location
75	Stoddard # 1	north end Conoco 1
12	Pierce # 1	intersection 4M and Conoco 1
55	El Maton # 1	intersection 2M and 4M
51	Louise Steele # 1	middle of 4M
20	Clive Runnels, Jr. A-1	south end of Conoco 1
6	G.G. Chance # 1	south end of Conoco 1

The logs consist of runs using two or three resistivity/conductivity and SP probes. Logs for wells 75, 12, 20, and 6 provided confirmatory information on the seismic "picks" of faulting north of the plant along Conoco Line 1. Well logs 20 and 6 were especially useful near the plant site. Well logs 51 and 55 provided additional information on the amount of offset along Fault A.

B. Reports and Other Data

Other related materials were reviewed to gain an overall understanding of the structural geologic issues at the site. They were not used to support or confirm the geophysical interpretation. These materials include:

1. Geophysical Interpretation Calibration Study (PSAR)

2. FSAR Text

3. Previous NRC questions

4) Cambe maps T-4 and T-7

C. Fault Criteria

Faulting, as it occurs in the vicinity of the South Texas Project, is in large part growth faulting, i.e., faulting that occurs contemporaneously

with deposition. Growth faults are characterized by thickening sedimentary sections on the downthrown side of the fault, differential compaction, and gravity sliding. As such, this process affects both the geologic stratigraphy and hence the seismic stratigraphic reflection characteristics. Significant indicators of faulting on seismic sections include:

1. Abrupt termination of reflections that are essentially continuous linear events
2. Misclosures in tying prominent seismic reflectors on seismic cross sections that form loops in the data
3. Changes in reflector dip and thickening of the seismic stratigraphic section with accompanying reflector "rollover"
4. A family of diffraction patterns that line up consistent with the dip of local faulting
5. Disappearance of reflections below fault planes (fault shadows)
6. Repetition of reflection "sets" above and below the fault plane

A.W. Bally (1983), and M.J. Quarles (1950) have described these and other characteristic structural styles for growth faults in the Texas coastal area. There are many others, most of which have been extensively reported in the FSAR and numerous geophysical publications. We have adopted and used nearly all of these criteria in the identification of faulting at STP. Fault parameters are summarized in Figures 2 through 4.

V GEOPHYSICAL DATA ANALYSIS

Seismic reflection data have been examined for five different surveys conducted between 1966 and 1982 (Plate 1). The data quality varied for a number of reasons. For example, data acquired by Jaecon in 1982 is far superior to Conoco data shot in 1966, partly because of state-of-the-art changes in field data collection and post-survey processing. Additionally, some of the data were acquired directly for evaluation of the South Texas Project rather than for oil and gas exploration and, therefore, field recording and data processing parameters were generally optimized on the more recent data to detect targets of interest: growth faults. The data include:

CONOCO - 1, 2, and 3 collected in 1966

PETTY RAY - 73-1, 2, 3, 4, 5, and 6 collected in 1973

GUS - A, B, and C collected in 1974

TXO - 1, 2 collected in 1981

JAECON - 2M and 4M collected in 1981/1982.

Electric logs for six deep wells were made available for this study and their locations are also shown on Plate 1. Other pertinent information for those wells is shown in Table 1.

Table 1. Electric Logs Used For This Study

Map Designation	Name	Texas State Plane Coordinates in Feet		Depth (feet)
		Northing	Easting	
6	G.G. Chance Trustee No. 1	365,250	2,939,375	2100-10,600
12	Pierce Est. No. 1	377,950	2,937,900	1210-11900
20	Clive Runnels, Jr., A-1	369,900	2,945,125	1210-9700
51	Louise M. Steele et al., No. 1	373,000	2,927,775	1600-11,300
55	El Maton Gas Unit No. 2, Well No. 1	374,030	2,922,400	100 - 11,100
75	Stoddard No. 1	387,700	2,929,780	2082-13,082

A. Depth Calculations

Depth estimates are normally derived from sonic well logs where available or, in their absence, from stacking velocities used to process seismic reflection time sections. Depth estimates for this study were derived from the latter.

Stacking velocities are known for Jaecon 2M and 4M only; that is, for 2 of the 16 data lines. Root mean squared (RMS) velocities are provided every mile along those lines. Stacking velocities are used to correct for normal moveout, but for this investigation the velocities were plotted against

the two-way travel time over which they were applied. The stacking velocities along the length of the lines are similar and their plots describe an envelope that encompasses the majority of the data. Within that envelope these investigators described a straight line that "best fit" the curve of the majority of the analysis. The envelope and "best fit" curve describing the velocity variation with two-way travel time on the seismic sections Jaecon 2M and 4M are shown on Figure 1. The velocity function used to convert two-way travel time to depth is shown below:

Time (ms)	Velocity (RMS) (feet/sec)	Approximate Depth (feet)
0	5500	0
500	6100	1,525
1000	7000	3,500
1500	7600	5,700
2000	8100	8,100
2500	8500	10,625
3000	8800	13,200
4000	9100	18,200
5000	9300	27,900

In the absence of any other available data, the velocities shown above were applied to all seismic data lines.

B. Seismic Interpretation

Conventional seismic reflection interpretation techniques were applied during data reduction. Faulting was assessed and described according to the growth faulting criteria described earlier in this report. Seismic reflecting horizons were picked from the superior data on Jaecon 2M and 4M and tied

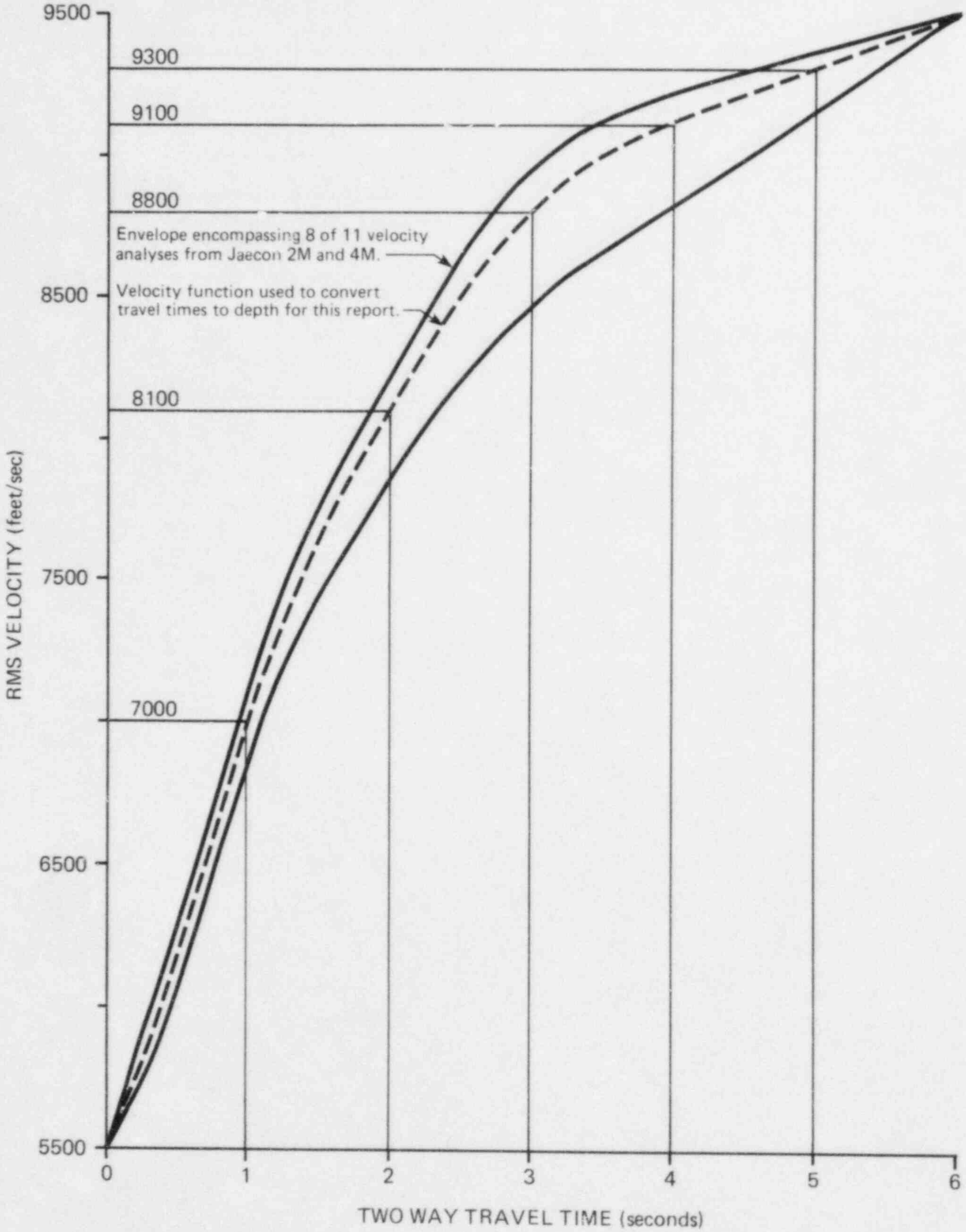

Figure 1. Velocity function used to convert travel time on seismic reflection sections to depth.

in loops around the site to assure closure, accurate correlation, and proper assessment of faulting.

Plates 2 through 6 are maps of the depths to fault plane surfaces defined during this study and Plates 7 and 8 show cross sections depicting the relationship between the seismic stratigraphic section and growth faulting.

1. Faulting

Ten faults have been described across the South Texas Project site and of those, eight are growth faults and two are antithetic faults. The faults are designated A through J with A through F, I, and J being the growth faults and G and H the antithetic faults. The majority of faults described are north and west of the plant site.

Of the ten faults described in this report, three approach closer than 5000 feet to the surface: Faults A, I, and J. Following is a brief description of each fault.

a. Fault A

Fault A is one of the three shallow faults that extend closer to the ground surface than 5000 feet. In fact, Fault A appears to be the shallowest and it was traced seismically to approximately 490 feet below the surface on GUS Line A. Plate 2 shows a map of the fault plane constructed from seismic reflection data and well logs and Plate 8 shows a cross section of GUS-A. Fault A intersects Well 51 (Louise M. Steele et al., No. 1) at 7680 feet with 400 feet of offset and Well 55 (El Maton No. 1) at 7310 feet with 440 feet of offset.

Fault A strikes approximately west-northwest and it was found on seismic sections for Jaecon 2M and 4M, TXO 1 and 2, GUS-A, Petty Ray 73-1, 73-2, 73-4, and Conoco 1. On Jaecon 2M offset seismic reflectors show that the fault plane ascends to within at least 300 milliseconds, or approximately 900 feet of the surface.

Fault A is the southernmost of three en echelon faults designated A, B, and C.

b. Fault B

Fault B is the centermost of three en echelon faults designated A, B, and C. The south-dipping fault was mapped from seismic reflection profiles Jaecon 2M and 4M, TXO 1 and 2, Petty Ray 1, 2, and 4, and Conoco 1 (Plate 3). Fault B approaches no closer than 7380 feet of the surface and extends down to at least 16,000 feet. Offset along the fault cannot be evaluated because of complex reflection patterns, comprising diffractions and scattered reflection energy created within the "fault zone" containing faults A, B, and C.

c. Fault C

The most northerly of the three en echelon faults (A, B, and C), Fault C never rises shallower than 7000 feet, but it extends to a depth of at least 15,000 feet (Plate 4). As with Fault B, the offset along Fault C cannot be evaluated because of complex reflection patterns and fault shadows in the en echelon "fault zone". Fault "shadows" result from trying to penetrate a fault plane with seismic waves. The velocity structure of the fault zone has been disturbed by movement along the fault and the result is the scattering of seismic waves rather than useful reflection.

Fault C was not found between Wells 12 and 20 suggesting it is below the total depth of Well 20 and terminates before intersecting Well 12.

d. Fault D

Plate 5 shows a map of fault plane D visible on two seismic lines, Jaecon 2M and Petty Ray 73-1. There are faint indications of Fault D on TXO-2. The south-dipping fault extends from about 18,000 feet up to 10,400 feet. Fault D could not be traced laterally farther than shown on the map. Correlating seismic horizons across the fault suggest that up to 200 feet of offset has occurred at the 12,000-foot level.

e. Fault E

Fault E (Plate 5) was found on seismic profile TXO-1 only, and there are indications that the fault cuts profile Conoco 2. Data quality along TXO-1 precludes any estimate of offset along the fault. The fault strikes approximately east-west and extends between 10,400 feet and 15,000 feet.

f. Fault F

Fault F (Plate 5) has probably experienced more offset than any other fault described, but it does not rise shallower than 9620 feet in the mapped area. Although correlation across the fault is difficult because of its closeness to the end of Jaecon Profile 2M, there appears to be approximately 800 feet of offset of depths greater than 13,000 feet. Within the mapped area, Fault F was found between 9620 and 18,000 feet below the surface.

g. Fault G

Fault G is antithetic to Fault A. Plate 6 shows that it has been mapped in the southwest corner of the site using seismic reflection profiles Jaecon 2M, Conoco 3, and Petty Ray 73-1. The north-dipping fault was found between 7100 and 19,000 feet in the mapped area.

Plate 7a, a cross section of Jaecon 2M, shows that Fault G terminates against shallow south-dipping Fault I discussed below.

h. Fault H

The longest antithetic fault found during the investigation is Fault H. It traverses the entire site north of the power plant, but it is not a shallow fault. Plate 6 indicates the fault is 6000 to 12,000 feet below the surface within the mapped area. Fault H passes through Well 6 where a missing stratigraphic section on electric logs suggests up to 60 feet of displacement has occurred along the fault approximately 6700 feet below the surface.

i. Fault I

Fault I, Plate 6, rises close to the ground surface. Jaecon Profile 2M shows that south-dipping Fault I can be traced seismically to approximately 900 feet (300 ms) of the surface. A fairly continuous seismic reflector appears offset by Fault I by about 40 feet along the fault at this depth.

The fault trend is nearly east-west and Fault G beneath it terminates against fault plane I. Fault I was defined by Jaecon 2M, and Conoco 3. Petty Ray Line 73-1 does not provide a clear complete

reflection record in the shallow section to trace Fault I to the east. Fault I was not identified on GUS Line A as the record shows a series of coherent seismic reflectors in the shallow section for the Main Cooling Pond area. The shallowest expression of Fault I occurs 4.5 miles southwest of the Plant Site.

j. Fault J

The examination of GUS-A reveals a shallow fault, Fault J, a north-dipping structure that extends from approximately 3900 feet down to 6250 feet, or the limit of seismic data on GUS-A. Reflector correlation across the fault indicates 35 feet of fault offset about 4900 feet below the surface. No trend could be established for Fault J as it was found only on GUS-A.

k. Examination of Faulting in the Main Cooling Area

Three faults, designated recently P, Q, and R, were purported to cross the Main Cooling Area on the basis of missing stratigraphic sections from well logs during the initial interpretation conducted for the PSAR. As part of the scope of services Petty Ray 73-4 and GUS-A were carefully examined for evidence of two of those faults, Q and R. The results were negative and there is no evidence for those faults along Petty Ray 73-4 or GUS-A in the main cooling area.

C. Well Logs and Seismic Stratigraphic Cross Sections

Electric logs from six petroleum exploration wells were available for this study (Plate 1). Although the logged intervals vary, all six logs cover the interval between 2082 feet and 9700 feet. Logging intervals for each well are shown below.

WELL NO.	LOG STARTS (feet)	LOG ENDS (feet)
6	2100	10,600
12	100	11,894
20	1210	9,704
51	1600	11,300
55	10	11,101
75	2082	13,032

Correlation between wells is excellent above the base of a prominent sand unit, approximately 6000 to 6400 feet below the ground surface. There, alternating sand and shale facies correlate well between borings. Below approximately 6000 to 6400 feet in the mapped area the geologic section is comprised of shales with little sand. The logs available for this study provided only fair correlation between 6000 and 9000 feet.

The well logs available for this study were used to check the interpretation along Conoco 1 using well numbers 75, 12, 20, and 6. Additionally, logs from wells 51 and 55 that are intersected by Fault A were compared with those from Well 12, which is not intersected by Fault A, to determine the amount of offset on the fault.

Plate 7d shows a cross section of Conoco 1 including both seismic stratigraphic and well log correlations. Three of the four seismic reflecting horizons traced around the site are shown on this profile. The shallowest, Reflector 1, defined on Jaecon 2M, is lost in low frequency ground roll returns on Conoco 1.

Seismic reflectors are numbered 1 through 4 in descending order. Reflector 1 is the shallowest, coherent reflector below time zero on the seismic data. The reflector was chosen to define the shallowest fault offset on Jaecon 2M.

Reflector 2 is near the top of a prominent sand unit, and its seismic character is distinctive and relatively easy to trace from line to line.

Reflector 3 is at the base of the shale section underlying the prominent sand unit and again, it is easy to carry across the site between the different seismic data sets.

Reflector 4 is the top of what appears to be an unconformity with flat-lying reflectors above and north-dipping reflectors below. Below the unconformity line to line correlation of dipping reflectors is poor, primarily because of the variation in data quality between the five seismic data sets.

Cross sections are presented on Plate 7a through 7d for Jaecon 2M and 4M, Conoco 1, and Petty Ray 73-4. Eight of the ten faults described are shown on the cross sections along with seismic Reflectors 1-4. These profiles along with those on Plate 8 characterize the entire site from east to west.

Cross section 2M, Plate 7a, is the "type" section for this study because of its superior data quality. Its two outstanding features are the extensions of Faults A and I into the very shallow seismic section. Reflector 1 may have up to 100 feet of offset as shallow as 1200 feet below the ground surface on both faults.

Cross section Conoco 1 (Plate 7d) also shows Fault A, the only shallow penetration fault in the north half of the study area covered by seismic data.

Petty Ray 73-4, Plate 7c shows the only fault in the vicinity of the plant site is Fault H, a relatively deep antithetic fault that is at least 6000 feet below the surface.

Plate 8 contains cross sections for GUS-A, TXO-1 and 2, and Petty Ray 73-1. Plate 8a shows the seismic stratigraphic cross section of GUS-A. Note only the upper 6000 feet of the site are included in the data. Fault A is identified up to at least 440 feet below the surface. Fault J on the southern end of the line rises to within 3850 feet of the surface.

The most outstanding feature of GUS-A is the excellent data quality along the line and the fact that no faults were found in the shallow section near the plant site. Fault A is approximately 3.4 miles north of the center of the plant site at its shallowest point on GUS-A and Fault J is 5.7 miles south of the center of the plant site at its shallowest point.

TXO-1 and TXO-2 on Plate 8 demonstrate why the fault parameter matrix of Figures 2-4 uses the designation "not applicable" under the heading "Depth to Seismic Cap". For example, 8c shows that Faults A, B, and C are

intersected below their shallowest point on TXO-1 and they run off the edge of the cross section. Therefore, it is not possible to determine whether the faults are capped using this profile.

Plate 8d shows Petty Ray 73-1 in cross section. Faults A, B, C, D, H, and G are depicted as well as all four seismic reflectors traced across the site.

D. Fault Summary Chart (Matrix)

Faults identified on the seismic record have also been identified in a Fault Summary Chart (Figures 2, 3, and 4). The chart includes a column for each seismic line interpreted and a listing of fault information including: location, shot point, offset, shallowest point time and depth on the fault plane (fault "pick"), and reflecting time and depth of the seismic capping layer. The capping layer is defined as a continuous seismic reflection that can be traced unbroken over and above the fault plane.

	Jaecon		GUS				
	2 m	4 m	A	B	C	1	
FAULT A							
Present?	Yes	Yes	Yes	No	No	Yes	No
SP Location	139	475	25	-	-	11930	-
Shallowest Fault "Pick" - feet (seconds)	915.0 (0.30) 50†	1068.0 (0.35) 50†	488.0 (0.16) 25†	-	-	2000.0 (0.62) 50†	-
Depth of Seismic Cap - feet (seconds)	**	**	**	-	-	**	-
FAULT B							
Present?	Yes	Yes	No	No	No	Yes	No
SP Location	150	495	-	-	-	929.5	-
Shallowest Fault "Pick" - feet (seconds)	8605.0 (2.1)	8605.0 (2.1)	-	-	-	7380.0 (1.85)	-
Depth of Seismic Cap - feet (seconds)	8250 (2.03)	8200 (2.02)	-	-	-	5700.0 (1.5)	-
FAULT C							
Present?	Yes	Yes	No	No	No	Yes	No
SP Location	146	488	-	-	-	930.5	-
Shallowest Fault "Pick" (seconds)	10370.0 (2.45)	7620.0 (1.9)	-	-	-	7380.0 (1.85)	-
Depth of Seismic Cap - feet (seconds)	10120.0 (2.4)	5700.0 (1.5)	-	-	-	7140.0 (1.8)	-
FAULT D							
Present?	Yes	No	No	No	No	No	Yes
SP Location	186	-	-	-	-	-	81
Shallowest Fault "Pick" - feet (seconds)	10370.0 (2.45)	-	-	-	-	-	16 (3.
Depth of Seismic Cap - feet (seconds)	10270.0 (2.43)	-	-	-	-	-	**

*1. Not applicable; strike line or off end of line
**2. Not identifiable
†3. Offset at most shallow fault pick
††4. Upward termination of fault not seen on section

Conoco		Petty Ray						TXO	
2	3	73-1	73-2	73-3	73-4	73-5	73-6	1	2
	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes
	-	213	265	303	350	-	-	1	1
	-	10630 2.5 ††	12680.0 (2.9) ††	10370.0 (2.45) ††	9360.0 (2.25) ††	-		8350.0 (2.05)	8605.0 (2.1) ††
	-	*	*	*	*	-	-	*	*
	No	Yes	Yes	No	Yes	No	No	Yes	Yes
	-	213	273	-	350	-	-	1	1
	-	12170.0 (2.8)	14730.0 (3.3)	-	9620.0 (2.3)	-	-	10730.0 (2.52)	10630.0 (2.5)
	-	*	*	-	*	-	-	*	*
	No	Yes	No	No	No	No	No	Yes	Yes
	-	213	-	-	-	-	-	1	1
	-	14420.0 3.24	-	-	-	-	-	12680.0 (2.9)	13710.0 (3.1)
	-	*	-	-	-	-	-	*	*
	No	Yes	No	No	No	No	No	No	Possible
.5	-	239	-	-	-	-	-	-	-
80.0 75)	-	11140.0 (2.6)	-	-	-	-	-	-	-
	-	10930.0 (2.56)	-	-	-	-	-	-	-

TI APERTURE CARD

8512300155-01

Figure 2. **Fault Summary Chart (A,B,C,D)**

Also Available On Aperture Card

	Jaecon		GUS			C	
	2 m	4 m	A	B	C	1	
FAULT E							
Present?	No	No	No	No	No	No	No
SP Location	-	-	-	-	-	-	-
Shallowest Fault "Pick" - feet (seconds)	-	-	-	-	-	-	-
Depth of Seismic Cap - feet (seconds)	-	-	-	-	-	-	-
FAULT F							
Present?	Yes	Yes	No	No	No	Yes	No
SP Location	100	457	-	-	-	936	-
Shallowest Fault "Pick" - feet (seconds)	10630.0 (2.5)	12680.0 (2.9)	-	-	-	9620.0 (2.3)	-
Depth of Seismic Cap - feet (seconds)	*	11140.0 (2.6)	-	-	-	9460.0 (2.27)	-
FAULT G							
Present?	Yes	No	No	No	No	No	No
SP Location	257	-	-	-	-	-	-
Shallowest Fault "Pick" - feet (seconds)	7380.0 (1.85)	-	-	-	-	-	-
Depth of Seismic Cap - feet (seconds)	*	-	-	-	-	-	-
FAULT H							
Present?	Yes	No	No	No	Yes	Yes	Yes
SP Location	200	-	-	-	147	925	810
Shallowest Fault "Pick" - feet (seconds)	5940.0 (1.55)	-	-	-	6180.0 (1.6)	7620.0 (1.9)	936 (2.
Depth of Seismic Cap - feet (seconds)	5700.0 (1.50)	-	-	-	5480.0 (1.45)	6180.0 (1.8)	*

*1. Not applicable; strike line or off end of line
**2. Not identifiable
†3. Offset at most shallow fault pick
††4. Upward termination of fault not seen on section

onoco		Petty Ray						TXO	
2	3	73-1	73-2	73-3	73-4	73-5	73-6	1	2
	No	No	No	No	No	No	No	Yes	No
	-	-	-	-	-	-	-	30	-
	-	-	-	-	-	-	-	10370.0 (2.45)	-
	-	-	-	-	-	-	-	10120.0 (2.4)	-
	No	No	No	No	No	No	No	No	No
	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-
	Yes	Yes	No	No	No	No	No	No	No
	130.5	348.5	-	-	-	-	-	-	-
	7140.0 (1.8)	8350.0 (2.05)	-	-	-	-	-	-	-
	**	*	-	-	-	-	-	-	-
	No	Yes	Yes	No	Yes	No	No	Yes	Yes
.8	-	260	230	-	301	-	-	27	25
0.0 25)	-	5940.0 (1.55)	10370.0 (2.45)	-	6180.0 (1.6)	-	-	7140.0 (1.8)	6180.0 (1.6)
	-	5390.0 (1.43)	*	-	5990.0 (1.56)	-	-	6180.0 (1.6)	6040.0 (1.57)

Figure 3. **Fault Summary Chart (E,F,G,H)**

FAULT I	Jaecon		GUS			Con	
	2 m	4 m	A	B	C	1	2
Present?	Yes	No	No	No	No	No	No
SP Location	249	-	-	-	-	-	-
Shallowest Fault "Pick" - feet (seconds)	915.0 (0.30) 75†	-	-	-	-	-	-
Depth of Seismic Cap - feet (seconds)	**	-	-	-	-	-	-
FAULT J							
Present?	No	No	Yes	No	No	No	No
SP Location	-	-	1006	-	-	-	-
Shallowest Fault "Pick" - feet (seconds)	-	-	3940.0 (1.1) 100†	-	-	-	-
Depth of Seismic Cap - feet (seconds)	-	-	3720.0 (1.05)	-	-	-	-

*1. Not applicable strike line or off end of line
**2. Not identifiable
†3. Offset at most shallow fault pick
††4. Upward termination of fault not seen on section

oco		Petty Ray						TXO	
	3	73-1	73-2	73-3	73-4	73-5	73-6	1	2
	Yes	No	No	No	No	No	No	No	No
	130	-	-	-	-	-		-	-
	3940.0 (1.1) 100†	-	-	-	-	-	-	-	-
	**	-	-	-	-	-	-	-	-
	No	No	No	No	No	No	No	No	No
	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-

8512300155-03

Figure 4. **Fault Summary Chart (I,J)**

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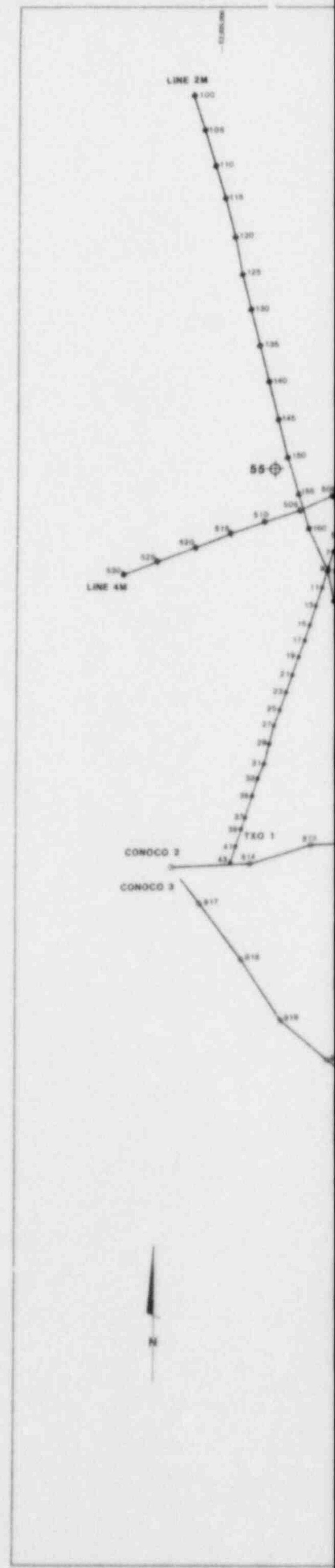
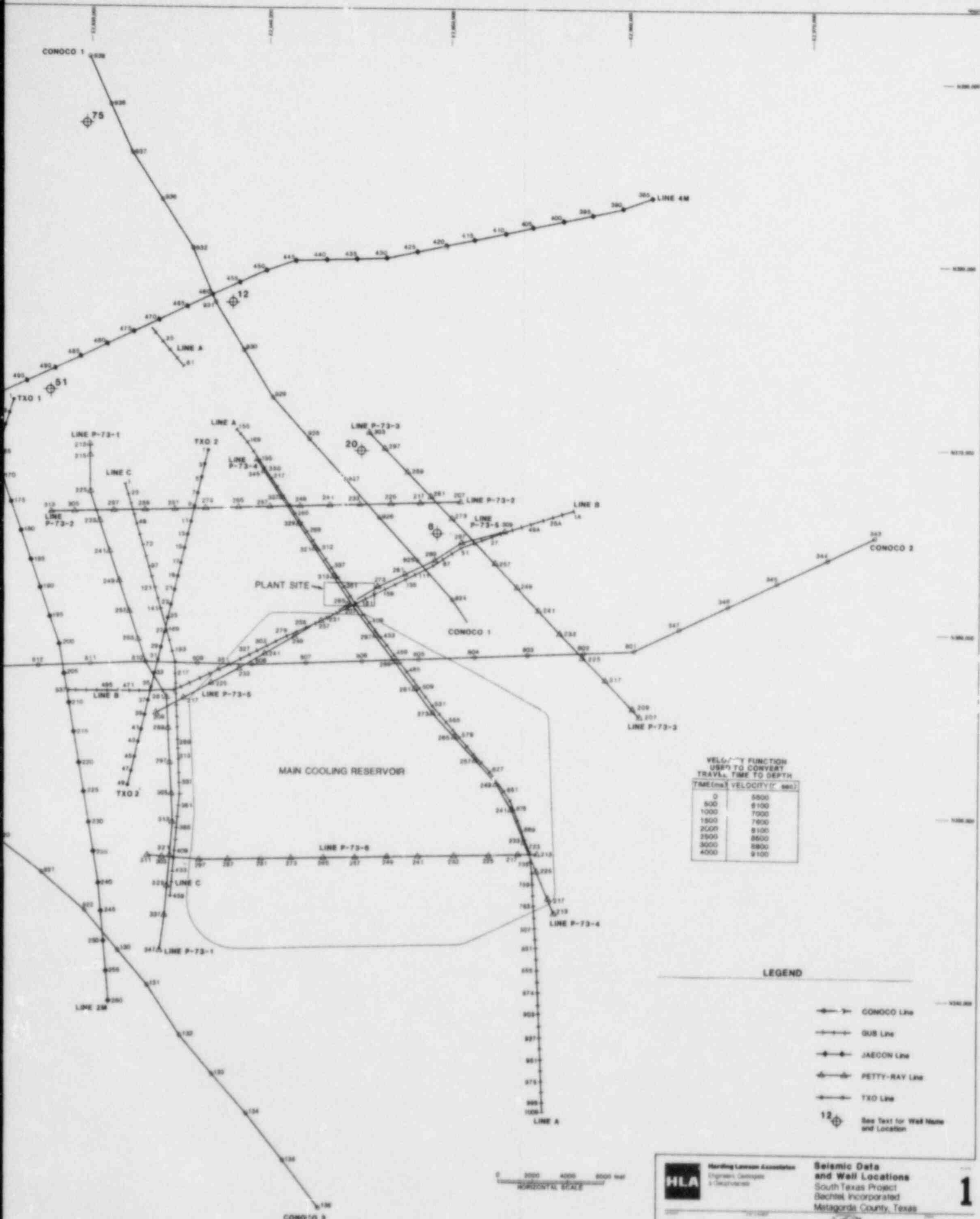
VII ILLUSTRATIONS



LINE 2M
LINE 4M
55
CONOCO 2
CONOCO 3
TXO 1
N



VELOC..Y FUNCTION USED TO CONVERT TRAVEL TIME TO DEPTH

TIME(ms)	VELOCITY(ft/sec)
0	5800
500	6100
1000	7000
1500	7600
2000	8100
2500	8600
3000	8800
4000	9100

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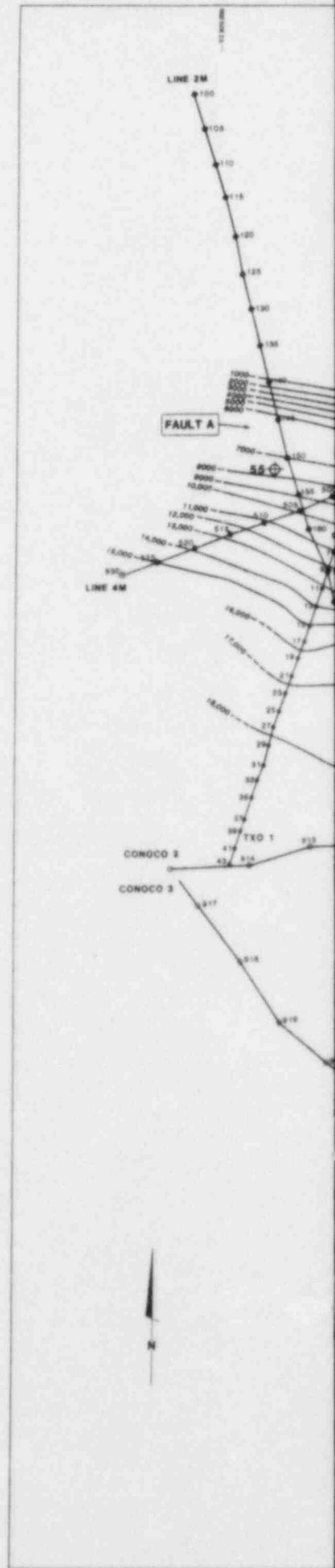
Seismic Data and Well Locations
South Texas Project
Bechtel Incorporated
Matagorda County, Texas

1

JAS 3854,091.09 10/85
FAS 10/28/85

8512300155-04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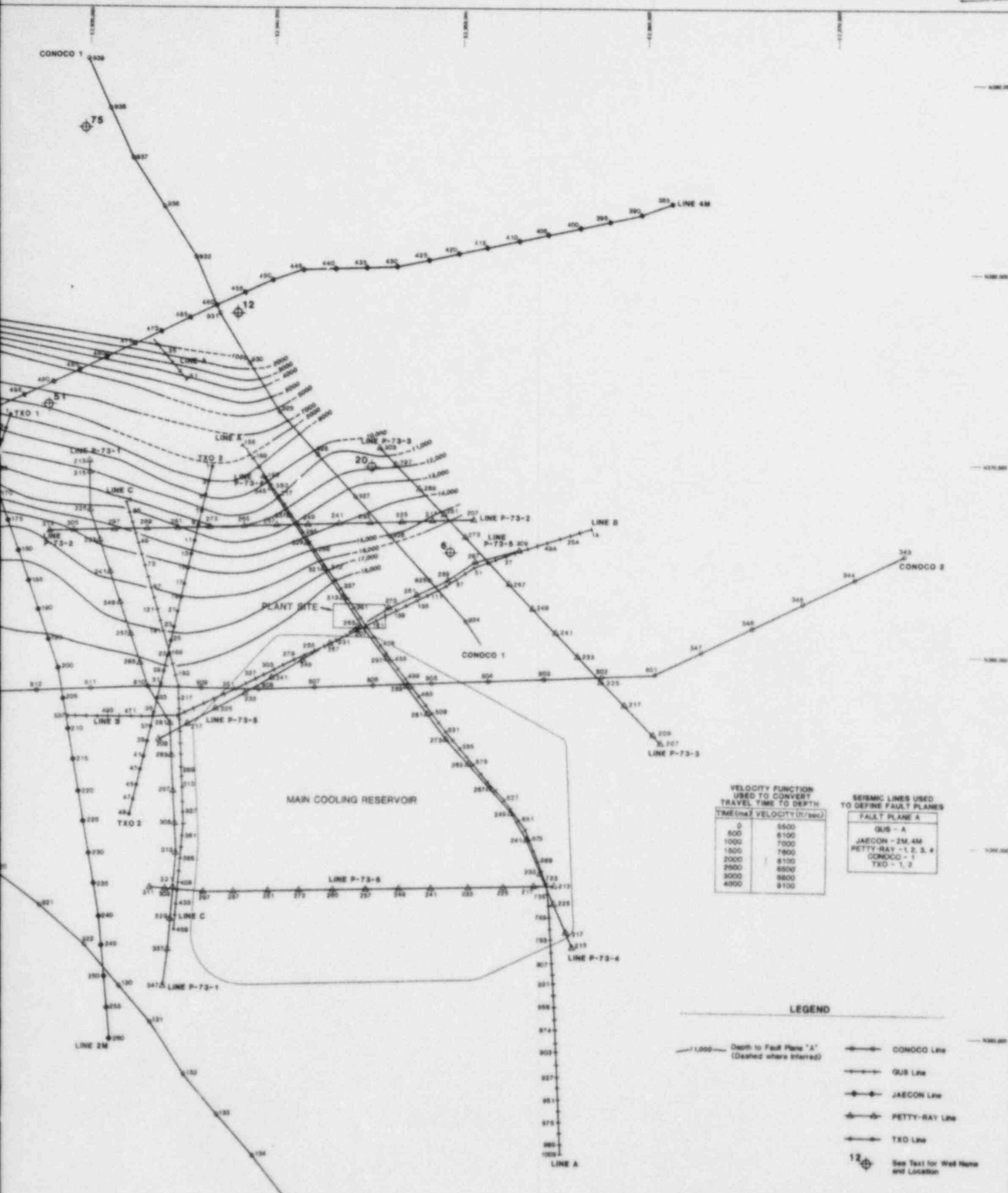
FAULT A
LINE 4M
TXO 1
CONOCO 2
CONOCO 3
N



VELOCITY FUNCTION USED TO CONVERT TRAVEL TIME TO DEPTH

TIME (ms)	VELOCITY (ft/sec)
0	5500
500	6100
1000	7000
1500	7800
2000	8100
2500	8500
3000	8800
4000	9100

SEISMIC LINES USED TO DEFINE FAULT PLANES

FAULT PLANE A
GUS - A
JAECON - 2M, 4M
PETTY-RAY - 1, 2, 3, 4
CONOCO - 1
TXO - 1, 2

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Depth Contours of Fault Plane "A"
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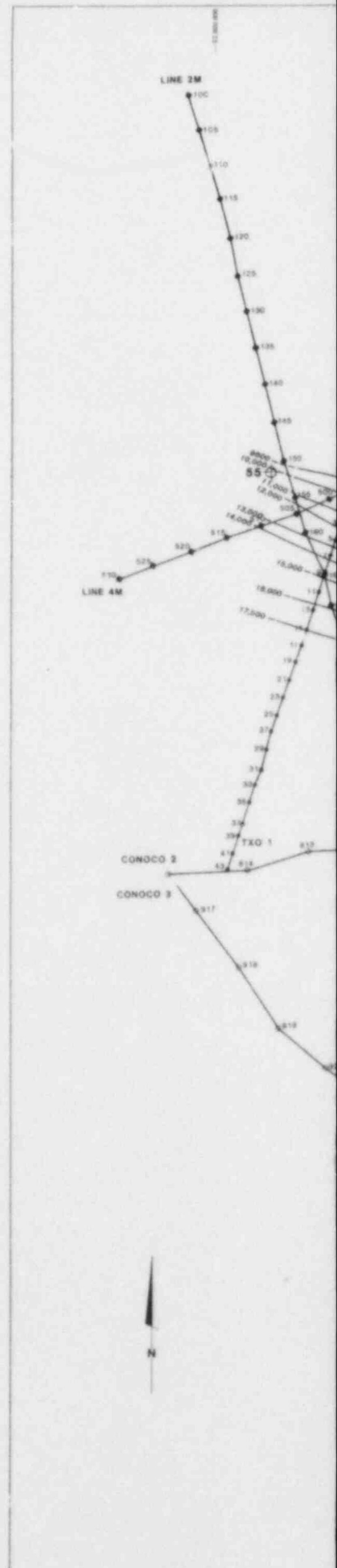
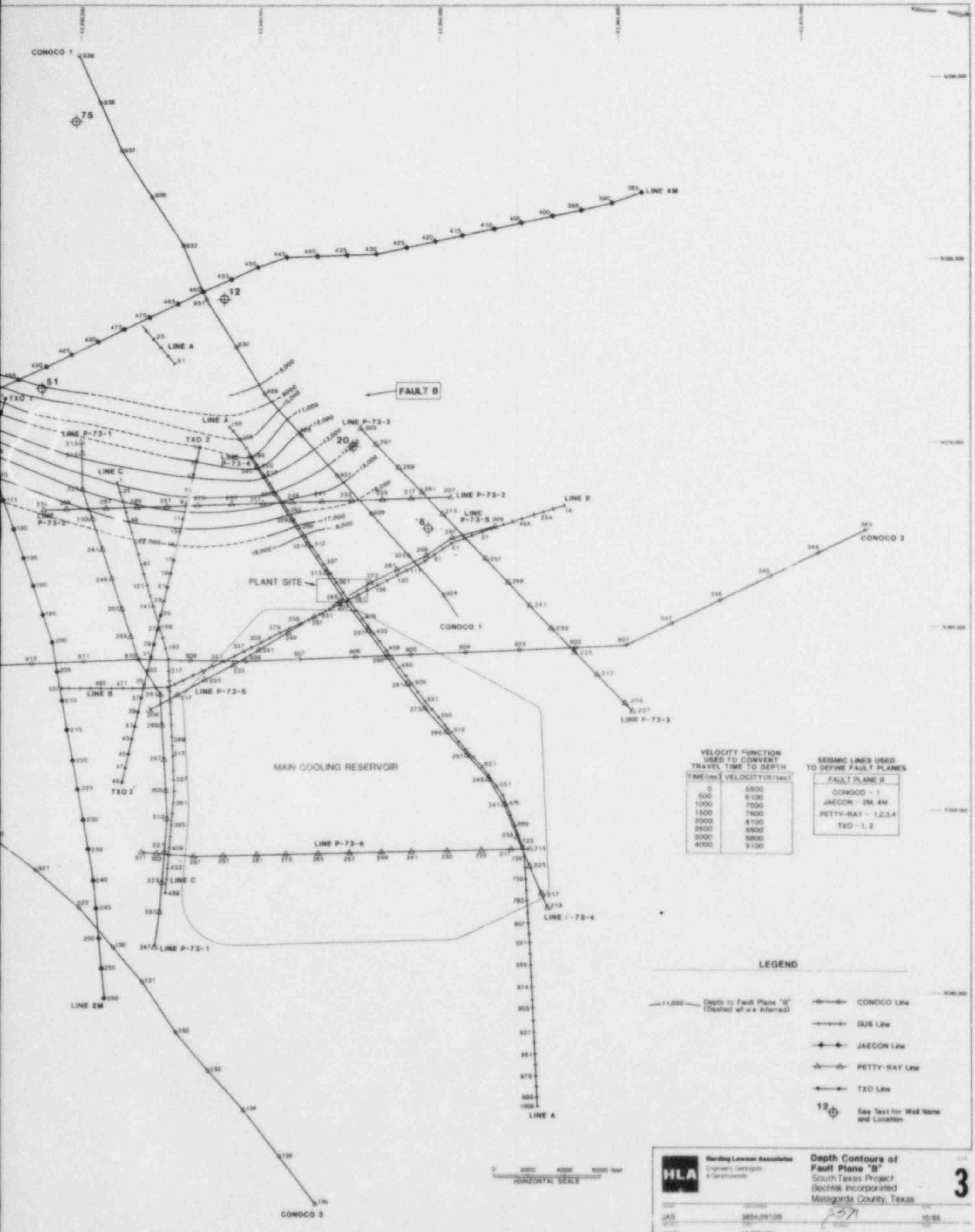
2

JAS | 3884,097,09 | 10/85
PAS | 10/28/85

8512300155-05


LINE 2M
LINE 4M
CONOCO 2
CONOCO 3
TXO 1
N



VELOCITY FUNCTION USED TO CONVERT TRAVEL TIME TO DEPTH

TIME (ms)	VELOCITY (ft/sec)
0	5500
500	6100
1000	7000
1500	7600
2000	8100
2500	8500
3000	8800
4000	9100

SEISMIC LINES USED TO DEFINE FAULT PLANES

FAULT PLANE B
CONOCO - 1
JAECON - 2M, 4M
PETTY-RAY - 1,2,3,4
TXO - 1, 2

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Depth Contours of Fault Plane "B"
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3

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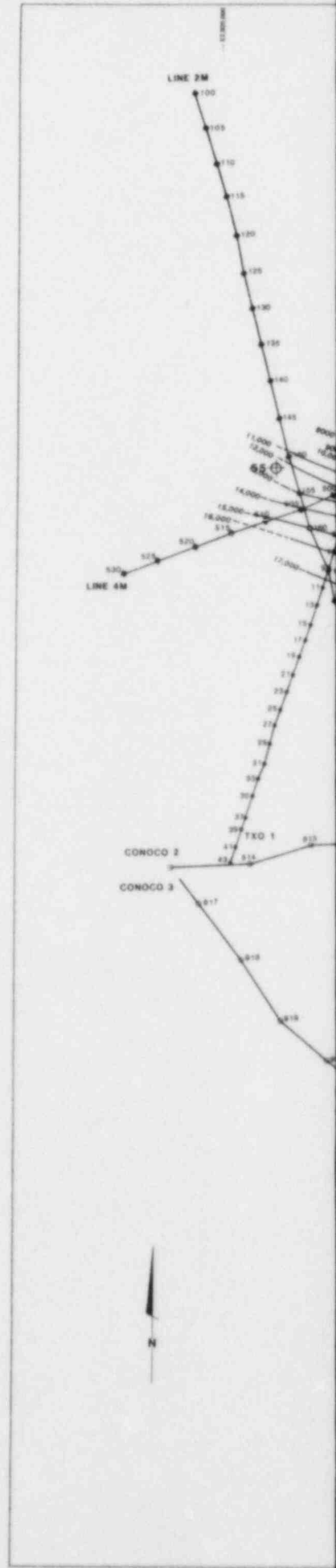
PAS	10/28/85		

8512300155-06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LINE 4M
CONOCO 2
CONOCO 3
TXO 1
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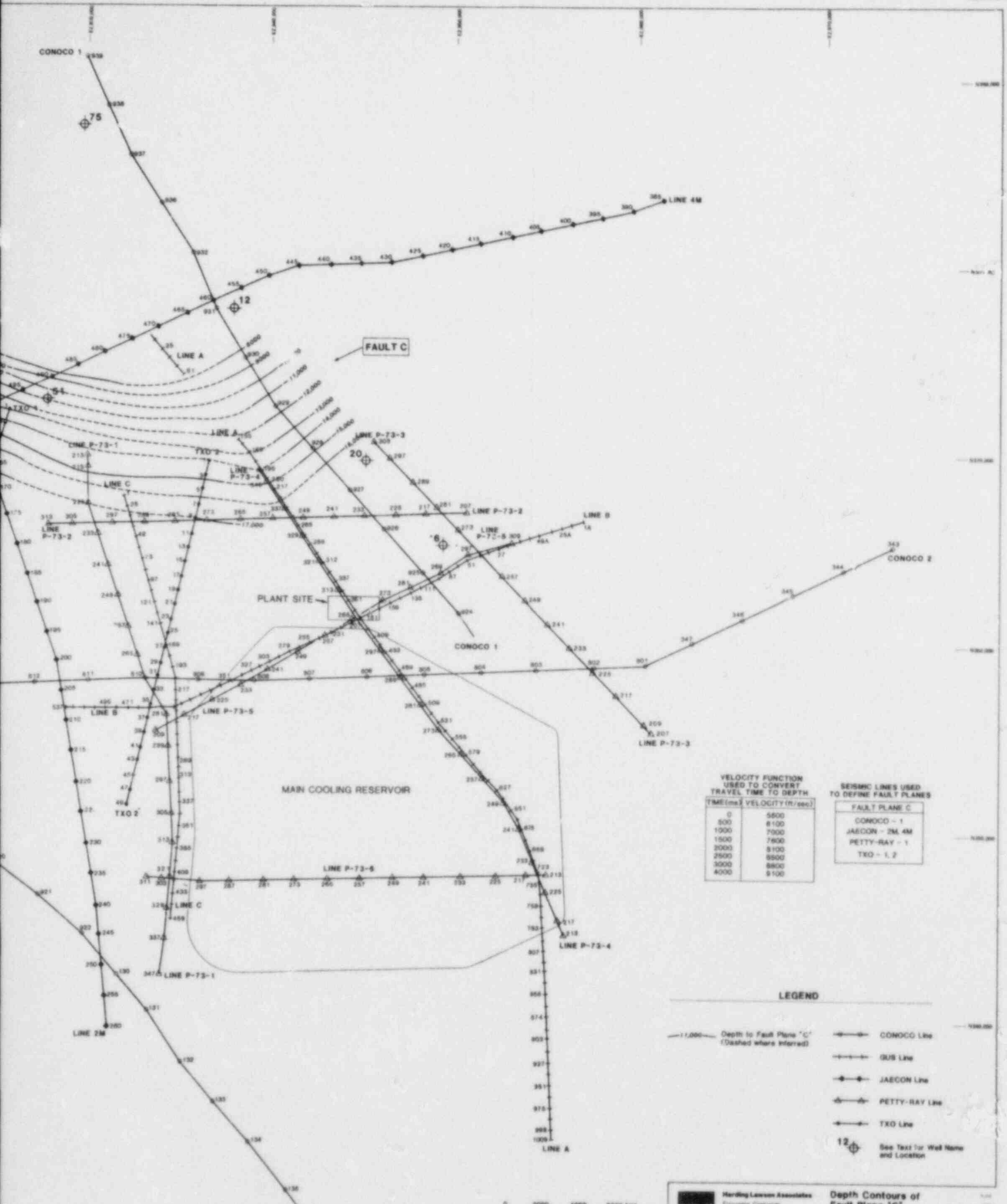

VELOCITY FUNCTION USED TO CONVERT TRAVEL TIME TO DEPTH

TIME(ms)	VELOCITY(ft/sec)
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500	6100
1000	7000
1500	7600
2000	8100
2500	8500
3000	8800
4000	9100

SEISMIC LINES USED TO DEFINE FAULT PLANES

FAULT PLANE C
CONOCO - 1
JAECON - 2M, 4M
PETTY-RAY - 1
TXO - 1, 2

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Depth Contours of Fault Plane "C"
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4

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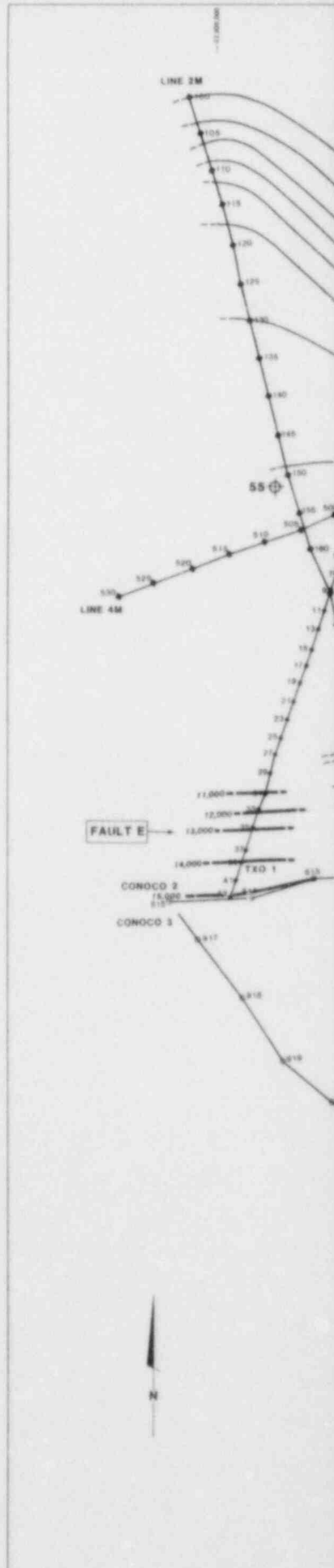
PAS	10/28/85		

8512300155-07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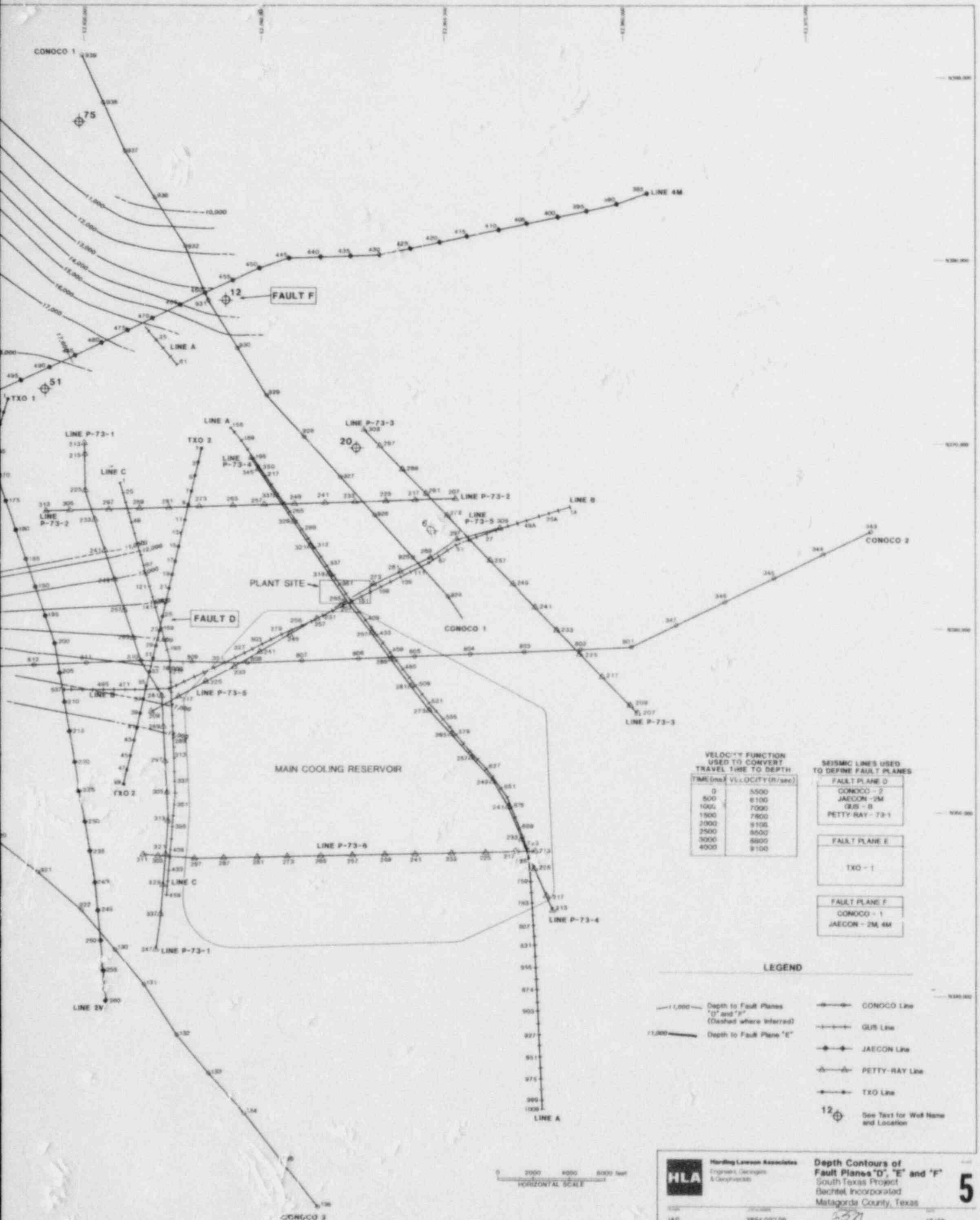
FAULT E
11,000
12,000
13,000
14,000
15,000
TXO 1
CONOCO 2
CONOCO 3
N



VELOCITY FUNCTION USED TO CONVERT TRAVEL TIME TO DEPTH

TIME (ms)	VELOCITY (ft/sec)
0	5500
500	6100
1000	7000
1500	7800
2000	8100
2500	8500
3000	8800
4000	9100

SEISMIC LINES USED TO DEFINE FAULT PLANES

FAULT PLANE D
CONOCO - 2
JAECON - 2M
GUS - B
PETTY-RAY - 73-1

FAULT PLANE E
TXO - 1

FAULT PLANE F
CONOCO - 1
JAECON - 2M, 4M

LEGEND

- 11,000 — Depth to Fault Planes "D" and "F" (Dashed where inferred)
- 11,000 — Depth to Fault Plane "E"
- CONOCO Line
- GUS Line
- JAECON Line
- PETTY-RAY Line
- TXO Line
- 12 ⊕ See Text for Well Name and Location

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Depth Contours of Fault Planes "D", "E" and "F"
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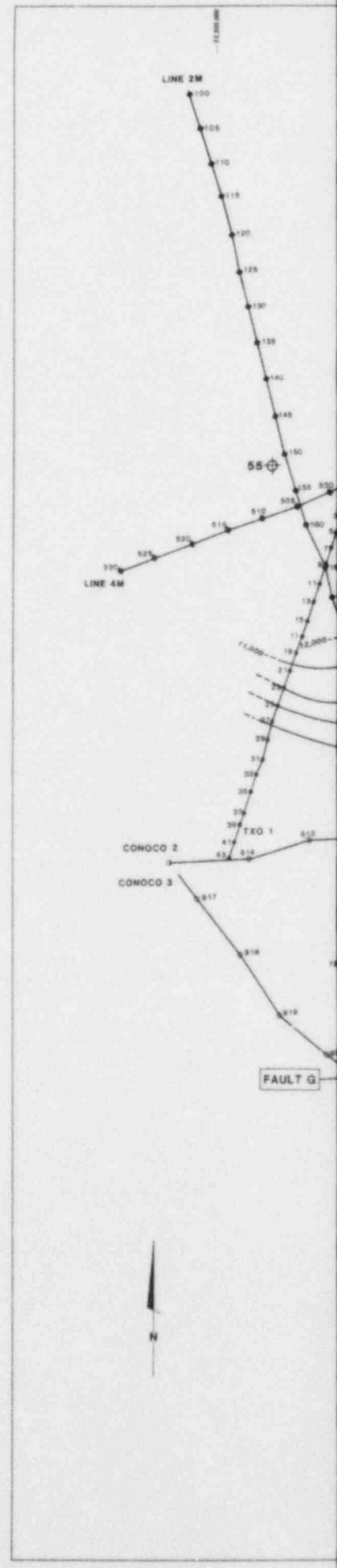
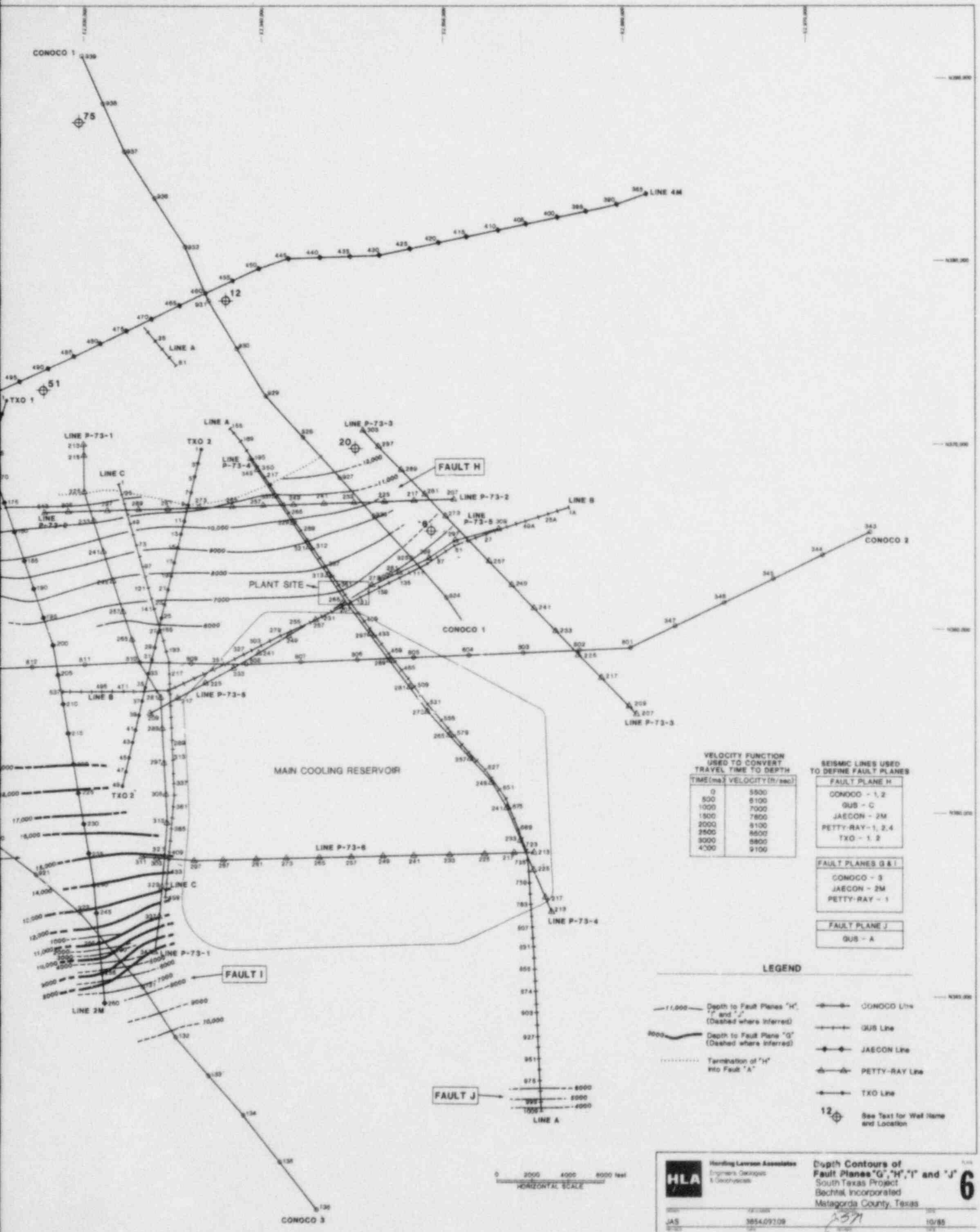
5

JAS 3554,097.09 10/85
PAS 10/28/85

8512300155 -08


LINE 2M
55
LINE 4M
TXO 1
CONOCO 2
CONOCO 3
FAULT G
N



VELOCITY FUNCTION USED TO CONVERT TRAVEL TIME TO DEPTH

TIME (ms)	VELOCITY (ft/sec)
0	5500
500	6100
1000	7000
1500	7600
2000	8100
2500	8600
3000	8800
4000	9100

SEISMIC LINES USED TO DEFINE FAULT PLANES

FAULT PLANE H
CONOCO - 1, 2
GUS - C
JAECON - 2M
PETTY-RAY - 1, 2, 4
TXO - 1, 2

FAULT PLANES G & I
CONOCO - 3
JAECON - 2M
PETTY-RAY - 1

FAULT PLANE J
GUS - A

LEGEND

- 11,000 — Depth to Fault Planes "H", "I" and "J" (Dashed where Inferred)
- Depth to Fault Plane "G" (Dashed where Inferred)
- Termination of "H" into Fault "A"
- CONOCO Line
- GUS Line
- JAECON Line
- PETTY-RAY Line
- TXO Line
- 12 See Text for Well Name and Location

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Depth Contours of Fault Planes "G", "H", "I" and "J"
South Texas Project
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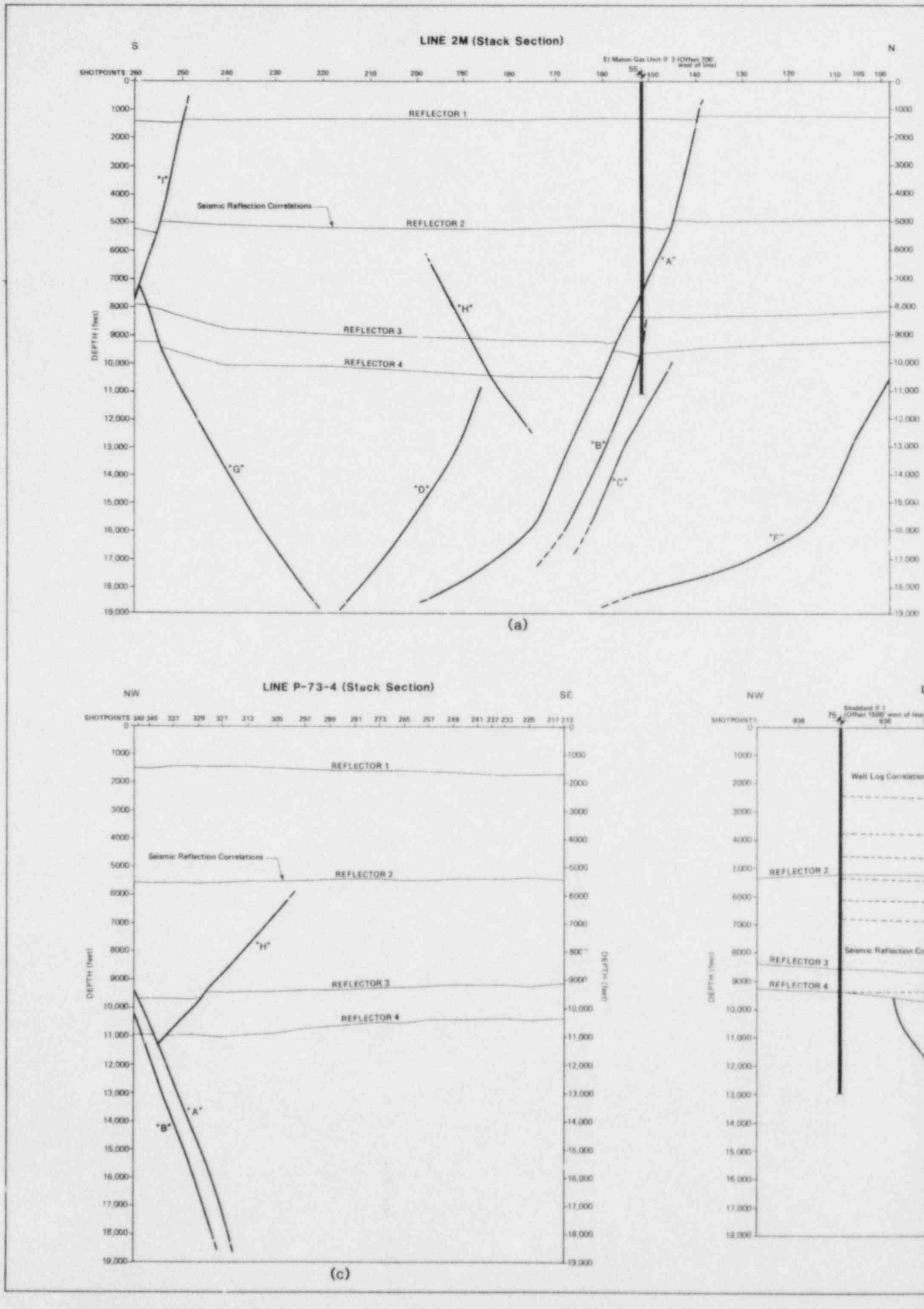
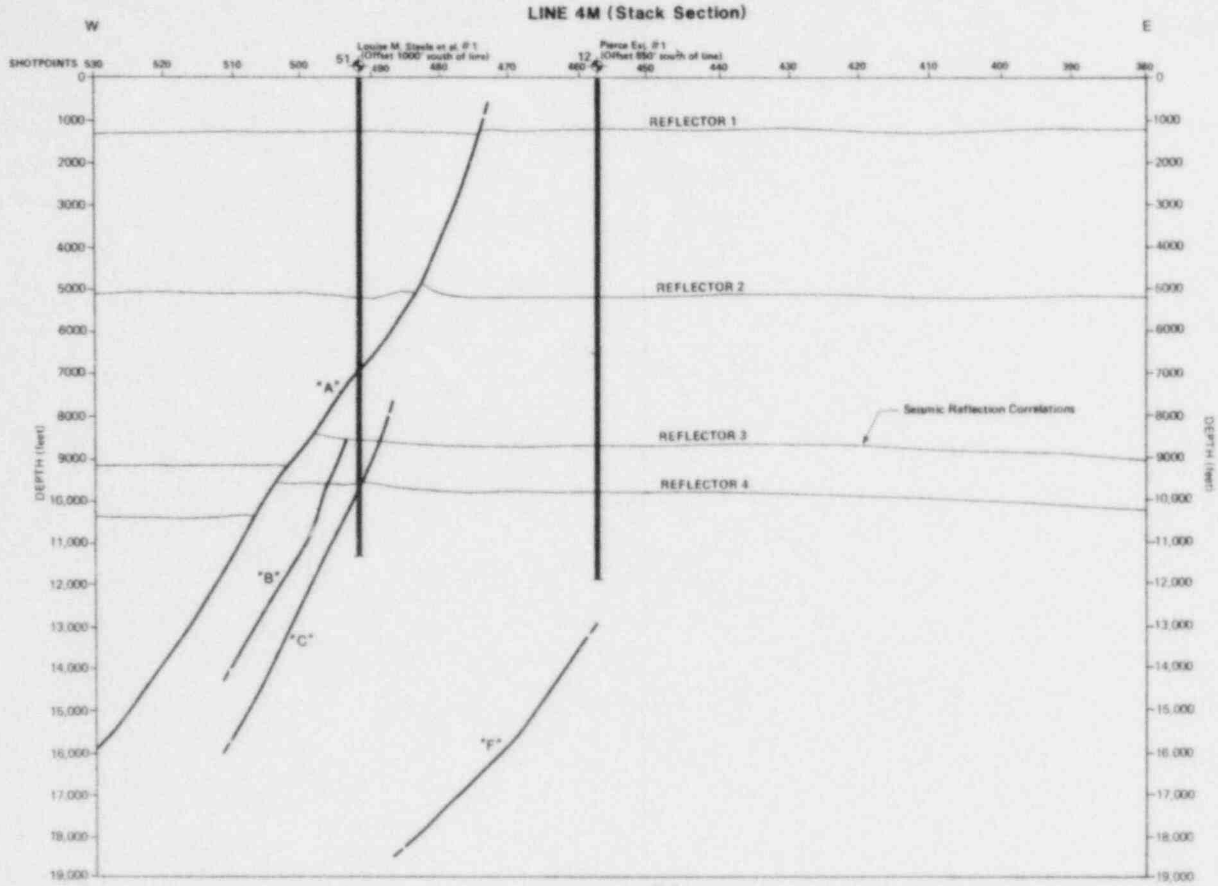
6

JAS	3854,097.09		10/85
PAS	10/28/85		

8512300155-09



LINE 2M (Stack Section)
S
N
SHOTPOINTS
El Maton Gas Unit # 2 (Offset 700' west of line)
REFLECTOR 1
Seismic Reflection Correlations
REFLECTOR 2
REFLECTOR 3
REFLECTOR 4
DEPTH (feet)
"I"
"H"
"A"
"G"
"D"
"B"
"C"
"F"
(a)
LINE P-73-4 (Stack Section)
NW
SE
SHOTPOINTS
REFLECTOR 1
Seismic Reflection Correlations
REFLECTOR 2
"H"
REFLECTOR 3
REFLECTOR 4
"A"
"B"
DEPTH (feet)
(c)
NW
SHOTPOINTS
Stoddard # 1 (Offset 1500' west of line)
Well Log Correlations
REFLECTOR 2
Seismic Reflection Corr
REFLECTOR 3
REFLECTOR 4
DEPTH (feet)



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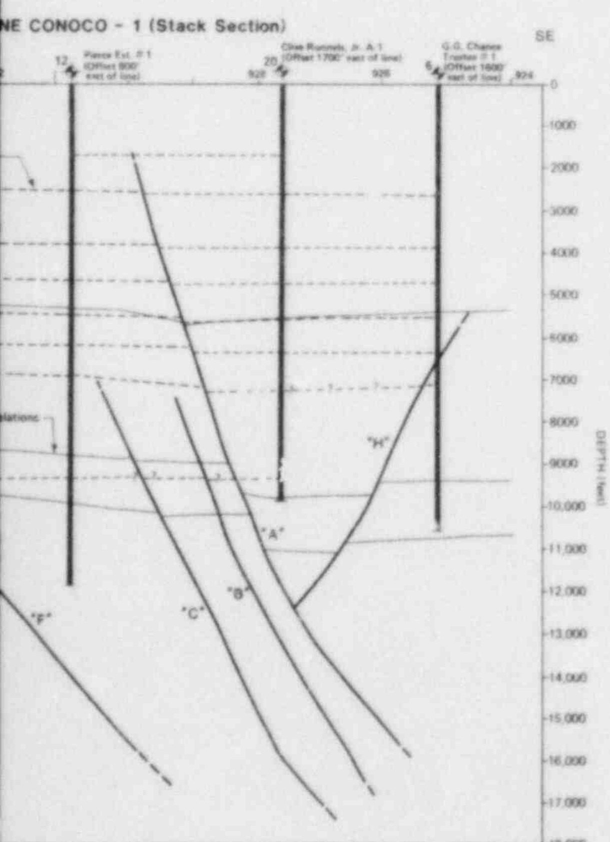

(d)

TI APERTURE CARD

Also Available On Aperture Card

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Seismic Stratigraphic Cross Sections
South Texas Project
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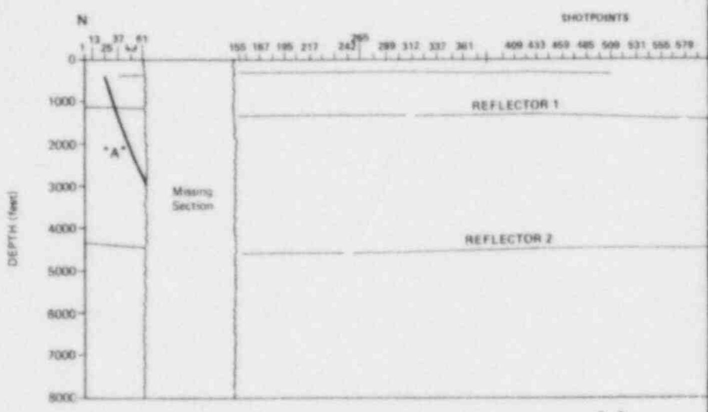
PLATE **7**

DRAWN	JOB NUMBER	APPROVED	DATE
JAS	3854,092.09	JSM	10/85
REVISED	DATE	REVISED	DATE
PAS	10/28/85		

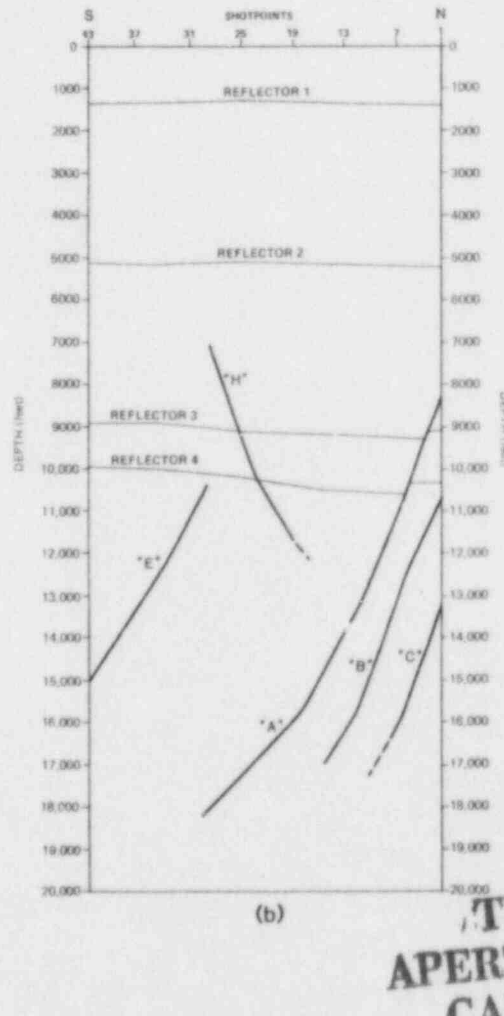
8512300155-10

LINE GUS - A



(a)

LINE TXO - 1 (Migrated Section)



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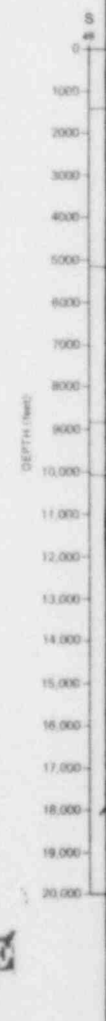
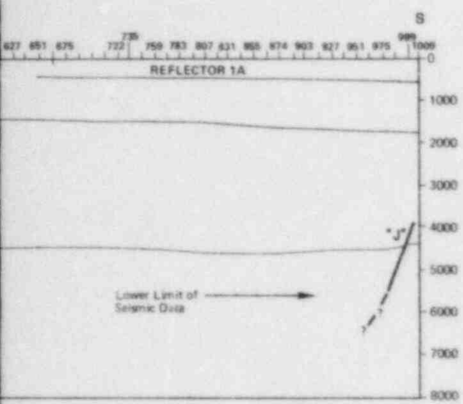
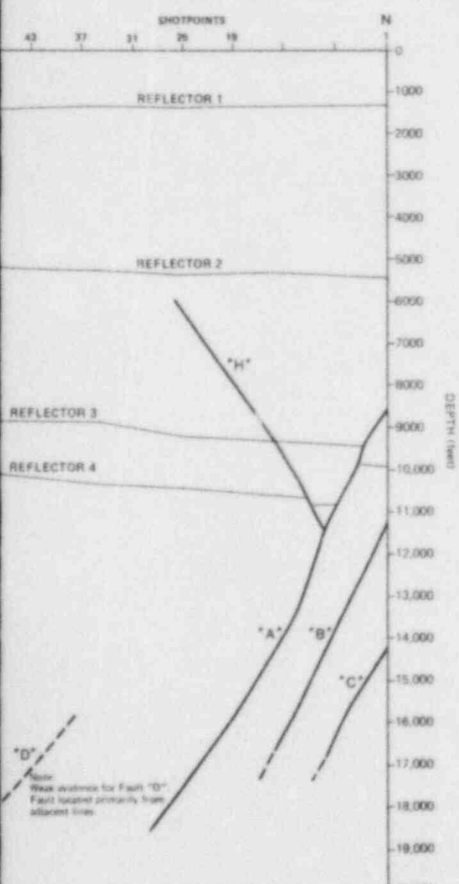


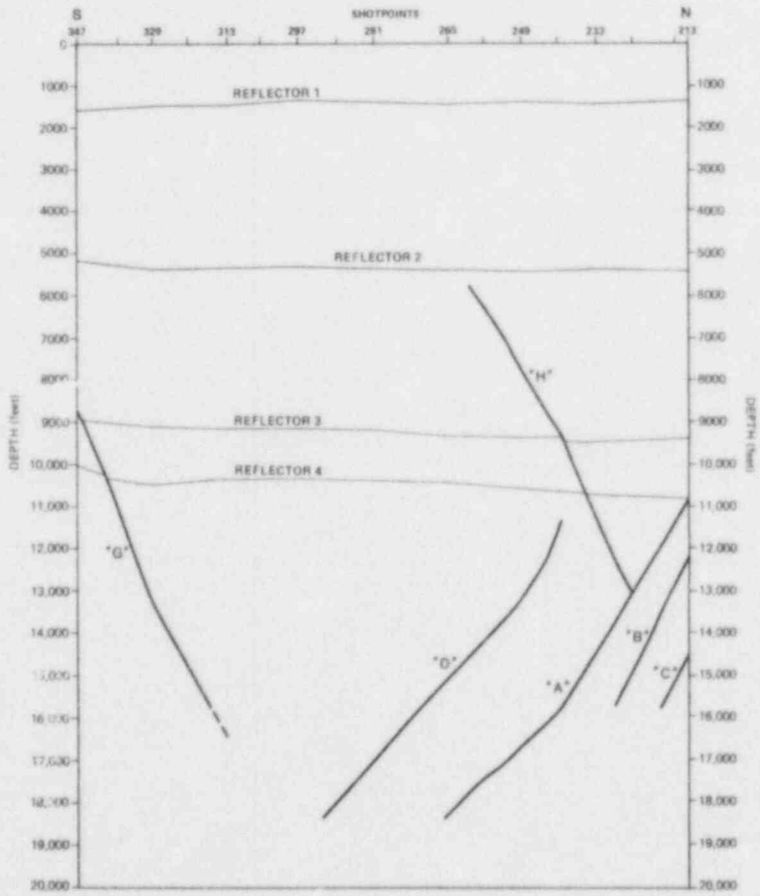


LINE TXO - 2 (Migrated Section)



(c)

LINE P-73-1 (Stack Section)



(d)

0 4000 8000 12,000 feet
HORIZONTAL SCALE

HLA

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Seismic Stratigraphic Cross Sections
South Texas Project
Bechtel, Incorporated
Matagorda County, Texas

PLATE **8**

DRAWN	JOB NUMBER	APPROVED	DATE
JAS	3854,092.09	[signature]	10/85
REVISED	DATE	REVISED	DATE
PAS	10/28/85		

8512300155 - 11

Attachment 3

SUMMARY STATEMENT ON GEOLOGIC STRUCTURES & SIGNIFICANCE

Results of Analysis: Geophysical Data

1. Faults identified from reflection profiles and well logs are typical down-to-the-south, syndepositional growth faults (and associated down-to-the-north antithetic faults) characteristic of the Texas Gulf Coastal Plain. The structures identified individually and collectively demonstrate the properties associated with the interpretation of growth faulting, including thickening of section on the down-thrown side, increased displacement with depth, and flattening of dip with depth. None of the structures identified has unique properties at variance with this conclusion.

2. Ten growth faults have been identified from the present interpretation of the geophysical record. Seven of these faults are confined to the sedimentary section below 5000 feet, i.e., Miocene and older. Three faults (A, I, and J) are more shallow.

3. The south-dipping Fault A is identified on geophysical data about 2.5 miles north of the north property line. It is identified to cut reflectors to a depth of about 490 feet below ground surface. Above this depth the seismic record is not definitive. Projection of Fault A to the ground surface would form a trace about 2.8 mi north of the Category I structures.

4. The south-dipping Fault I is identified on geophysical data about 1 mile west of the southwest property line. It is identified to cut reflectors to a depth of about 900 feet below ground surface. Above this depth the seismic record is not definitive. Projection of Fault I to the ground surface above where it is identified would form a trace about 4 mi southwest of Category I structures. Seismic reflection line GUS - A is located within the reservoir area about 24,000 ft east of where Fault I is identified. There are continuous seismic reflectors on GUS - A down to a depth of at least 5000 ft across the projection of Fault I in that area.

5. The north-dipping Fault J is identified on the geophysical data about 1.7 miles south of the south property line. It is overlain by continuous seismic reflectors at a depth of about 3700 ft.

6. The antithetic Fault H extends no nearer than 7000 feet below ground surface.

7. Growth faults identified from well logs in PSAR studies as occurring beneath the Main Cooling Reservoir at depths below 6000 feet (more recently designated Faults P, Q, and R with Q and R being bifurcating splays of P) have been re-evaluated in the current work in terms of confirming continuity of overlying units. These structures are not identifiable on the deep seismic line P73-4. The shallow seismic line GUS A defines continuous seismic reflections in this area, and therefore, these structures, if present, do not extend above 5000 feet below ground surface.

Surface Projection of Faults A and I

1. The closest approach to safety-related structures of a hypothetical trace from a surface projection of either Fault A or I is about 2.8 miles.

2. Based on review of previous and current lineament studies, review of imagery specifically in the area of the hypothetical traces of A and I, and field inspection of these areas, there is no evidence of Faults A and I at the surface. Mapping of exposures in Relocated Little Robbins Slough has defined an undisturbed contact between silty sands and clays of the Pleistocene Beaumont Formation which overlies the surface projection of Fault I. Based on areal geology presented in Doering, 1955, and correlation with glacial age assignments by Van Siclen, 1985, these sediments are probably lower Beaumont and are in excess of 70,000 years in age.

Significance of Growth Faults to Safety-Related Structures

1. The geologic structures identified in the subsurface at STP do not constitute a safety hazard to the Plant Site either from surface displacement or seismic ground motion.

2. The structures are the result of gravitational processes and are non-tectonic.

3. If displacement is assumed to occur, it would be as slow deformation or creep or yielding possibly associated with small earthquakes (e.g. Magnitude 1.5).

Attachment 4

2.5.1.2.5.6 Postulated Surface Projection of Growth Faults Identified in Upper 1000 ft - The review of geophysical data (reflection lines and electrical logs) has identified two growth faults which offset sediments within the upper 1000 ft of the ground surface. Fault A, which is located north of the Plant Site, is identified on GUS reflection line A up to a depth of about 440 ft below ground surface. A projection of this plane to the surface forms a trace approximately three miles north of the Plant Site. Fault I is identified on Jaecon reflection line 2M up to a depth of about 800 ft below ground surface. A projection of this plane to the ground surface forms a trace approximately four miles south-southwest of the Plant Site. ~~Therefore,~~ Both projected traces have been reviewed using remote sensing imagery and field inspection of the area of projection.

Post-CP review of geophysical data, incorporating more recent seismic lines, has resulted in a slightly different alignment of the major growth fault north of the Plant Site (Fault A) than shown in the CP studies; however, the projected trace of the realignment is within the area investigated in previous work, and observations and conclusions regarding surface evidence remain applicable. (Fault I is based on review of post-CP data.)

The surface projections of both features, A and I, have been compared to the results of the CP lineament study (Figure 1) and the 1985 lineament study (Figure 2). None of the lineaments identified in either study coincides with or closely parallels the surface projection of either growth fault.

The low-altitude black and white photography flown in May 1973 for the CP lineament study and the NASA U-2 color infrared imagery flown in November 1979 and used for the 1985 lineament study were specifically reviewed in the areas of the projected traces of Faults A and I. (Projected traces of both original and revised Fault A alignments were reviewed.) The examination of this imagery does not reveal evidence of topographic scarps, tonal anomalies, or sag ponds indicative of surface faults in the areas north or southwest of the Plant Site which would correspond to the ground surface projections of either of the features identified in the subsurface within these areas.

The areas in the vicinity of the ground surface projections of Fault A and Fault I have been examined in the field for surface effects of growth faulting. A ground reconnaissance of the area within 5 miles north of the Plant Site was conducted in December 1982. No topographic scarps or sag ponds were observed in this area, nor were pavement breaks, indicative of fault displacement, observed on roads which cross the projection of Fault A. A similar field investigation was performed to determine whether or not a surface expression of Fault I exists. The investigation consisted of several traverses across the hypothetical trace of the growth fault and a careful examination of the megascopic properties of all exposures. There were no distinct changes in the megascopic properties of visible soils along the traverses, and there were no abrupt changes in ground surface elevations. Relocated Little Robbins Slough (RLRS) is an excavated channel, approximately 10-12 ft deep, constructed along the west side of the Main Cooling Reservoir (MCR) as a diversion for natural

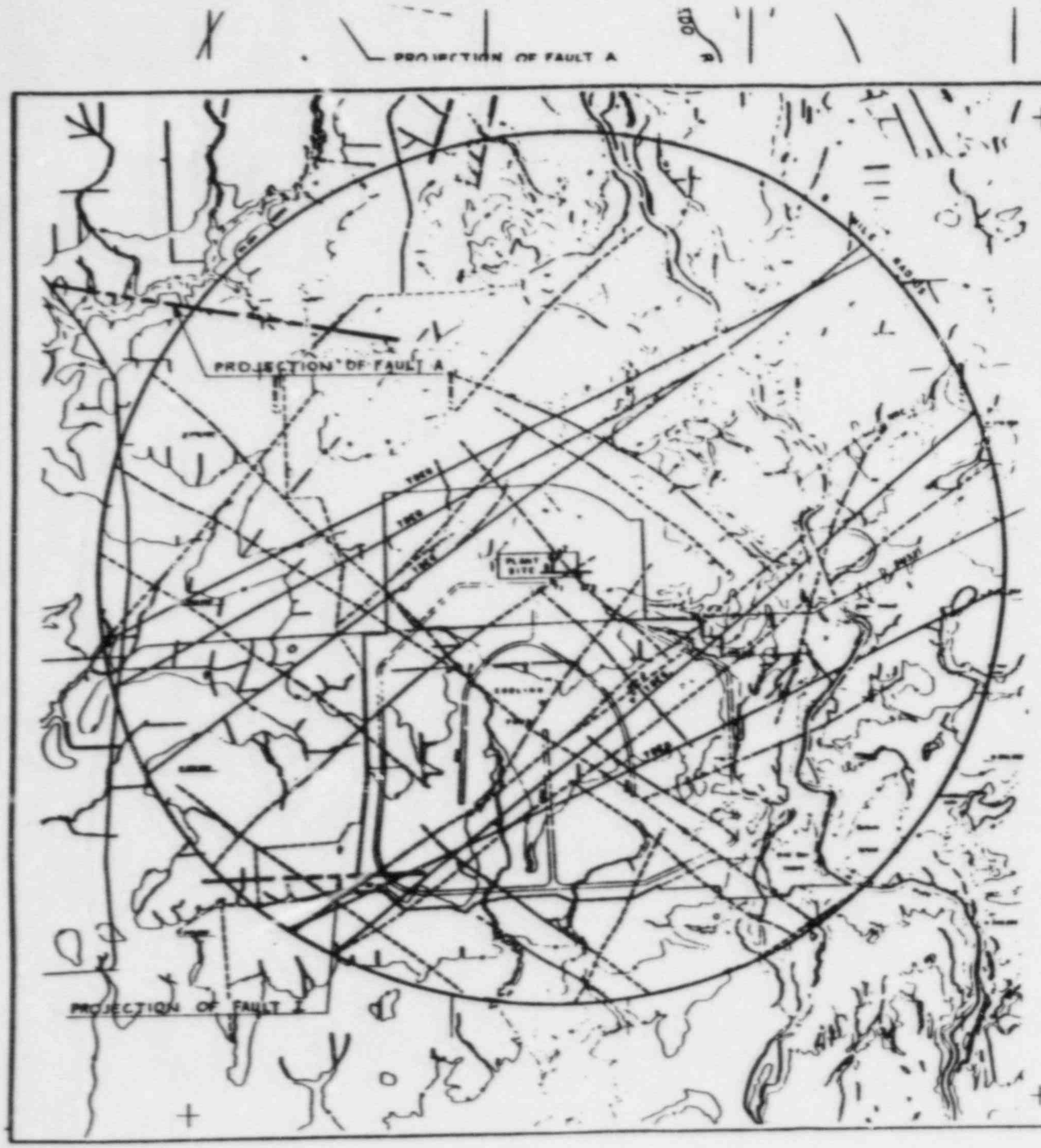
drainage. The sediments exposed in the channel consist mainly of silty sands and silty clays which are correlated with the Beaumont Formation elsewhere onsite. Prior to identification of Fault I, field mapping of the RLRS channel was performed to identify and locate any sand layers that might be exposed in the channel. A silty sand layer overlain by a stiff clay layer was found near the bottom of the channel and was mapped as a continuous contact between embankment stations 430 and 460 (Figure 3). After Fault I was identified in the subsurface by geophysical methods, the plane of the fault was projected to ground surface and plotted as an hypothetical trace in plan view. The hypothetical trace crosses RLRS between embankment stations 440 and 445. A 2000-ft section of RLRS (between stations 435 and 455) was re-examined and this investigation confirmed that the sand-clay contact was continuous and showed no signs of offset or disturbance.

Amoco Production Company, Bay City, Texas is the operator of the Petrucha field immediately northeast of STP. They report no damage to subsurface casing, pipelines, and oil and gas production facilities due to subsidence along the growth fault which forms the trap for the field. Amoco has also never heard of damage by faults from other oil field operators in this area.

According to Duncan Oil Properties, principal operator in the South Duncan Slough field, there has never been any production problems that could be associated with casing damage throughout their tenure in this field, nor

were they aware of such damage to any other wells in the area. The South Duncan Slough field is located northwest of the site.

Based on these data there is no evidence of Faults A or I at the ground surface. Stratigraphic evidence from mapping in Relocated Little Robbins Slough indicates that there is an undisturbed sand/clay contact in Pleistocene Beaumont sediments overlying the surface projection of Fault I.



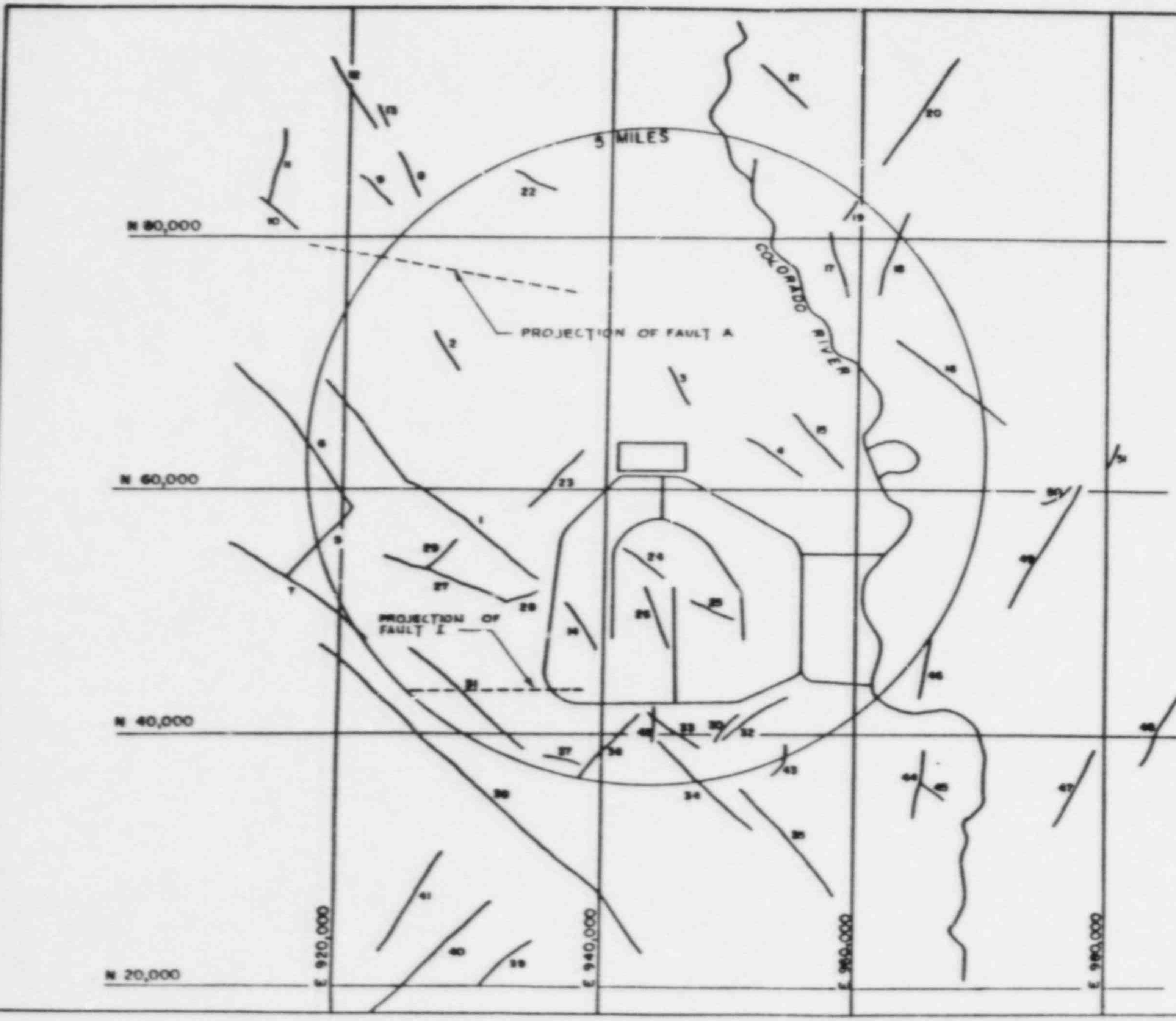
NOTE :

REFER TO P.S.A.R. FIGURE NO. 2.5.1-44A FOR EXPLANATION

PROJECTION OF GROWTH FAULTS ON SOUTH TEXAS PROJECT 1975 LINEAMENT STUDY

FIGURE 1

10/27/85



EXPLANATION

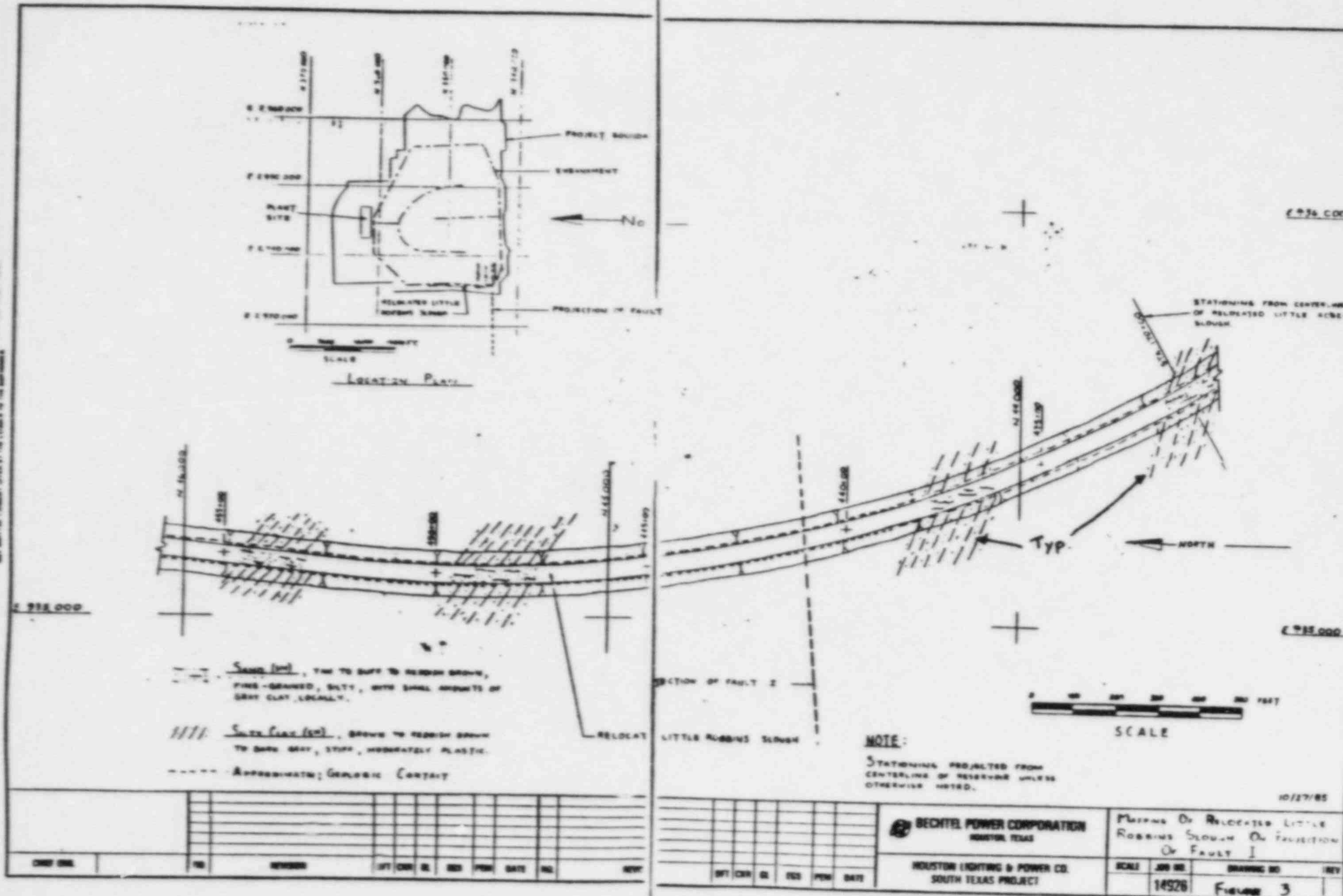
——— 16 Lineament

Lineament identified on NASA color infra-red U-2 photography flown in 1979. Refer to Table 2.5.1-2 for field descriptions.

PROJECTION OF GROWTH FAULTS ON SOUTH TEXAS PROJECT 1985 LINEAMENT STUDY

FIGURE 2

10/27/85



PROJECT SLOUGH
EMBANKMENT
PLANT SITE
RELOCATED LITTLE ROBBINS SLOUGH
PROJECTION OF FAULT
SCALE
LOCATION PLAN
No
E 936,000
E 935,000
STATIONING FROM CENTERLINE OF RELOCATED LITTLE ROBBINS SLOUGH
Typ
NORTH
SAND (SM), TAN TO BUFF TO REDDISH BROWN, FINE-GRAINED, SILTY, WITH SMALL AMOUNTS OF GRAY CLAY LOCALLY.
SILTY CLAY (CH), BROWN TO REDDISH BROWN TO DARK GRAY, STIFF, MODERATELY PLASTIC.
APPROXIMATE GEOLOGIC CONTACT
NOTE:
STATIONING PROJECTED FROM CENTERLINE OF RESERVOIR UNLESS OTHERWISE NOTED.
SCALE
10/27/85
BECHTEL POWER CORPORATION
HOUSTON, TEXAS
HOUSTON LIGHTING & POWER CO.
SOUTH TEXAS PROJECT
MAPPING OF RELOCATED LITTLE ROBBINS SLOUGH ON PROJECTION OF FAULT I
14926
FIGURE 3

Attachment 5

Question 231.19N

Using guidance contained in the Standard Review Plan conduct a lineament analysis of an area within at least five miles of the site using imagery derived from Landsat, Skylab and other appropriate sources not included in the PSAR lineament study (PSAR Figure 2.5.1-44). In addition to identification, discuss the possible origin and address the safety significance of any lineament which may be structurally controlled. Conduct field truth investigations as required. As indicated by the Standard Review Plan, provide the staff with a copy of the imagary used in your analysis.

Response

Section 2.5.1.2.5.5 has been revised to incorporate the results of a lineament study conducted Summer, 1985, using post CP imagery. Lineaments identified during this study were reviewed using field checks and comparison with other project data. None of the lineaments identified are correlated with geological structure. Section 2.5.1.2.5.5 describes the scope of the study and provides a location map (Figure 2.5.1-15) of the lineaments.

The 1985 lineament study was performed as a confirmatory review to supplement the extensive CP multi-spectral study. The present study used NASA U-2 false-color infrared imagery flown in 1979, based on the evaluation that these data provide the best overview of the five-mile radius study area. Other post-CP imagery was identified. Several Landsat Multispectral Scanner scenes obtained subsequent to 1975 are available (February, 1976; December, 1976, October 1980; and April 1984, with site area at edge); however, as in the CP study (refer to PSAR Figures 2.5.1-44 and 2.5.1-44A) this imagery was not considered to be appropriate to review within the

five mile study radius because of its scale. Side-looking airborne radar imagery was flown along the Texas coast by Litton Aerospace in late 1976 for speculation. This imagery in the form of a 1:400,000 composite mosaic was reviewed. Given the mosaic scale and the relatively low relief of the terrain, it was concluded that the 1976 radar imagery does not represent an improvement over the site-specific radar flown with multiple look-directions for the STP site in 1973. No post-CP NASA imagery other than the U-2 coverage was identified during the search. High-altitude black and white photography of approximately the same scale as the false-color U-2 imagery was flown for the ASCS in 1979. The latter imagery were considered to provide the better coverage over the low-relief site area. The false-color photography are also a better tool for identifying surface soil tonal, soil moisture, and vegetation features than black and white photography. Aerial photography in the form of black and white sheets at an approximate scale of 1:12,000 flown in 1981 for the ASCS as well as color-slides at an approximate scale of 1:8000 flown annually for crop monitoring is on file at the ASCS in Matagorda County. This photography was not used in the lineament analysis but the black and white photographs and the slides from 1985 were inspected during a field review of the previously identified lineaments. No new lineaments were observed on these photographs.

features such as those listed above. From this investigation and other geologic studies conducted for the STP described in preceding sections and in Appendix 2.5.B, it has been observed that none of the IOTAs or TBEG linears is related to surface faulting or subsidence displacement. The hypothesis that linears are surface expressions of growth "faults" is not valid for the area of the STP site.

Insert A

2.5.1.2.5.6 Postulated Projection and Age of Movement of the Growth Fault North of the Site - As described in Subsection 2.5.1.2.5.3, analysis of seismic reflection data has indicated the presence of a down-to-the-coast growth fault which dies out at a depth of about 1000 ft at a distance of 15000 ft north of the STP plant site. Two prominent reflectors, one at about 320 ft and another at about 630 ft have been correlated through the area and are unbroken by faulting. Subsequent to this analysis the postulated projection of this fault toward the surface in the upper 1000 ft has been evaluated.

Color infrared photography taken in November 1979 does not reveal evidence of topographic scarps, IOTAs and sag ponds indicative of surface faults in the area north of the site which would correspond to the ground surface projection of the regional subsurface fault within this area.

A ground reconnaissance of the area within 5 miles north of the plant site was conducted in December 1982. No topographic scarps, or sag ponds were observed in this area nor were pavement breaks, indicative of fault displacement, observed on roads which cross the projection of the regional subsurface fault north of the plant site. 32 Q231. 06N

This fault does not disrupt regional groundwater flow in the deep aquifer. A fault which has displaced transmissive units in the upper 1000 feet of sediment may often act as a dam to regional groundwater flow, increasing the gradient across the fault. It would be reflected as a series of water level contour lines paralleling the fault signifying a steep gradient between the upthrown and downthrown sides of the fault. Groundwater contour maps of the deep aquifer for two time periods are shown on Figures 2.4.13-6 and 2.4.13-7. These maps exhibit no linearity in contours or abnormally steep gradients in the vicinity of the projected fault.

Amoco Production Company, Bay City, Texas is the operator of the Petrucha field. They report no damage to subsurface casing, pipelines, and oil and gas production facilities due to subsidence along the growth fault which forms the trap for the field. Amoco has also never heard of damage by faults from other oil field operators in this area.

Based upon regional correlations made by Solis (Ref. 2.5.1-167) the upper 1000 ft of sediments north of the site are Quaternary in age and are comprised of units of the Lissie and Beaumont Formations. The Upper Lissie Formation is regionally correlated with the Montgomery Formation and was deposited in the Sangamon Interglacial Stage (Ref. 2.5.1-9). Studies by Beard and others (Ref. 2.5.1-166) have placed the age of Sangamon deposition at between 100,000 and 75,000 years before present (Ref. 2.5.1-9 Bernard and others, ascribes the age of the Sangamon interval to 100,000 to 300,000 years before present). Thus, the units that overlie and are unbroken by faulting are reported to be at least 75,000 years old.

Insert on Page 2.5.1-108

A lineament study was conducted in June, 1985, using recent aerial photography to determine if any new surface features of geologic significance, such as the surface expression of growth faulting, could be identified in the vicinity of STP. The following photography and maps were used in the updated lineament study which supplements the original study conducted in 1973.

- o Woodward-Lundgren 1973 lineament study as presented in the PSAR and FSAR
- o 1973 low-altitude color-infrared aerial photography
- o 1973 low-altitude black and white aerial photography
- o 1979 U-2 high-altitude color-infrared aerial photography
- o USGS topographic maps at a scale of 1:24000

The study was conducted in three phases which are described below:

1. The lineament studies presented in this section of the FSAR and Section 2.5.1.2.5.6 of the PSAR were reviewed. The 1973 black and white and the color-infrared low-altitude aerial photographs were examined to identify those lineaments shown on the FSAR figures.
2. Independent of phase 1, the 1979 U-2 color-infrared aerial photographs were analyzed to identify lineaments having a possible geologic origin (i.e. lineaments not readily identifiable as property lines, roads, etc.). This methodology prevented the present study from being biased by the results of the previous lineament study. The location of the 51 lineaments identified in the new study are shown on Figure 2.5.1-15. Those lineaments that are identified within a 5-mile radius are also shown on Figure 2.5.1-16 in relation to the seismic reflection lines.

Four U-2 color-infrared photographs, taken in 1979 and covering an area up to eight miles in radius from the Plant Area, were examined. The 51 lineaments were then drawn on the topographic maps to aid in their location during the field program.

Based on a review of the post-CP imagery available, it was concluded that the 1979 U-2 imagery cited above represented the best means of review for the five-mile radius study area. This conclusion considered the extensive site-specific imagery obtained for the previous study and the availability and quality of specific types of imagery.

3. A field program consisting of a helicopter survey and a ground survey was conducted in June, 1985, to examine the surface trace of all 51 lineaments including those outside the 5-mile radius study area. The entire length of each lineament was flown during the helicopter survey. Each lineament was traversed in one or more locations during a ground survey except lineaments 3, 15, 17, 19, 21, 29, 35, 39, 40, 44 and 45. The above lineaments were under flooded agricultural fields or in gas-production well areas where access was not readily available. These lineaments were revisited during a second helicopter survey for further verification based on the observations of the first aerial review and the ground check of the other lineaments. The 1973 low-altitude photography, both black and white and color-infrared, was used to assist in locationing during the field survey.

Based on the visual inspection of the 1979 U-2 photography and the 1985 field survey the eight parameters shown in Table 2.5.1-2 are used to describe or evaluate the 51 lineaments identified:

1) distance greater than 5 miles from STP
2) lineament length
3) lineaments related to oil and gas pipelines
4) lineaments related to native vegetation
5) lineaments related to soil tonal features
6) lineaments related to natural drainage
7) lineaments related to cultural features
8) lineaments related to agricultural features

Parameters 1, 3, 7 and 8 are considered in the evaluation of each lineament. These parameters together with existing geological data, principally the results of seismic interpretation (as indicated where appropriate in the last column of Table 2.5.1-2), provide the basis for the determination of significance of the lineament to the Plant Site. The remaining parameters are used to describe the surface expression of the lineaments identified from the photography.

On the basis of this evaluation, all 51 lineaments identified in this study are eliminated as features of potential concern to STP.

As described above, all 51 lineaments identified in the imagery review were field checked; however as a first step, the review process eliminated those lineaments outside five mile study area radius for their entire length and those attributable to cultural features including oil or gas pipelines from further consideration. Certain aspects of the CP review methodology have been maintained, but are of limited significance in the present study. All 51 lineaments shown on Table 2.5.1-2 are in excess of 1000 ft. long. An association of any lineament with agricultural practices or patterns was not used by itself as a basis for elimination. The last column of Table 2.5.1-2 cites "Applicable Geophysical Data". This column covers two categories of evaluation of lineaments within the five-mile study radius (Figure 2.5.1-16) and not related to man made features: 1) the crossing or immediate proximity (±5000 ft) of a lineament to a favorably oriented seismic reflection line on which a structural interpretation is made (indicated by a "D" in the last column), and 2) the location of the lineament within or adjacent to an area in which generally well-defined structures or structural trends have been identified based on interpretation of the seismic reflection data (indicated by an "I" in the last column).

The following conclusions are based on the findings of the study. Of the 51 lineaments identified, 20 are over five miles from the Plant Area over their entire length; of the 31 lineaments identified inside five miles, seven appear to be related to cultural features, principally oil or gas pipelines.

The remaining 24 lineaments were evaluated using other information; primarily the interpretation of the seismic reflection data which indicates there are no structures or projections of structures with which these features may be associated. The lineaments were first compared to data and interpretations from seismic reflection lines which crossed the lineament or its projection (if that projections distance was 5,000 ft. or less). All reflection lines were considered though, if a lineament crossed several lines, primary consideration was given to the better quality and/or shallower records. This level of review eliminated 16 of the 24 lineaments from further consideration. The remaining eight lineaments (5, 16, 18, 33, 34, 36, 37, 42) were reviewed in the context of the interpretation of the structures from seismic records and incorporated projections of over 5,000 ft. The dominant structural trend in the immediate vicinity of Lineament 5 is east-west and no correlative feature is identified on Line 2M. Lineament 16 has a northwest-southeast orientation which is somewhat similar to the alignment of structures interpreted (in CP-studies, apparently on the basis of well logs) as occurring at the approximately 8,900 ft. depth; however, these features were not identified as occurring higher in the section. Lineament 18 crosses Line 4M on projection outside the area covered by the study; however, the dominant structural trend through this area is generally east-west, controlled by the down to the south growth "fault" (Fault A) and approximately normal to the roughly north-south aligned Lineament 18. Lineaments 33, 34, 36, 37 and 42 are located south of the Main Cooling Reservoir in an area not directly covered by reflection data. The area is however, surrounded in large part by a number of lines which allow it to be included in the overall interpretation. No structures have been identified on this data which can be correlated with the lineaments.

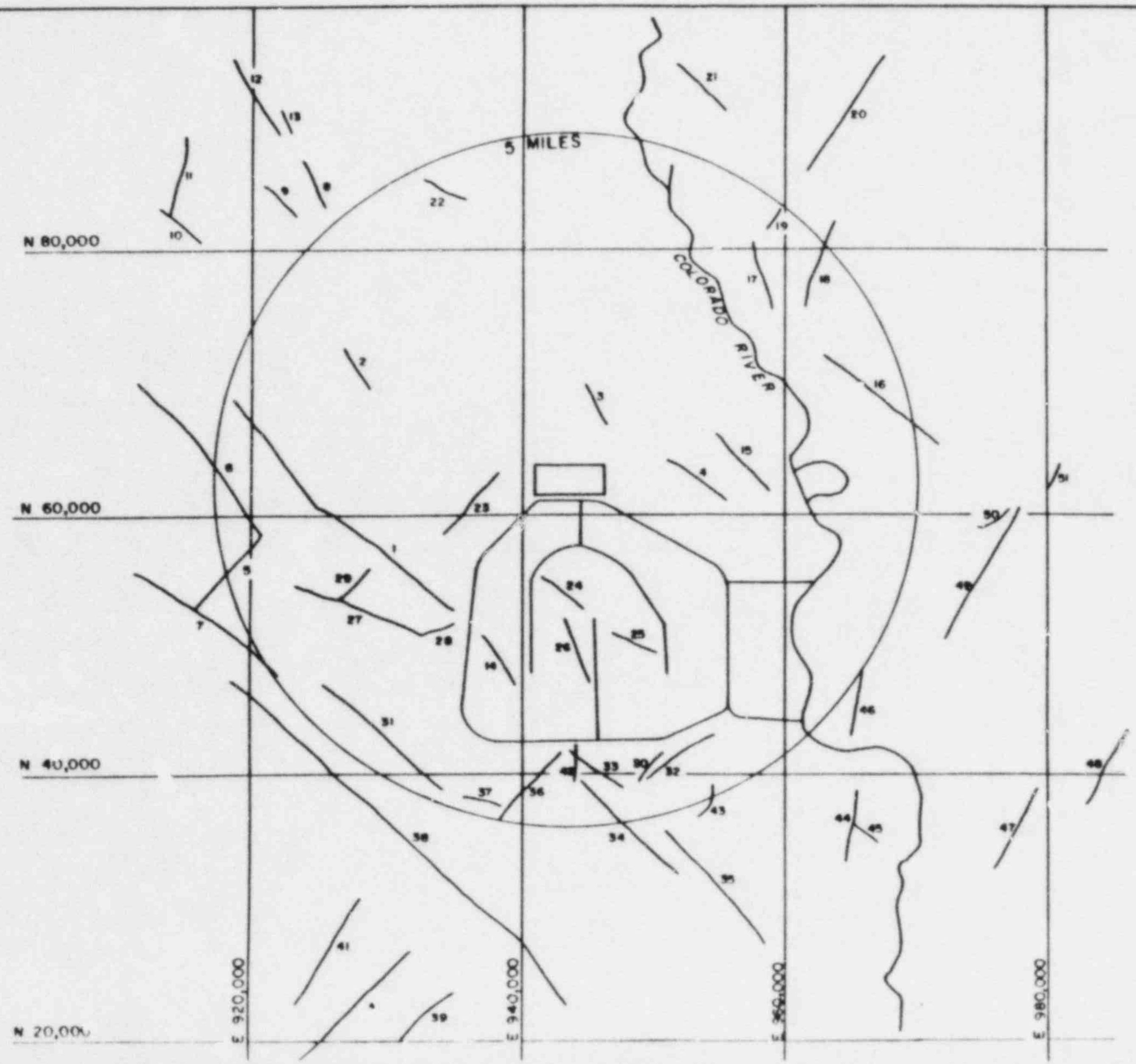
While the parameter of agricultural control was not used as an exclusive basis for elimination of any lineament, additional review of the lineaments south of the reservoir indicated that ploughing patterns have a very strong causative effect on observed tonal anomalies.

It is concluded none of the 51 lineaments is the surface expression of structural, and in particular, growth "fault" activity. These independent results support the conclusions of the previous study.

TABLE 2.5.1-2

SUMMARY OF 1985 LINEAMENT EVALUATION RESULTS

LINEAMENT NUMBER	BASIS FOR EVALUATION OR ELIMINATION OF LINEAMENTS								
	IMAGERY STUDY		FIELD EXAMINATION						
	DISTANCE FROM STP>5 MILES	LINEAMENT LENGTH (FEET x 1000)	RELATED TO OIL OR GAS PIPELINE	RELATED TO NATIVE VEGETATION	RELATED TO SOIL TONAL FEATURE	RELATED TO NATURAL DRAINAGE	RELATED TO CULTURAL FEATURE	RELATED TO AGRICULTURE	APPLICABLE GEOPHYSICAL DATA
1		22.9	x	x		x		x	
2		3.7						x	D
3		3.5					x	x	D
4		5.5						x	D
5		7.5				x			I
6		14.8	x			x		x	
7		13.0	x			x		x	
8	x	4.0						x	
9	x	3.4						x	
10	x	4.0	x	x		x			
11	x	6.2	x					x	
12	x	6.8	x					x	
13	x	1.9						x	
14		4.5							D
15		5.8		x		x			D
16		10.8		x		x			I
17		5.4				x			D
18		6.9		x					I
19		1.8			x	x			D
20	x	10.3	x			x			
21	x	5.2				x			
22		3.5	x				x		
23		6.1			x			x	D
24		4.0							I
25		3.5							D
26		5.2							D
27		10.0	x					x	
28		2.6			x			x	D
29		3.2						x	D
30		2.8				x			I
31		12.0		x		x			D
32		6.1		x	x				D
33		4.9				x		x	I
34		10.1				x		x	I
35	x	11.4	x						
36		6.8			x			x	I
37		2.9						x	I
38	x	34.9		x	x	x		x	
39	x	5.2				x		x	
40	x	12.5						x	
41	x	9.2		x		x			
42		5.7						x	I
43		2.8				x			D
44	x	5.5				x			
45	x	2.3		x		x			
46		4.9				x	x		
47	x	5.9		x				x	
48	x	6.5		x		x			
49	x	11.4		x		x			
50	x	2.[illegible]		x					
51	x	2.1						x	



N

0 10,000
SCALE IN FEET

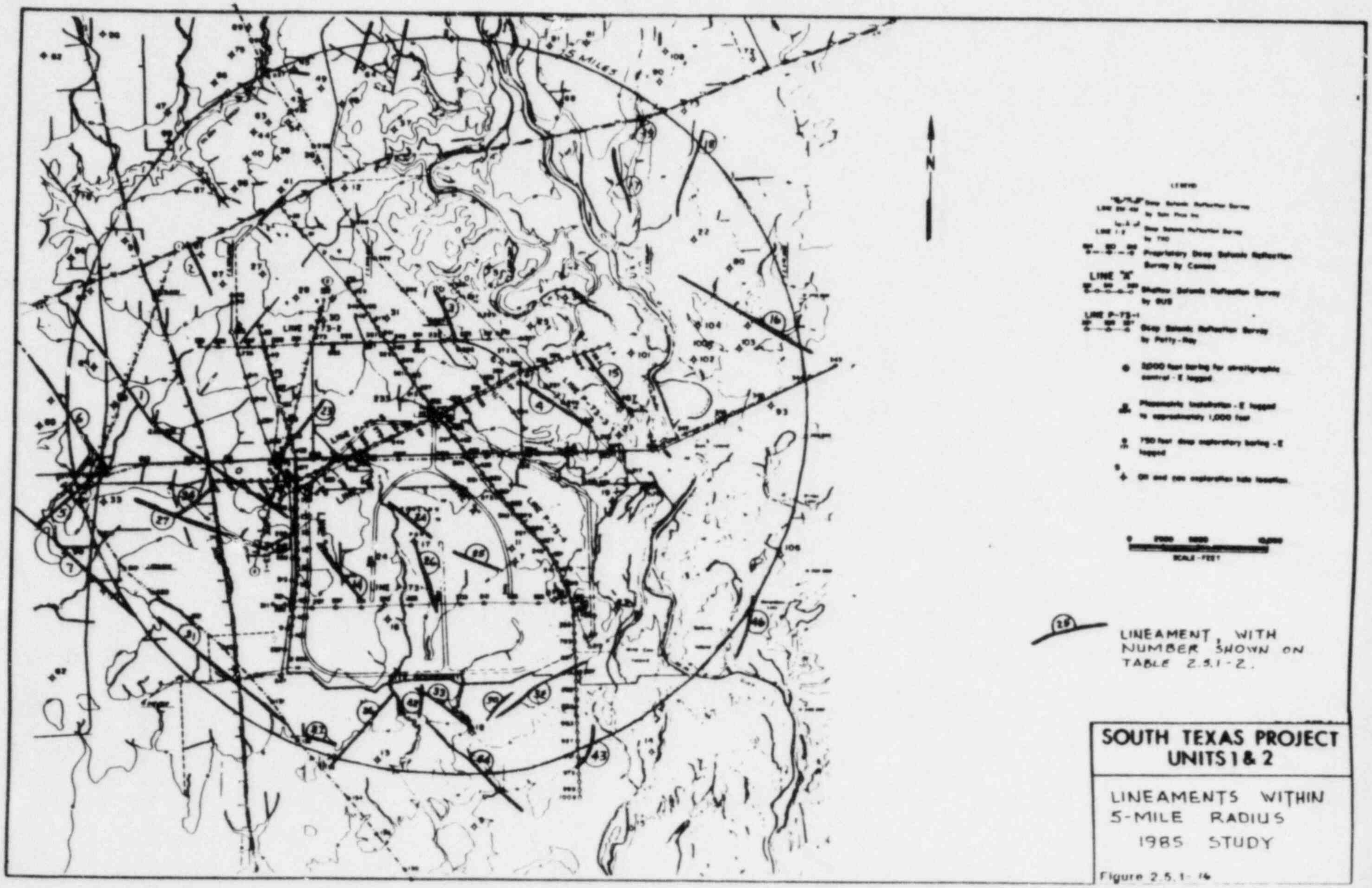
EXPLANATION

16 Lineament

Lineament identified on NASA color infra-red U-2 photography flown in 1979. Refer to Table 2.5.1-2 for field descriptions.

SOUTH TEXAS PROJECT
1985 LINEAMENT STUDY

FIGURE 2.5.1-15



SOUTH TEXAS PROJECT
UNITS 1 & 2

LINEAMENTS WITHIN
5-MILE RADIUS
1985 STUDY

Figure 2.5.1-14

Attachment 6

C. Salt Hypothesis

It has been suggested that a body of salt occurs at depth several miles south of STP. This suggestion is based on the anomalous northward dip of Oligocene sediments at approximately 8000 ft depth at the site and on the presence of a gravity low centered approximately seven miles south of the Plant Site. The data suggest that these features could have resulted from a deep-seated east-west trending salt ridge, and has led to speculation that salt movement may be the underlying cause of structural features on and near the Plant Site (Ref. 1).

Because available data do not provide information on deep structural configuration, particularly the relationship at depth between growth "faulting" in the immediate vicinity of STP and the suspected salt body, the possibility cannot be precluded that salt deformation in the geologic past has affected geologic structures. However, evidence indicates that mobilization within a deep salt structure and hypothetical associated activation of existing geologic structures do not constitute a credible hazard to the integrity of the Plant Site.

If a salt structure is present, interpretation of gravity data suggests that it would take the form of a deep-seated salt ridge. Review of the literature (Refs. 2,3) indicates that salt movement in domes in the East Texas Basin, about 225 miles northeast of the site, is currently less than 1 mm per year. If mobilization of the suspected salt body south of the site is hypothesized, less than 4 cm (0.13 ft) of movement would occur over the life of the plant, and this movement would occur at a depth of

more than 16,000 ft (Ref. 4). A significant portion, if not all movement translated from that depth, would be absorbed in the overlying sediments (which include massive shales), particularly since the structure suggested is not a localized piercement of relatively shallow strata.

Miller and Lents, Ltd. (Ref. 1) report that marker horizons within the Oligocene Frio Formation display a well developed northward dip into the growth "fault" north of the Plant Site. This dip is also shown on the interpretations of deep reflectors corresponding to Oligocene and older horizons shown on PSAR Figures 2.5.1-42G and 2.5.1.-42H. The Miller and Lents interpretation is that these layers are on the north limb of a broad, low relief anticline with a crest somewhere south of the Plant Site and that this anticlinal feature may be associated with arching over a corresponding deep salt rige. Higher in the section, contoured reflectors in the Miocene (PSAR Figures 2.5.1.-42F) do not show the north dip of the deeper units but rather a generally eastward dip at about the 6200 ft depth (Fig. 2.5.1.-42F) and a generally northeasterly dip at about the 5400 ft depth (Fig. 2.5.1.-42F). The realignment of dip direction and the relative degree of dip suggest some disassociation from the structural framework of the deeper section. Still higher in the section, contouring on a reflector at approximately 700 ft depth (PSAR Fig. 2.5.1-42d) indicates an overall dip to the south, similar to the regional trend and toward the depocenter of the recent past and present sedimentary basin, and opposite to that dip suggesting anticlinal development. Based on correlations by Solis (Ref. 4) and Van Siclen (Ref. 5) a horizon at 700 ft depth is within the Lissie Formation of 600,000 to 1,200,000 years. This dip direction of the relatively near-surface units to the south suggests that if a north dip on deep sediments is speculated to represent

anticlinal growth, this growth would have ceased at least by the early Pleistocene.

The orientation of structures identified from subsurface data suggest that they are part of a regional system extending beyond the limits of the hypothesized salt body. It is doubtful therefore that the primary features were initiated by salt movement. While the secondary subparallel features associated with the regional growth "fault" are of lesser lateral extent and a generic relationship to salt movement could therefore be hypothesized, the interpretation does not suggest these features are part of the radial patterns of faulting observed near other salt bodies in the region.

The East Texas Salt Basin located approximately 225 miles northeast of the Plant Site is for the most part geologically unlike the site area; however, a number of salt bodies of varying size and configuration occur here, and because salt bodies are present, the area has been considered in terms of potential waste repository sites. Consequently the seismic effects of salt deformation have been considered. Given that the stratigraphic units involved are generally much older and the salt much shallower than in the site area, conclusions regarding seismic potential of salt movement in that area would constitute a conservative upper bound in terms of the site along the Gulf Coast.

The East Texas Salt Basin is bounded by the Angelina flexure on the south, the Sabine arch on the east and the Mexia-Talco fault zones on the west and north. The uppermost units are Eocene in age and the bulk of the section is Cretaceous to Upper Jurassic. The north and west limits of the

basin represent the limits of the Louann Salt which ranges from 10,000 ft below the surface at the limits to 15-20,000 in the central part of the basin. A variety of salt structures are present, some rising to present ground surface.

Principal fault systems are related to gravitational mechanisms by Jackson (Ref. 7) whose study does not evaluate diapirically-generated faults because they are considered not significant to a seismic risk study. Jackson states:

> "East Texas faults share numerous indicators of low seismic risk. Normal displacements ensure that stresses are neutralized by tensile fracture at low stresses because the tensile strength of materials is generally much lower than their compressive strength Furthermore, almost all these faults are related to slow gravitational creep of salt and its sedimentary overburden rather than to movement of lithospheric plates."

and he concludes: "No geologic evidence indicates that any of these faults poses a seismic threat to a hypothetical nuclear-waste repository."

Because the units involved are much more consolidated and salt structures more prevalent and more shallow than in the site area, the conclusions regarding the negligible hazard of salt-related displacement in the East Texas Basin permit a similar conclusion for the site area where a

significant portion of the geologic column is younger, less consolidated units and the salt is at greater depth.

It is therefore concluded that hypothetical salt movement as a causative force for structural deformation on existing structures in the immediate vicinity of STP does not constitute a credible hazard to the Plant Site.

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Attachment 7

STP site, high-pressure shales are detected in well logs at a depth of 6,400 ft and extend at least into the Eocene rocks at 23,000 ft. The extensive and deep-seated occurrence of high-pressure shales within the Tertiary section has had a significant role in the structural geology of this section. Because of the difficulty of obtaining representative in situ samples, mechanical properties of the shales have been inferred (Refs. 2.5.1-15, 2.5.1-27, and 2.5.1-107). The occurrence of diapiric shale masses and the behavior of high-pressure shale during drilling provide evidence (Ref. 2.5.1-27) for its highly plastic behavior. Contemporaneous growth "faulting" is closely related to the occurrence of mobile shale masses (see Section 2.5.1.1.6.6.5). 35

2.5.1.1.5.4.2 Quaternary Period - The Pleistocene Series of the Texas Gulf Coast consists, from youngest to oldest, of the Willis, Bentley, Montgomery, Beaumont, and Deweyville Formations. The Lissie Formation, which is often mapped in the lower coastal area, is equivalent to the combined Bentley and Montgomery Formation. The Deweyville Formation consists of low-level stream terrace deposits confined to the alluvial valleys and is not present in the STP site vicinity.

On the upper Gulf Coast, the Willis Formation consists of a basal gravel overlain by sand and minor clay. In the lower Gulf Coast, the formation consists of sand, that grades laterally into clay. The Willis Formation conformably overlies the Goliad Formation in the upper Gulf Coast, but the contact is unconformable in the lower Gulf Coast. The Bentley, Lissie, and Montgomery Formations of the upper Gulf Coast consist of interbedded sand, clay, and minor amounts of gravel.

The Beaumont Formation in the upper Gulf Coast consists of lenticular sands and clays. The Deweyville Formation of late Pleistocene age consists of gravel, sand, and clay.

The site of the STP is located on a surface of the Beaumont Formation. The stratigraphy of the Beaumont Formation beneath the project site is described in detail according to boring samples and electric logs in Section 2.5.1.2.
> INSERT (A)

Holocene sediments consist of sands, silts, clays and some gravels deposited by streams on alluvial and deltatic plains and by wave action along the shoreline of the Gulf of Mexico, where they form barrier islands and bars. These sediments also are accumulating in coastal lagoons, bays, and marshes. Alluvial sediments floor the valleys of modern streams for long distances inland; such flood plain deposits are present on the eastern part of the project site. The greatest inland expanse of Holocene sediment is Eolian deposits found in the Rio Grande embayment and in western Texas.

The foregoing paragraphs are a summary of the stratigraphy of Texas which reflects the events of geologic history in each of the major regional tectonic provinces shown on PSAR Figure 2.5.1-5. These regional tectonic provinces are the Foreland or stable interior region, which includes the Llano uplift; the Wichita System, which includes the Arbuckle and Wichita Mountains; the Southern Cordillera; the Ouachita Tectonic Belt; and the Gulf Coast Geosyncline. The Paleozoic section of the Texas Foreland, except in western Texas and along the boundary of the Foreland and the Ouachita Tectonic Belt,

Insert on Page 2.5.1-26

Based on regional correlations by Solis (Ref. 2.5.1-167) the upper 700 to 800 ft of sediments beneath the site are Pleistocene in age and comprise units of the Beaumont and Lissie Formations (Figures 2.5.1-1b and 2.5.1-1c). "Operational stratigraphic units" are defined by Solis on the basis of lithostratigraphic correlation between wells in the area and by correlation of these units with equivalent formations in outcrop. The "operational stratigraphic units" closely correspond to time stratigraphic units which are based on Doering, 1935 (Ref. 2.5.1-171). Figure 2.5.1-1b is a north-south aligned, regional stratigraphic section through the area immediately east of STP; Figure 2.5.1-1c is a regional section aligned east-west through the site. Based on these sections, the Beaumont unit extends to an estimated depth of 350-380 ft. The Lissie unit is identified by Solis to a depth of 750 to 800 ft.

A correlation chart (Figure 2.5.1-1e) was developed in order to relate Solis' subsurface units to the surface unit identifications and age assignments by Van Siclen (Ref. 2.5-1-170). Solis' subsurface operational units and surface units are based on Doering, 1935 (Ref. 2.5.1-171). Doering, 1955 (Ref. 2.5.1-172), revised his 1935 Pleistocene stratigraphic column on two points: the upper Pleistocene Beaumont was divided into Eunice and Oberlin, or as also described by Doering, upper and lower Beaumont respectively, and; the upper Pliocene Willis was reassigned to a new unit, the lowermost Pleistocene Citronelle.

These relationships are shown on Figure 2.5.1-1e as presented in Doering, 1955 (Ref. 2.5.1-172). The areal geology by Doering, 1955 (Figure 8, Ref. 2.5.1-172), indicates that STP is underlain by the Oberlin unit, i.e. lower Beaumont.

Van Siclen's stratigraphic assignments for meander belt ridges (Ref. 2.5.1-170), generally correlate with Doering, 1955, for the Beaumont units (Figure 2.5.1-1e). Thus, Van Siclen's Oberlin unit appears to be equivalent to Doering's Oberlin unit, which is lower Beaumont. Based on Doering's assignment of sediments at the surface along the coast at STP to the Oberlin (i.e. equivalent to the lower part of the Beaumont on which Solis' unit assignments are made) the sediments from surface to a depth of about 400 ft would be Sangamonian in age or about 70,000 to 300,000 years old. This age is based on Van Siclen's glacial time correlation scale (Figure 2.5.1-1d).

The Lissie Formation is correlated with the middle Pleistocene Yarmouthian Interglacial Stage, which is 750,000 to 1,300,000 years before present (Figure 2.5.1-1d). Van Siclen's unit assignments, which are based on the Houston area, further define the lower Pleistocene and appear to concur with the Doering, 1955, redefinition of the Plio-Pleistocene boundary. At the 1200 ft depth, sediments correlated with Solis' Upper Goliad-Willis may be equivalent to Van Siclen's Bentley-Willis Regolith units with an age in excess of 1.75 mybp.

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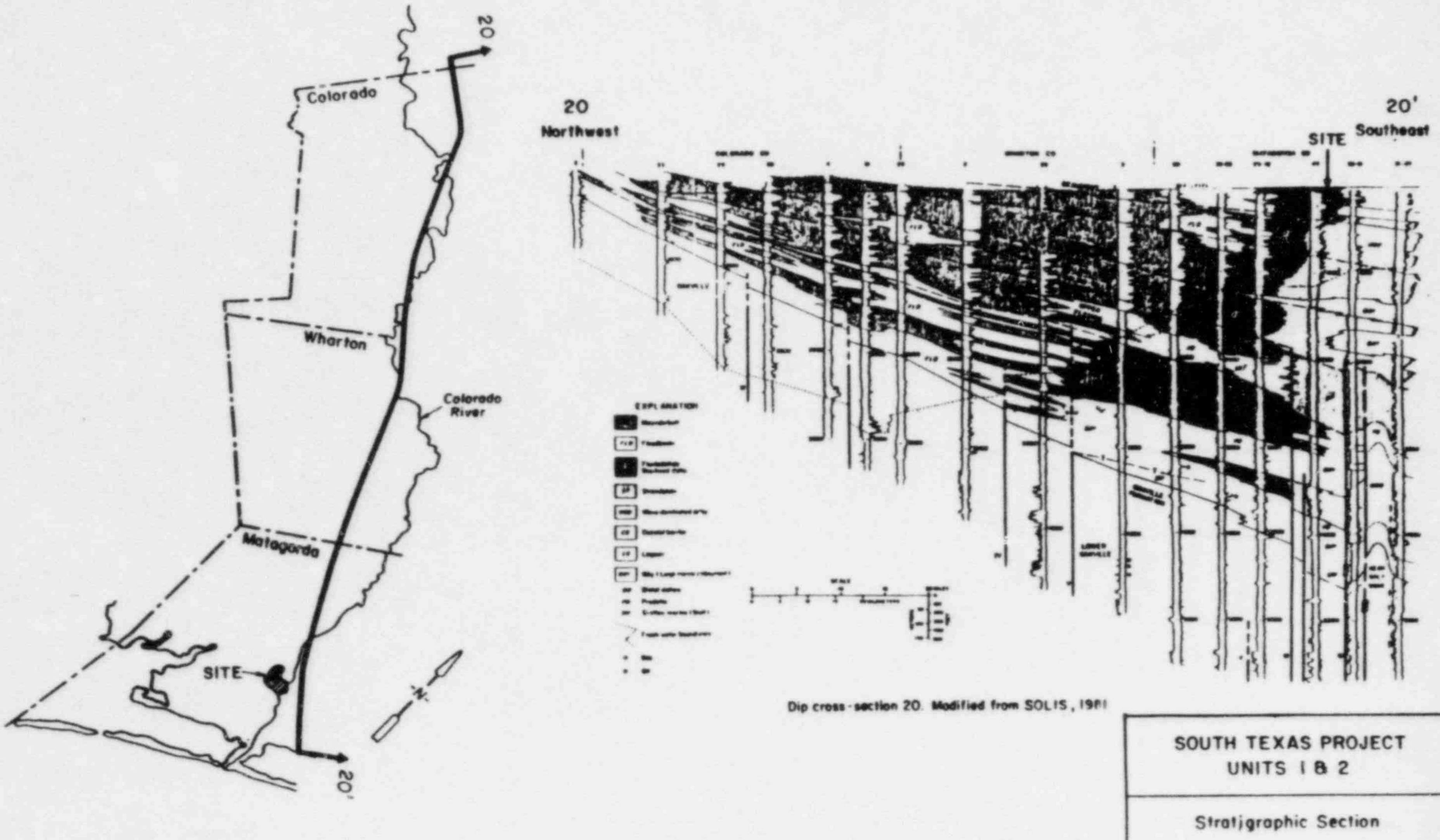
2.5.1-172 Doering, J. A., "Review of Quaternary surface formations of Gulf Coast region," American Association of Petroleum Geologists Bulletin, Vol. 40, No. 8 (1955).

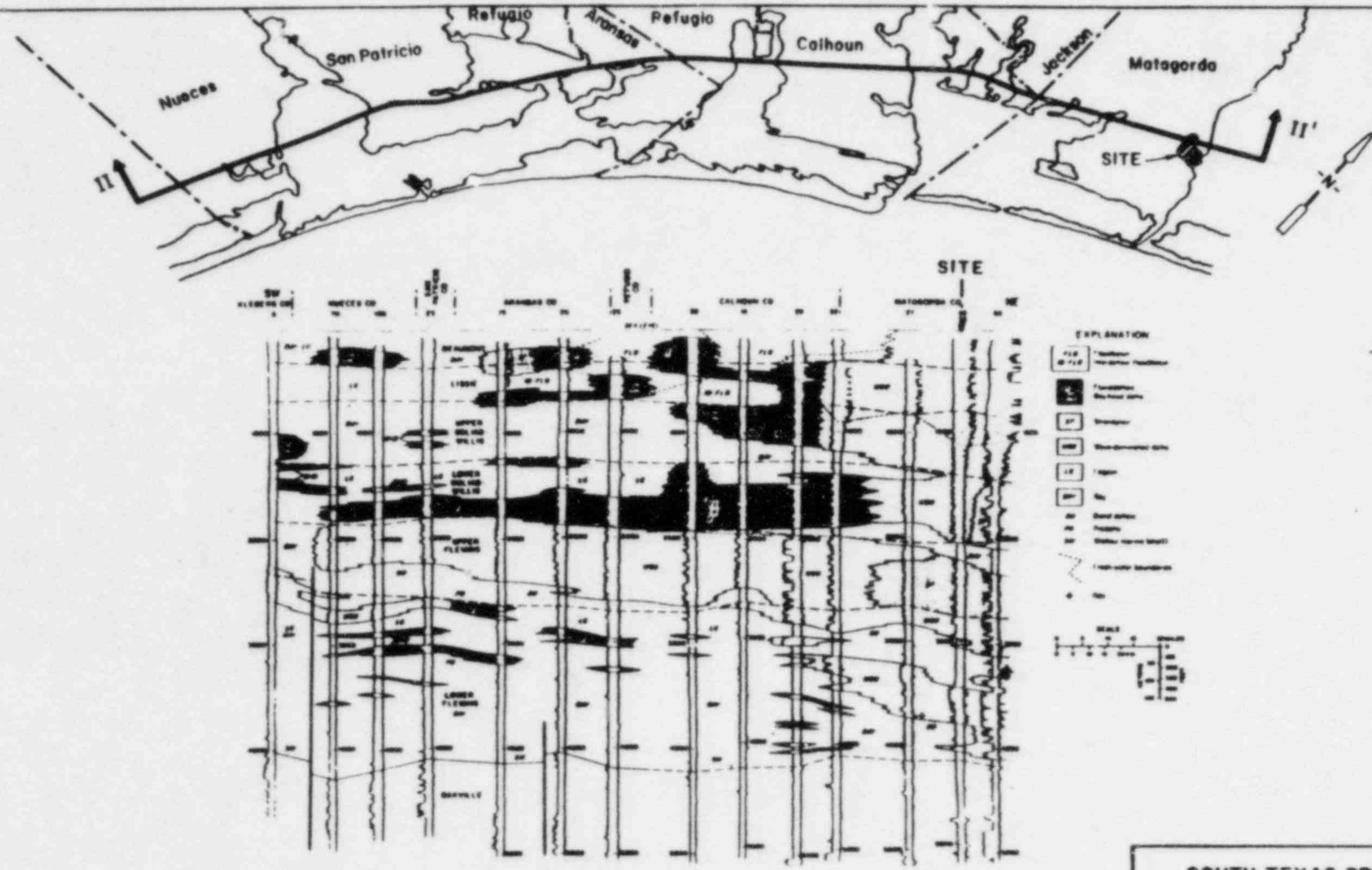


Dip cross-section 20. Modified from SOLIS, 1981

SOUTH TEXAS PROJECT
UNITS 1 & 2

Stratigraphic Section

FIGURE 2.5.1-1b

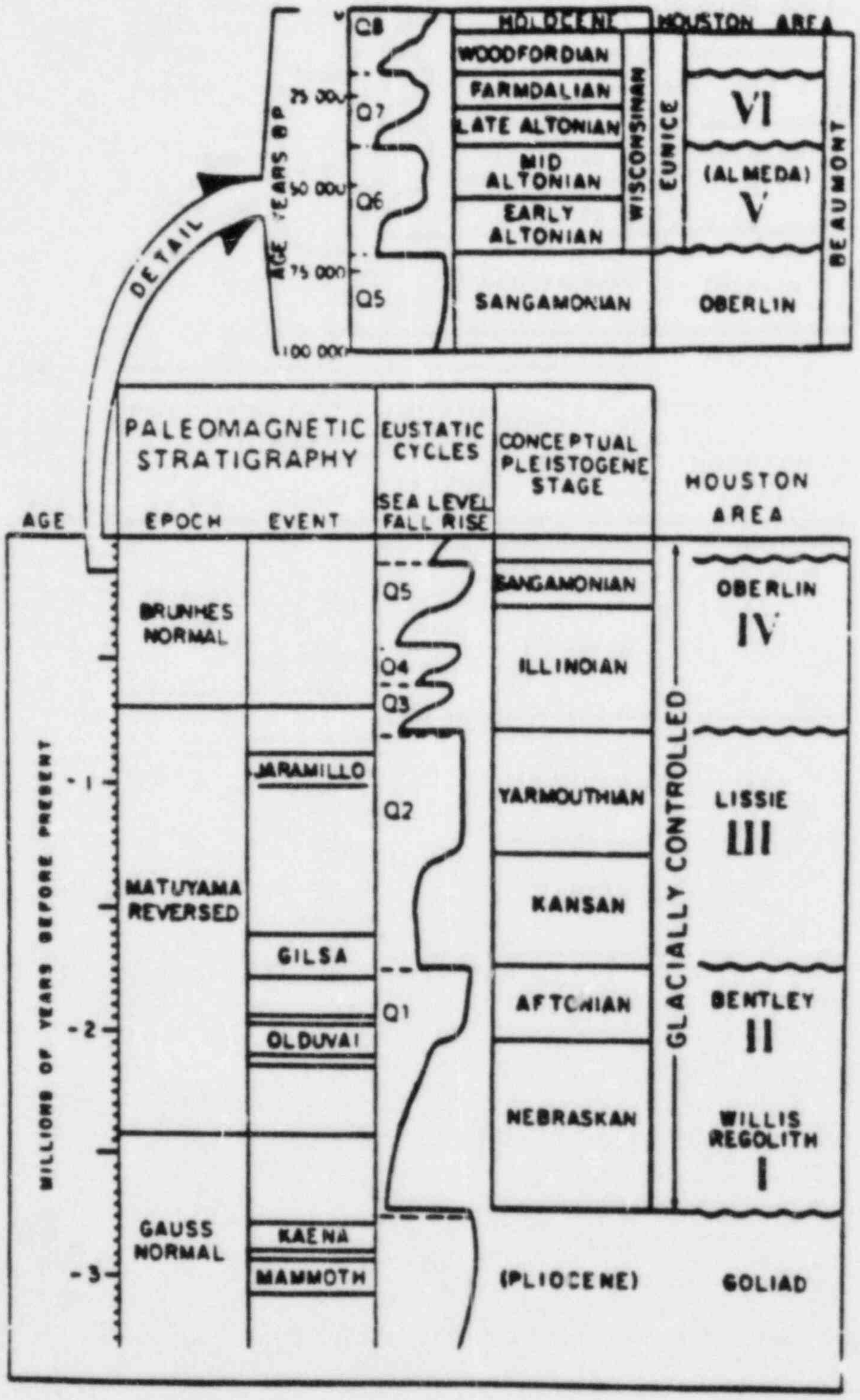


Strike cross-section II. Modified from SOLIS, 1981

SOUTH TEXAS PROJECT
UNITS 1 & 2

Stratigraphic Section

FIGURE 2.5.I - 1c



After Van Siclen, 1985. Modified from Beard and others, 1982

SOUTH TEXAS PROJECT
UNITS 1 & 2

Stratigraphy - Chronology Correlation Chart
FIGURE 2.5.1-1d

(1) 1	2	3	4		5		6	7		8	
SOLIS 1981	SOLIS 1981	SOLIS 1981	DOERING 1935 (3)		DOERING 1955 (3)		BERNARD & LEBLANC 1965	VAN SICLEN 1985		VAN SICLEN 1985	
SERIES	OPERATIONAL STRATIGRAPHIC UNIT	SURFACE FORMATION (2)	SERIES	UNIT	SERIES	UNIT	UNIT	UNIT		YEARS B.P. (5)	CONCEPTUAL PLEISTOCENE STAGES
PLEISTOCENE	BEAUMONT	BEAUMONT	PLEISTOCENE	BEAUMONT	PLEISTOCENE	EUNICE (4)	PRAIRIE OR BEAUMONT	BEAUMONT	EUNICE / ALMEDA	10K–70K	WISCONSIN
						OBERLIN (4)			OBERLIN	70K–300K	SANGAMONIAN
	LISSIE	LISSIE		LISSIE		LISSIE	MONTGOMERY OR UPPER LISSIE	LISSIE		750K–1.3M	YARMOUTHIAN
PLIOCENE	UPPER GOLIAD–WILLIS	WILLIS	PLIOCENE	WILLIS		CITRONELLE	BENTLEY OR LOWER LISSIE	BENTLEY		1.75M–2.05M	AFTONIAN
							WILLIANA OR WILLIS	WILLIS REGOLITH		2.7M	NEBRASKAN
	LOWER GOLIAD–WILLIS	GOLIAD		GOLIAD	PLIOCENE	GOLIAD		GOLIAD			PLIOCENE
UPPER MIOCENE	UPPER FLEMING	FLEMING	MIOCENE	FLEMING ?	MIOCENE	FLEMING ?		?			
	LOWER FLEMING										

NOTES:

(1) ALL COLUMNS OF CHART DERIVED FROM SOURCE INDICATED EXCEPT COLUMN 4, DOERING, 1935 WHICH IS FROM TABLE 1 OF DOERING 1955 AND COLUMN 6, BERNARD AND LEBLANC, 1965, WHICH IS FROM VAN SICLEN 1985.

(2) REPORTED BY SOLIS TO BE BASED ON DOERING, 1935.

(3) COLUMNS 4 AND 5 DO NOT SHOW CLASSIFICATION OF RECENT SEDIMENTS FROM TABLE 1 OF DOERING, 1955.

(4) DOERING, 1955 EQUATES EUNICE WITH UPPER BEAUMONT, OBERLIN WITH LOWER BEAUMONT.

(5) FROM FIGURE 9, VAN SICLEN, 1985. ILLINOIAN AND KANSAN NOT SHOWN.

CORRELATION CHART

FIGURE 2.5.1-1e

Attachment 8

I. Assessment of Potential Ground Motion Associated with Growth Faulting

The Tertiary sedimentary sequence in which coastal plain growth faulting has been identified in the vicinity of the South Texas Project does not have the potential to store the elastic strain energy necessary to release an earthquake with an intensity similar to the SSE (approximate $M_b 5$), nor is the style of movement on the coastal plain growth faults conducive to the release of seismic energy comparable to such an earthquake. The seismic history of the Gulf Coast supports these conclusions.

a. Introduction

The principal geologic structure of the coastal plain is a system of basinward-dipping, normal fault planes, marking the rim of the Gulf of Mexico, which is likened by O'Neill and Van Siclen (Ref. 1) to "... a great slowly-moving earth flow ...." The rates of movement associated with such a model are in the opinion of Verbeek (Ref. 2) "... probably so low as to be of little consequence to man." In the Houston area where such displacements have apparently been reactivated or accelerated by man's activities (fluid withdrawal), O'Neill and Van Siclen (Ref. 1) report, "Movement is not generally reflected as a recordable seismic event..." Naturally occurring seismic activity (Magnitude 1.5) has been associated spatially with growth faults in Texas and Louisiana by Mauk, et al. (Ref. 3). Low level seismicity in the Gulf Coast attributed to subsidence effects or stress drops due to pore pressure changes, resulting from fluid withdrawal (or injection) have been discussed by Yerkes and Castle (Ref. 4), Carlson (Ref. 5), and Agnew, et al. (Ref. 6). Gravity as the principal force causing displacement within the

sedimentary section is demonstrated in the modeling of the province stress field by Zoback and Zoback (Ref. 7). The data from these and other sources comprise material properties, type of faulting, seismic history and regional stress state. The evidence presented in the following discussions indicates that the design earthquake Intensity VI exceeds credible seismic ground motion associated with growth faulting within the Tertiary stratigraphic section.

b. Sedimentary Column

A sedimentary column must be capable of accumulating sufficient elastic strain energy to be a possible source zone for generation of earthquakes. The principal factors affecting this capability are the strain energy storage capacity of the rock, strain rate, strain sources and shear stress release mechanisms. The composition and conditions of the sedimentary sequence below the Plant Site inhibit the accumulation of sufficient strain energy that would be capable of release as seismic ground motion of engineering significance to STP (i.e. exceedence of SSE).

The sedimentary sequence above the basement consists of Jurassic Louann Salt, Upper Jurassic/Lower Cretaceous shales and, possibly, thin limestones, Upper Cretaceous/Lower Tertiary clay with interbedded sand, and Upper Teritary/ Quaternary sand, silt and clay. The properties of the older, pre-Upper Cretaceous units, which occur at depth below the section in which growth faulting near STP is identified, are discussed in FSAR Section 2.5.1.1.6.6.2. The following addresses the materials in which growth faults have been identified.

The Upper Cretaceous and deeper Tertiary sediments (below 6200 ft) consist of clay interspersed with sand in a complex three dimensional array. Pore pressures in this material may be raised above hydrostatic levels normally associated with compaction and deep burial of low-permeability shales (Burst; Ref. 8). Overpressured shale has been determined to exist below the site between 6200 and 23,000 ft depth. Powers (Ref. 9) documents the plastic behavior of such shale. Material exhibiting plastic behavior could be expected to deform without storing any significant elastic energy.

The shallow Tertiary/Quaternary sediments above 6200 ft are essentially unconsolidated. Even under conditions of rapid stress loading from fluid withdrawal, such sediment responds by consolidation and plastic deformation or creep along pre-existing planes of weakness. (This behavior is demonstrated in the Houston area where significant geofluid extraction has occurred; faulting and seismicity of the Houston area are discussed below.) Therefore, these sediments are also incapable of storing and releasing significant amounts of strain energy.

c. Growth Faults

The controlling structural feature of the Gulf of Mexico coastal plain is a regional system of down-to-the-coast faults paralleling the gulf margin beneath the plain and continental embankment. In summarizing this system, O'Neill and Van Siclen (Ref. 1) state:

> "The origin of the regional faults, as revealed by their systematic pattern, is regional extension occasioned by very slow creep toward the Gulf of Mexico of the thick sediments down to and including the

thick section of halite near 10,000 m depth. This process is driven by gravity, continued tilting, and decreasing average age (hence density) of the material in the gulfward direction."

They further note that the resulting stress field may be modified locally by salt or shale diapirism. In the context of the Gulfward continental margin, O'Neill and Van Siclen (Ref. 1) also report: "The fundamental cause of the regional faulting must be the very slow creep of the thick mass of ductile materials, mainly below 3000 m, toward the deep Gulf of Mexico.", and liken this model to "... a great slowly-moving earth flow, upon which vertical instabilities are imposed locally by density inversions and ductility contrasts."

Because active surface displacement occurs on some components of the regional fault system, attention has been given to the engineering significance of such features where modern movements are most common and would have most impact on man-made structures; this has been the case in the Houston area in particular and has been considered in some detail recently by Verbeek and Clanton (Ref. 10) and O'Neill and Van Siclen (Ref. 1). The two central issues relative to this type of fault displacement are the identification of surface faulting and the proximity to structures. Seismic ground motion is not a significant factor, because, as O'Neill and Van Siclen (Ref. 1) state, "Movement is not generally reflected as a recordable seismic event, although some low magnitude (2-3, Richter Scale) events have been traced to sudden movements along a few faults in dense soils (Lee, 1978)" (Ref. 11) . At least 160 faults are reported as offsetting ground surface in the Houston area, with evidence which indicates that most of this displacement was produced by accelerated or reactivated movement resulting from the withdrawal of geofluids (water, oil

and gas). These displacements have occurred without any noticeable (i.e. detectable without instruments) concentration of earthquake activity and are modeled as creep behavior reflecting the internal consolidation of the sedimentary section following removal of fluids. Verbeek and Clanton (Ref. 10) report present day rates of movement at 0.5 to 2.0 cm/yr (0.2 to 0.8 in/yr) along these faults. They also estimate average rates of movement in prehistoric times to have been more than two orders of magnitude less than the current rates. Their conclusion is that the relatively high current rates of displacement have occurred only in the past few decades, coinciding with the large-scale withdrawal of geofluids. This correlation suggests that natural movement along growth faults in areas that have not been subjected to man's activities would occur at a very slow and fairly constant average rate. Using the Verbeek and Clanton estimate of two orders of magnitude less than 0.2 cm/yr, the calculated rate for current and prehistoric movement would be less than 0.02 cm/yr or 0.008 in/yr There is no evidence that such movement is occurring, however if displacement is assumed to occur in the vicinity of STP, a rate producing less than one-half inch of movement over the life of the plant will not be seismically significant.

d. Seismic History

The seismic history of the Gulf Coast Plain on which the Plant Site is located reflects the low strain accumulation environment indicated by review of the materials of the geologic section and the characteristics of typical fault motion in the coastal plain. The very quiet seismic nature of this general region of the country is well documented (e.g. Nuttli, in Barstow, et al.,

Ref. 15). The overall distribution of the seismic history of the vicinity of the site is shown on FSAR Figures Q230.05N-1 and Q230.N-2 (incorporated in response to NRC Question 230.05). These maps show that the coastal zone of Texas is almost aseismic in the range of event magnitudes covered by the historical tabulations. The distribution of growth faulting in coastal plain of Texas is documented in several sources: Murray (Ref. 12), AAPG (Ref. 13), Cambe maps, and is summarized on PSAR Figure 2.5.1-5. The lack of seismic events of Intensity VI or greater throughout an area characterized by such basinward faulting constitutes an empirical basis for concluding that the presence of such features in the vicinity of the Plant Site does not constitute a seismic hazard. This earthquake/structure distribution is also depicted by Carlson Figure 22, Ref. 5); his presentation which is described as a "composite isoseismal map of all earthquakes in east Texas" is superimposed on the major fault system. Intensities as low as the I-III range are shown. No seismic activity is identified by Carlson as occurring on the arcuate growth fault systems in the coastal margin.

Review of that seismicity which has been postulated to be correlative with growth faulting and review of literature on regional stress state support this conclusion. As discussed in FSAR Section 2.5.1.1.6.6.6, microseismic activity associated with growth faults has been reported by Mauk, et al. (Ref. 3) to have occurred in Brazoria County, Texas and Vermillion Parish, Louisiana. They state that the activity is "... very low and the size (magnitude) of the events is very small. No events have been recorded with magnitudes larger than 1.5". The seismic events that Mauk, et al. refer to are "natural" i.e., not induced by man's activities.

Yerkes and Castle (Ref. 4, see FSAR Section 2.5.1.1.6.6.7.2) report low-level seismic activity attributed to displacement along margins of subsidence "bowls" over oil fields at Goose Creek and South Houston. The Goose Creek events occurred in 1925 and have been assigned Intensity III-IV (MM); the 1969 South Houston events were Intensity I-II, Magnitude 1.5 (Ref. 4). In both localities median level of hydrocarbon extraction was shallow, 2000 to 4000 ft., and the stratigraphic units involved were Oligocene and younger.

e. Crustal Stress

The crustal stress state of the Gulf Coast has been discussed recently in general terms by Zoback and Zoback (Ref. 7) and more specifically in terms of observed seismicity of the northern Gulf Coast (Louisiana) by Nunn (Ref. 14). Basing their analysis on average local orientation of recently active growth faults and late Tertiary faulting, Zoback and Zoback (Ref. 7) conclude: "The state of stress throughout this [Gulf Coast] province is apparently quite uniform: the greatest principal stress is vertical, the orientation of the least principal stress is perpendicular to the continental margin ... It should be emphasized that the state of stress in this province is probably only the result of sediment loading and not tectonic forces."

The area modeled by Nunn is the coastal area of far southeastern Texas, Louisiana, Mississippi, and southwestern Alabama. As indicated on Figure Q230.5N-1 and Figure 3 of Ref. 14, this area is of very low observed seismicity, though relatively more so than the essentially aseismic mid-Gulf Coast of Texas in the site region. Nunn proposes that observed recent

movement and/or movement along faults originally formed in the Eocene-Oligocene is consistent with bending stresses caused by rapid sedimentation in the Gulf of Mexico since the Pleistocene. (The study area centers on the Atchafalaya-Mississippi delta region.) According to Nunn, the Pleistocene-Holocene sedimentation rates "... may be fast enough to accumulate stresses capable of reactivating pre-existing growth faults and generating small infrequent earthquakes ['... too small to determine focal mechanisms, they are spatially correlated with the systems of growth faults...']."

West of the area characterized by the proposed bending model of Nunn, Holocene displacement recognized on growth faults originating in the Teritary appears to be more a product of man's activity. Verbeek (Ref. 2) noting the occurrence of normal faults that offset Quaternary sediments fringing the Gulf of Mexico (though best known in Houston, an area of little or no seismicity) comments that: "Current fault activity is probably related to both natural and man-induced factors... In general, however, natural rates of fault motion are probably so low as to be of little consequence to man."

f. Conclusions

It is concluded that effective mechanisms for the release of stresses by slow deformation through plastic behavior or creep exist within the Tertiary/Quaternary sedimentary sequence. This limits the accumulation of elastic strain energy to levels not likely to exceed Magnitude 3 to 4 and Intensity VI. It is further concluded that this condition is demonstrated by the historical seismic behavior of the Texas Coastal Plain. Natural

microseismicity (Magnitude 1.5) has been associated with growth "faulting"; ground motion has been associated spatially with large volume, relatively rapid fluid withdrawals in the Houston area.

Geologic structures identified from seismic reflection and electric log data in the immediate vicinity of STP are evaluated as representative features of the Coastal Plain growth fault system, based on spatial configuration and horizontal/vertical differential movement in the subsurface. These features represent gravity consolidation and are non-tectonic. If displacement is assumed to occur on structures identified in the site area, it would occur as slow deformation or creep or yielding with associated small earthquakes (e.g. Magnitude 1.5) as proposed in other areas of the Gulf Coast. Clearly these non-tectonic events would not generate ground motions as large as those considered for the SSE.

Based on the general properties of the underlying sedimentary section and the observed seismic behavior it is concluded that any ground motion resulting from release of seismic energy in the Coastal Plain of the site region is enveloped by the O. : ismic design of STP.

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Attachment 9

RESERVOIR-INDUCED SEISMICITY

Reservoir-induced seismicity (RIS) is rare with only 64 cases reported from the better than 13,000 reservoirs throughout the world. The most comprehensive compilation of RIS was completed several years ago for the U.S. Geological Survey by D. R. Packer, et al., and is available as USGS Open File Report No. 80-1092. Sixty four of the 250 reservoirs studied by Packer, et al., report RIS; none are in the Gulf Coastal Plain nor associated with growth "faults".

In the open file report 64 reservoirs reporting RIS were evaluated for influence of the reservoir on the seismicity of the local area and categorized as accepted, questionable, and not accepted. A total of 43 were listed as accepted, 12 as questionable, seven were not accepted, and two could not be evaluated due to insufficient information. The reservoirs reporting RIS were compared using five different parameters: depth of water, size of reservoir, active faulting, stress, and geology.

Based on subdivisions used by Packer, et al., the Main Cooling Reservoir (MCR) has a small volume and is shallow; it is in an area of soft sediments with evidence of only very low strain accumulations and growth faults with very low historical seismicity. Therefore, conclusions drawn from Packer, et al., whose study is oriented toward tectonic features in rock, will be very conservative.

Review of Packer, et al., indicates that the depth of the MCR is less than half that of the shallowest pond recorded as showing RIS. Baecher and Keeney, 1982, in their discussion of Packer, et al., note that "... of the five attributes, depth is the one which best discriminates circumstances which may or may not lead to RIS. For very deep reservoirs, the conditional probability of RIS is 0.27 and for shallow reservoirs it is 0.03. This range is larger than for any other attribute. In interpreting this range, one should recognize that the data set includes only deep, very deep, and/or very large reservoirs. Shallow reservoirs that are not very large are not included in the analysis, and would of course have a probability of RIS very near zero."

A minor earthquake swarm occurred along the Texas-Louisiana border adjacent to the Hemphill Reservoir which initially were interpreted as RIS. More recent evaluation of these events, however, has shown that they were not related to the reservoir and its loading as originally thought but to the withdrawal of fluids at depth. Although there are numerous reservoirs built on the sediments of the Gulf Coast with their ubiquitous growth "faults", no record has been found of RIS in this environment.

Seismicity associated with Gulf Coastal Plain growth "faults" is less than approximate M = 1.5. Since reservoir loading does not contribute to the magnitude of events, only to the frequency, RIS would not impact the seismic design criteria of STP.

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