

**SEISMIC HAZARD DATA  
PREPARED FOR  
THE RESOLUTION OF USI A-46**

**ST LUCIE UNIT 1 AND TURKEY POINT UNITS 3 AND 4  
NUCLEAR POWER PLANT SITES**

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## SUMMARY OF SEISMIC HAZARD RESULTS

## 1.0 Introduction

The unresolved questions regarding the cause and source of seismicity in the region of the United States east of  $105^{\circ}$  W longitude (Eastern U.S.), led the U.S. Nuclear Regulatory Commission (NRC) to actively pursue the use of probabilistic methods, as alternatives to the deterministic approach used in the past, for re-evaluation of the seismic design of nuclear facilities in the eastern United States. This re-evaluation takes into account the uncertainties in source geometry, seismicity parameters and ground motion for the large earthquakes that occur in the Eastern U.S. As part of the NRC-funded investigations, the Lawrence Livermore National Laboratory (LLNL) conducted probabilistic seismic hazard evaluations for ten "sample sites" whose locations are shown on Figure 1. A parallel probabilistic seismic hazard study, based on an intensive data collection and evaluation effort, was implemented by the Electric Power Research Institute (EPRI) with the assistance of six Technical Evaluation Contractors (TEC). Both the NRC-funded LLNL studies, and the EPRI investigations, funded by a group of nuclear power plant owners in the Eastern U.S., utilize comprehensive seismic and tectonic data bases and recent advances in the probabilistic methodologies for the evaluation of seismic hazard for sites located in the Eastern U.S.

In light of these recent advances in probabilistic seismic risk assessment, the Florida Power and Light Company (FPL) requested that Ebasco Services Incorporated (ESI) perform an up-to-date seismic hazard evaluation for their St. Lucie and Turkey Point nuclear power plant sites. This updated evaluation uses the methodology, computer programs, and the tectonic and seismic input parameters developed as a result of the EPRI investigations. In addition, the scope of the ESI investigation included an evaluation of the contribution to seismic hazard at the St. Lucie and Turkey Point sites from the occurrence of large magnitude earthquakes in the Northern Caribbean.

### 1.1 Procedure

Following the EPRI methodology, the seismic hazards were computed for the St. Lucie and Turkey Point sites using the seismic source zones and seismicity parameters established by each of the six EPRI Technical Evaluation Contractors (TEC), and the seismic source zones and seismicity parameters identified by ESI for the Northern Caribbean. The location and extent of the seismic source zones that were evaluated in this study are shown on Figures 2 through 8. The source zones that contributed to the seismic hazard at each of the two plant sites have also been listed on these figures. The TEC source zone names, labels, and the EPRI Data Base Manager code numbers are given in Table 1. Two of the Northern Caribbean sources, Cayman Trough and Jamaica-Western Hispaniola, that were identified during this study contributed to the seismic hazard at Turkey Point, but none contributed to the hazard at St. Lucie. Also contributions of New Madrid area sources to the seismic hazard at both plant sites for each of the six TECs were negligible. The scenarios and weights for the source zones that contributed to seismic hazard are given in Table 2. The seismic hazard values that were calculated from each TEC model were then aggregated in accordance with the EPRI recommended procedure to generate the final hazard curves. The source zones that contributed less than  $1.0E-10$  to seismic hazard at the sites were not included in the aggregation process.

### 1.2 Results

The results for the St. Lucie and Turkey Point sites are presented as constant percentile hazard curves for peak ground acceleration on Figures 9 and 10 respectively. On these figures the 85th, 50th, and 15th percentile curves represent the aggregated results of all TECs. The annual probability of exceedance and the corresponding return periods for the 50th percentile hazard at various levels of peak ground acceleration for the two plant sites are given in Table 3.

### 1.3 Summary and Conclusions

In summary, the results of the probabilistic seismic hazard evaluation carried out by Ebasco Services Incorporated for the Florida Power and Light Company indicate that for the St. Lucie and Turkey Point sites the hazard is very low.

As illustrated, the Peak Ground Acceleration (PGA) seismic hazard calculated for the St. Lucie site is very low. The annual probability of exceedance for the site SSE ( $98 \text{ cm/sec}^2$  or  $0.10g$ ) is  $1.27E-5$ , and is associated with a 79,000 years return period. The seismic hazard calculated for the Turkey Point site is even lower. The annual probability of exceedance for the site DBE ( $49 \text{ cm/sec}^2$  or  $0.05g$ ) is  $3.31E-5$ , and is associated with a 30,000 years return period. These values are significantly lower than the levels of seismic hazard associated with each of the test sites evaluated during the LLNL (ten sites) and EPRI (nine sites) studies.

It should be noted that the application of the EPRI methodology to evaluate seismic hazard at the St. Lucie and Turkey Point sites provides a conservative estimate. For example, one of the TEC teams, Woodward Clyde Consultants, specified the use of the following maximum magnitudes (and associated probabilities) for background sources along the entire East Coast: 5.8 (0.33), 6.2 (0.34), and 6.6 (0.33). Although these values may be appropriate for other regions along the East Coast, they do constitute an over-estimate of conditions in Peninsular Florida. Similarly, generalized assumptions made by other TECs can also be questioned for their over-conservative estimates of seismicity in Florida. This is especially important because most of the contribution to the St. Lucie and Turkey Point sites, in the case of each of the TEC source zones, is derived from the background source containing the sites.

Savy (1988) noted that ground motion modeling experts (G-experts) in LLNL study have now assigned a large weight to the class of "random vibration" models (the RV models). Recently Boore and Atkinson (1987) published a paper

on the stochastic prediction of ground motion and spectral response parameters at hard-rock sites in eastern North America. From a plot of peak ground acceleration versus hypocentral distance for a magnitude 6.5 earthquake, we observed that the EPRI attenuation for the random vibration model is very close to Boore and Atkinson (1987) ground motion model. If this model is considered more representative of eastern North America, then the hazard computed using all three EPRI attenuations (Nuttli, 1984; Empirical Model; and Random-Vibration Model) should be considered a conservative estimate.

#### REFERENCES

- Boore, D.M. and G.M. Atkinson (1987). Stochastic prediction of ground motion and spectral response parameters at hard-rock sites in eastern North America, Bull. Seism. Soc. Am., 77, 440-467.
- EPRI, 1986-87, Seismic Hazard Methodology for the Central and Eastern United States, volumes 1-10, EPRI NP-4726.
- Nuttli, O.W. (1984). Letter to Dr. Dae H. Chung, Appendix C-A in "Seismic Hazard Characterization of the Eastern United States: Methodology and Interim Results for Ten Sites", by D.L. Bernreuter et al., NUREG/CR-3756, pp. C-99 to C-105.
- Savy, J.B. (1988). Seismic hazard at 69 sites in the eastern U.S. based on expert opinion regional comparison, abstract, Seismological Research Letters, 59, p. 14.

Table 1  
Computerized Data Base Label No. of Source Zones

TEC Name	TEC Label No. (Used on TEC Maps)	Source Name	Data Base Label No. (Used on Computer Files)
Bechtel Group	13	Mesozoic Basins	013-00
	30	New Madrid	030-00
	31	Reelfoot Rift	031-00
	H	Charleston Area	052-00
	N-3	Charleston Faults	059-00
	BZ-0	New Madrid Region	001-00
	BZ-1	Gulf Coast Background	006-00
	BZ-4	Atlantic Coast Background	020-00
Dames & Moore	20	Southern Coastal Margin	020-00
	21	New Madrid	021-00
	22	Reelfoot Rift	022-00
	22-21B	Reelfoot Rift-New Madrid	915-00
	52	Charleston Rift	052-00
	53	Southern Appalachian Default	053-00
	54	Charleston Seismic Zone	054-00
	65	Dunbarton Triassic Basin	062-00
Law Engineering	04a	Reelfoot Rift(A)	004-01
	04b	Reelfoot Rift(B)	004-02
	08	Mesozoic Basins	008-16
	18	Reelfoot Rift Faults	018-00
	35	Charleston	035-00
	108	Brunswick Background	043-00
	126	Southern Coastal Block	060-01
	M-37	Mafic Pluton	038-37
	M-38	Mafic Pluton	038-38
	M-39	Mafic Pluton	038-39
	M-40	Mafic Pluton	038-40
	M-41	Mafic Pluton	038-41
	M-42	Mafic Pluton	038-42
	M-43	Mafic Pluton	038-43
	M-44	Mafic Pluton	038-44
	M-45	Mafic Pluton	038-45
	M-48	Mafic Pluton	038-48
	M-49	Mafic Pluton	038-49
	M-50	Mafic Pluton	038-50

Table 1 (Continued)  
Computerized Data Base Label No. of Source Zones

TEC Name	TEC Label No. (Used on TEC Maps)	Source Name	Data Base Label No. (Used on Computer Files)
Rondout Associates	1	New Madrid	001-00
	2	New Madrid Rift	002-00
	24	Charleston	024-00
	26	South Carolina	026-00
	49-05	Appalachian Basement Background	049-05
	51	Gulf Coast to Bahamas Background	051-00
Weston Geophysical	25	Charleston	025-00
	26	South Carolina	026-00
	31	New Madrid	031-00
	32	Reelfoot Rift	032-00
	104	Southern Coastal Plain Background	054-00
	107	Gulf Coast Background	057-00
	Z032-Z031	Combination (C-11)	911-00
	Z104-Z022	Combination (C-20)	920-00
	Z104-Z025	Combination (C-21)	921-00
	Z104-Z026	Combination (C-22)	922-00
	Z104-Z022	Combination (C-23)	923-00
	-Z026		
	Z104-Z022	Combination (C-24)	924-00
	-Z025		
	Z104-Z028BCDE	Combination (C-27)	927-00
	-Z022		
	-Z025		
	Z104-Z028BCDE	Combination (C-28)	928-00
	-Z022		
	-Z026		
Woodward-Clyde	1	Continental Shelf Edge	001-00
	29	South Carolina Option 1	029-00
	29A <sub>1</sub>	South Carolina Option 2	029-01
	29A <sub>2</sub>	South Carolina Option 2	029-02
	29B	South Carolina Option 3	029-03
	30	Charleston NOTA	030-00
	40	Central Reelfoot Rift	040-00
	41	Combination (C-8)	908-00
	44	New Madrid Loading Zone	044-00

TABLE 2  
Scenarios for Contributing Source Zones<sup>1</sup>  
St. Lucie

<u>TEC Team</u>	<u>Scenario</u> <sup>2</sup>	<u>Weight</u> <sup>3</sup>
Bechtel	00600 + 02000 + 01300 + 05200	.05
	00600 + 02000 + 01300	.05
	00600 + 02000 + 05200	.45
	00600 + 02000	.45
Background	00600	1.0
	02000	1.0
Dames and Moore	02000 + 05400	.196
	02000 + 05400 + 05200	.322
	02000 + 05400 + 05300	.182
	02000 + 05400	.084
	02000 + 05400 + 05200	.138
	02000 + 05400 + 05300	.078
Background	02000	1.0
Law Engineering	04300 + 06001 + 02200	.27
	04300 + 06001 + 00816	.27
	04300 + 06001	.46
Background	04300	.42
	06001	.49
Rondout Associates	02400 + 02600 + 04905 + 05100	1.0
Background	04905	1.0
	05100	1.0
Weston Geophysical Corporation	05700 + 92000	.001
	05700 + 02500 + 92100	.012
	05700 + 02600 + 92200	.069
	05700 + 02600 + 92300	.312
	05700 + 02500 + 92400	.368
	05700 + 02500 + 92700	.126
	05700 + 02600 + 92800	.100
	05700 + 05400	.012
Background	05700	1.0



TABLE 2 (continued)  
 Scenarios for Contributing Source Zones<sup>1</sup>  
 St. Lucie

<u>TEC Team</u>	<u>Scenario</u> <sup>2</sup>	<u>Weight</u> <sup>3</sup>
Woodward Clyde Consultants	WCCBK	.468
	WCCBK + 02903	.105
	WCCBK + 02900	.122
	WCCBK + 02901 + 02902	.305
Background	WCCBK	1.0

\*Note: 1) Source Zone numbers correspond to those on Table 1 and on Figures 2 through 7.

2) Each TEC scenario is made up of the allowable source zone combinations whose total weights, or probability of activity add up to 1.0.

3) Weight is defined as the fractional probability of activity.

TABLE 2 (continued)  
 Scenarios for Contributing Source Zones<sup>1</sup>  
 Turkey Point

<u>TEC Team</u>	<u>Scenario</u> <sup>2</sup>	<u>Weight</u> <sup>3</sup>
Bechtel	00600 + 02000 + CB001 + CB002	1.0
Background	00600	1.0
	02000	1.0
Dames and Moore	02000 + CB001 + CB002	1.0
Law Engineering	04300 + 06001 + 02200 + CB001 + CB002	.27
	04300 + 06001 + 00816 + CB001 + CB002	.27
	04300 + 06001 + CB001 + CB002	.46
Background	04300	.42
	06001	.49
Rondout Associates	04905 + 05100 + CB001 + CB002	1.0
Background	04905	1.0
	05100	1.0
Weston Geophysical Corporation	05700 + CB001 + CB002	1.0
Background	05700	1.0
Woodward Clyde Consultants	WCCBK + CB001 + CB002	1.0
Background	WCCBK	1.0

\*Note: 1) Source Zone numbers correspond to those on Table 1 and on Figures 2 through 7.

2) Each TEC scenario is made up of the allowable source zone combinations whose total weights, or probability of activity add up to 1.0.

3) Weight is defined as the fractional probability of activity.

Table 3  
Peak Ground Acceleration (PGA)  
Probability of Exceedance and Return Periods

Seismic Hazard Results  
Summary for St. Lucie Site  
50th Percentile

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Acceleration (%g)	Annual Probability of Exceedance	Estimated Return Period (yrs)
.005	6.71E-4	1,490
.01	2.92E-4	3,425
.03	7.88E-5	12,690
.05	3.95E-5	25,316
.10 (SSE)	1.27E-5	78,740
.15	6.35E-6	157,480
.20	3.54E-6	282,486
.25	2.13E-6	469,484
.30	1.32E-6	757,576
.50	2.48E-7	4,032,258

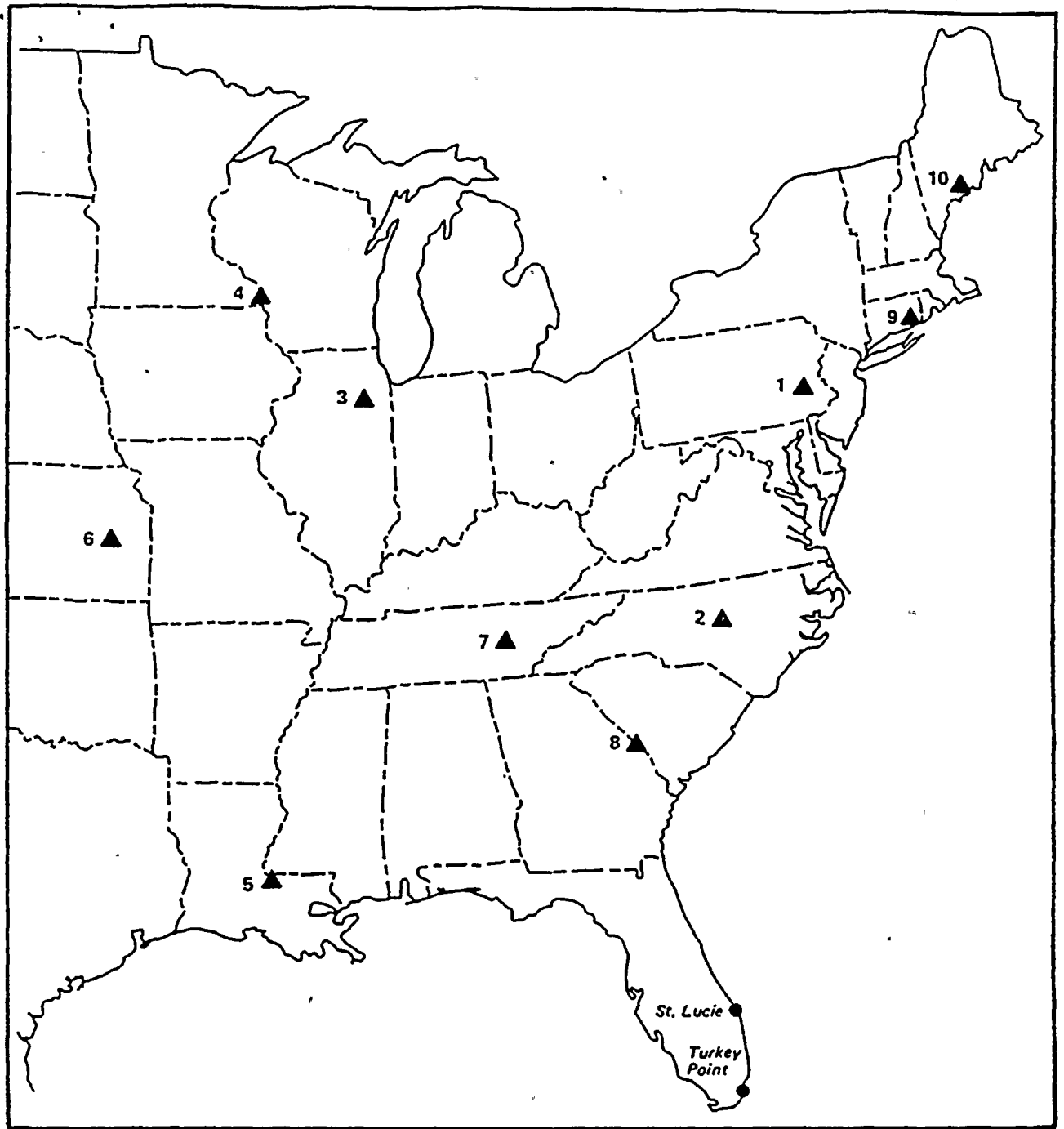
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Seismic Hazard Results  
Summary for Turkey Point Site  
50th Percentile

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Acceleration (%g)	Annual Probability of Exceedance	Estimated Return Period (yrs)
.005	6.31E-4	1,585
.01	2.43E-4	4,115
.03	6.77E-5	14,771
.05 (DBE)	3.31E-5	30,211
.10	1.05E-5	95,238
.15	4.97E-6	201,207
.20	2.54E-6	393,701
.25	1.35E-6	740,741
.30	7.70E-7	1,298,701
.50	1.31E-7	7,633,588

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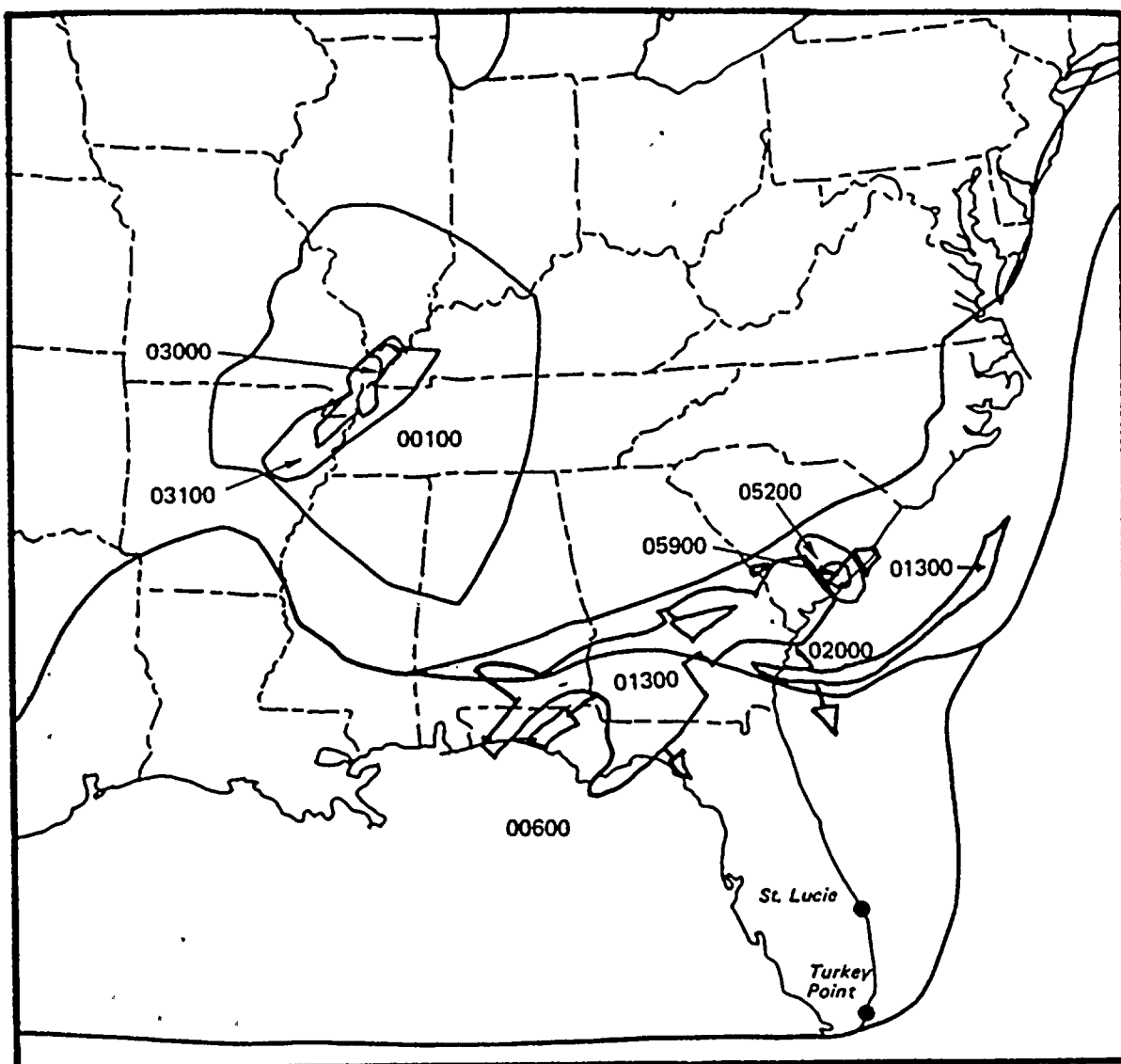
Key to Site Index Numbers

1. Limerick \*
2. Shearon Harris \*
3. Braidwood
4. La Crosse
5. River Bend
6. Wolf Creek
7. Watts Bar \*
8. Vogtle \*
9. Millstone
10. Maine Yankee

\* Sites considered by LLNL to fall in the Southeastern Region of the U.S.

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Location of the LLNL Sample Sites and St. Lucie and Turkey Point

FIGURE 1



Source Zone

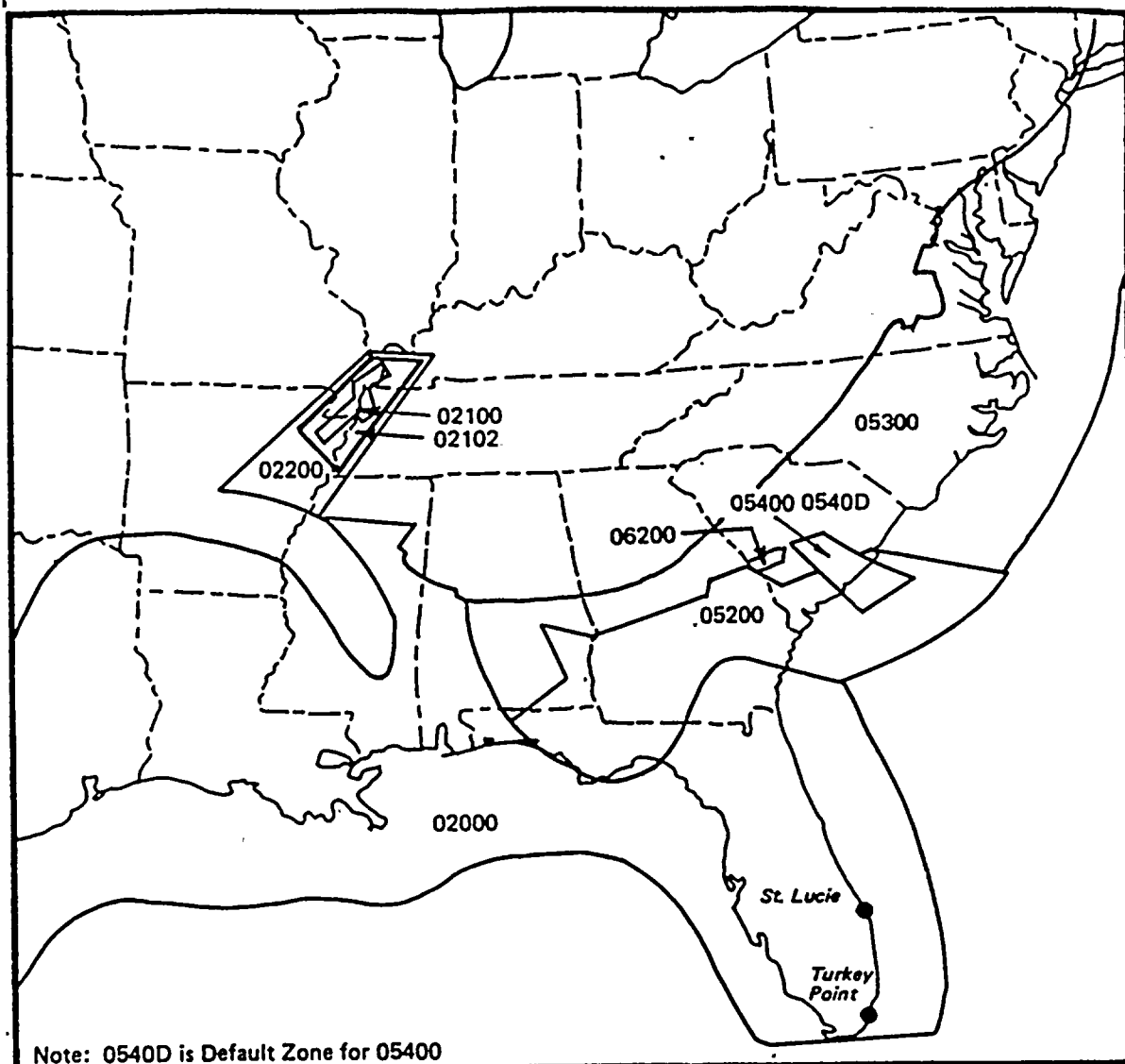
<u>Number</u>	<u>Name</u>
01300	Mesozoic Basins
03000	New Madrid
03100	Reelfoot Rift
05200	Charleston Area
05900	Charleston Faults
00100	New Madrid Background
00600	Site Background
02000	Adjacent Background

Source Zone Contributing to Hazard

<u>St. Lucie</u>	<u>Turkey Point</u>
01300	
05200	
00600	00600
02000	02000

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 Seismic Source Zones Considered for  
 the Florida Power and Light Company  
 (Bechtel Group Inc. Model)

FIGURE 2



Source Zone

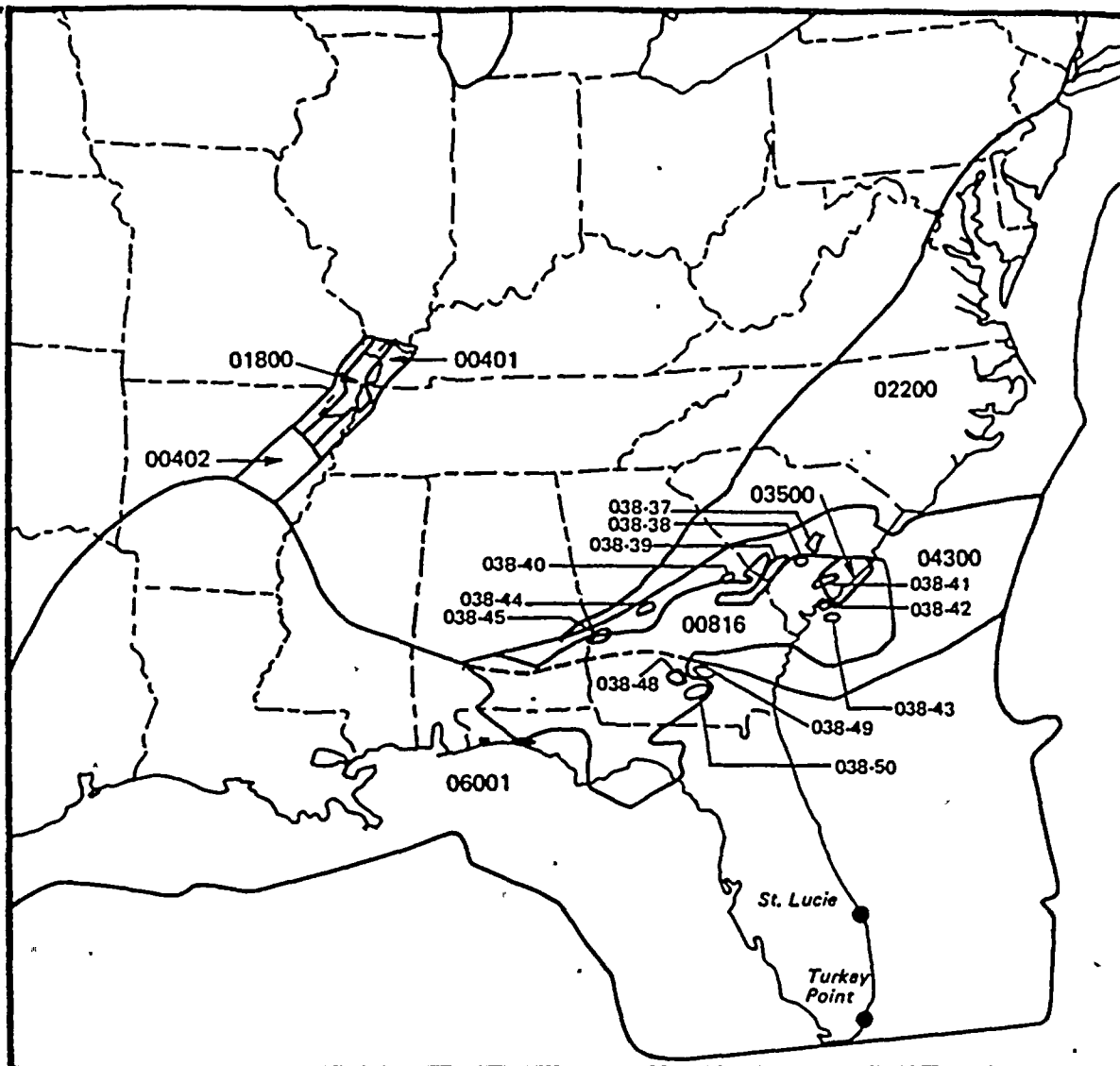
<u>Number</u>	<u>Name</u>
02000	Southern Coastal Margin
02100	New Madrid
02200	Reelfoot Rift
05200	Charleston Rift
05300	Southern Appalachian Default
05400	Charleston Seismic Zone
0540D	Charleston Default Zone
06200	Dunbarton Triassic Basin

Source Zone Contributing to Hazard

<u>St. Lucie</u>	<u>Turkey Point</u>
02000	02000
05200	
05300	
05400	
0540D	

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 Seismic Source Zones Considered for  
 the Florida Power and Light Company  
 (Dames and Moore Model)

FIGURE 3



Source Zone

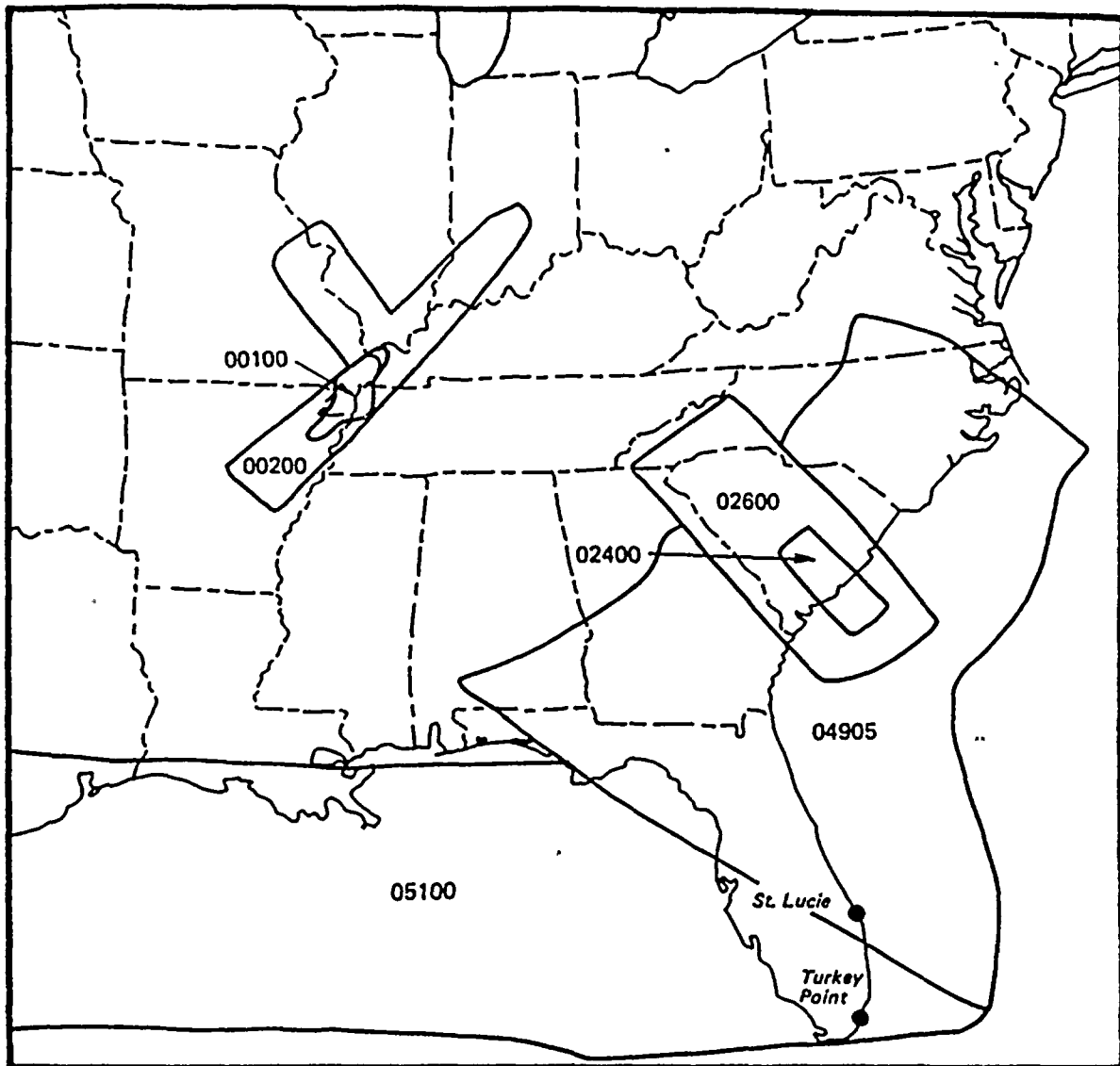
<u>Number</u>	<u>Name</u>
00401	Reelfoot Rift (A)
00402	Reelfoot Rift (B)
00816	Mesozoic Basins
01800	Reelfoot Rift Faults
02200	Reactivated Eastern Seaboard
03500	Charleston
04300	Brunswick
06001	Southern Coastal Block
03837 to 03845	Mafic Plutons
03848 to 03850	Mafic Plutons

Source Zone Contributing to Hazard

<u>St. Lucie</u>	<u>Turkey Point</u>
00816	00816
02200	02200
04300	04300
06001	06001

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 Seismic Source Zones Considered for  
 the Florida Power and Light Company  
 (Law Engineering Company Model)

FIGURE 4



Source Zone

<u>Number</u>	<u>Name</u>
00100	New Madrid
00200	New Madrid Rift
02400	Charleston
02600	South Carolina
04905	Appalachian Basement Background
05100	Gulf Coast to Bahamas Background

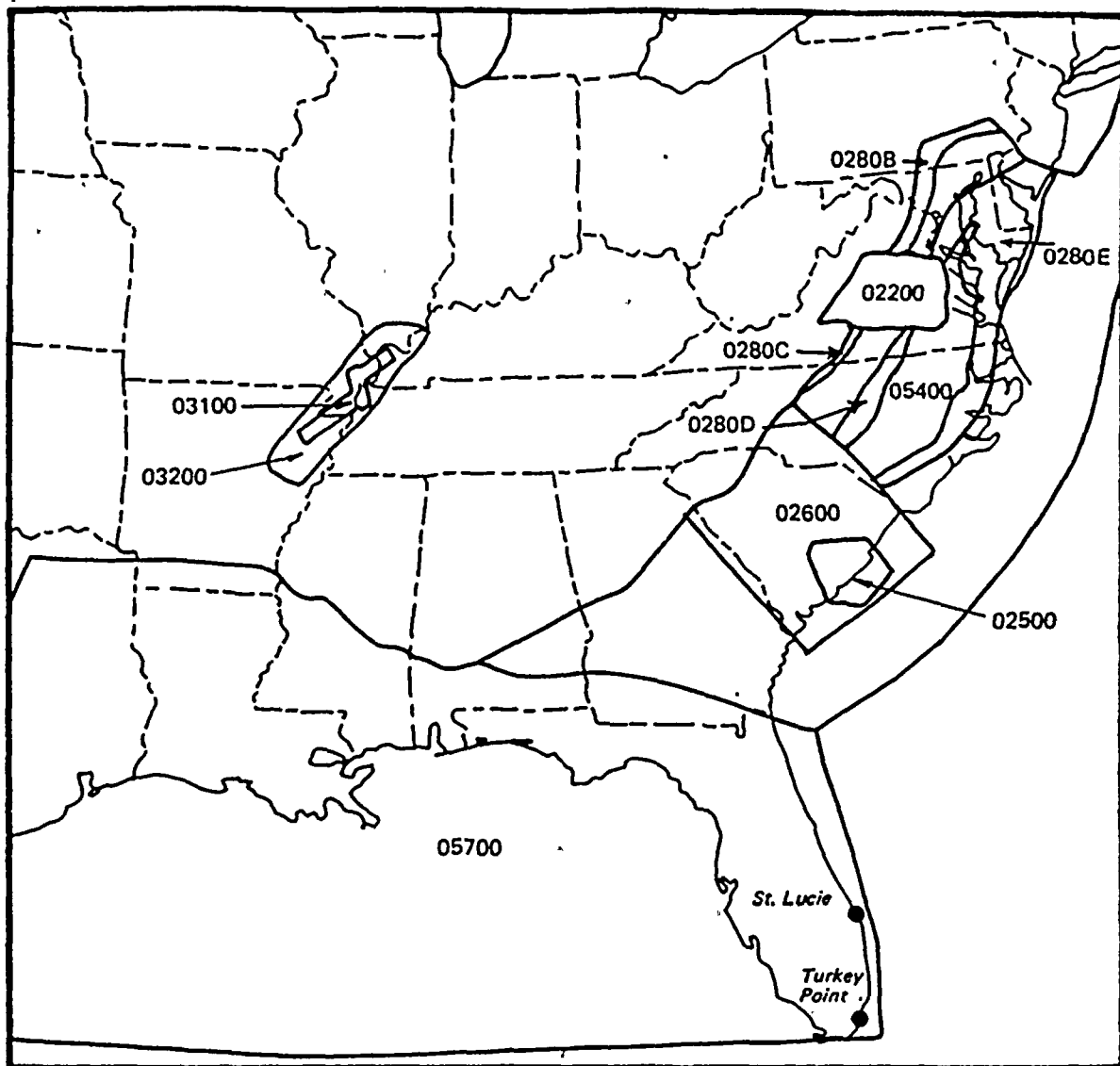
Source Zone Contributing to Hazard

<u>St. Lucie</u>	<u>Turkey Point</u>
02400	
02600	
04905	04905
05100	05100

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Seismic Source Zones Considered for the Florida Power and Light Company (Rondout Associates Model)

FIGURE 5





Source Zone

<u>Number</u>	<u>Name</u>
02500	Charleston
02600	South Carolina
03100	New Madrid
03200	Reelfoot Rift
05400	Southern Coastal Plain
05700	Gulf Coast Background
91100*	Combination 11
92000* to 92400*	Combinations 920 to 924
92700*	Combination 927
92800*	Combination 928

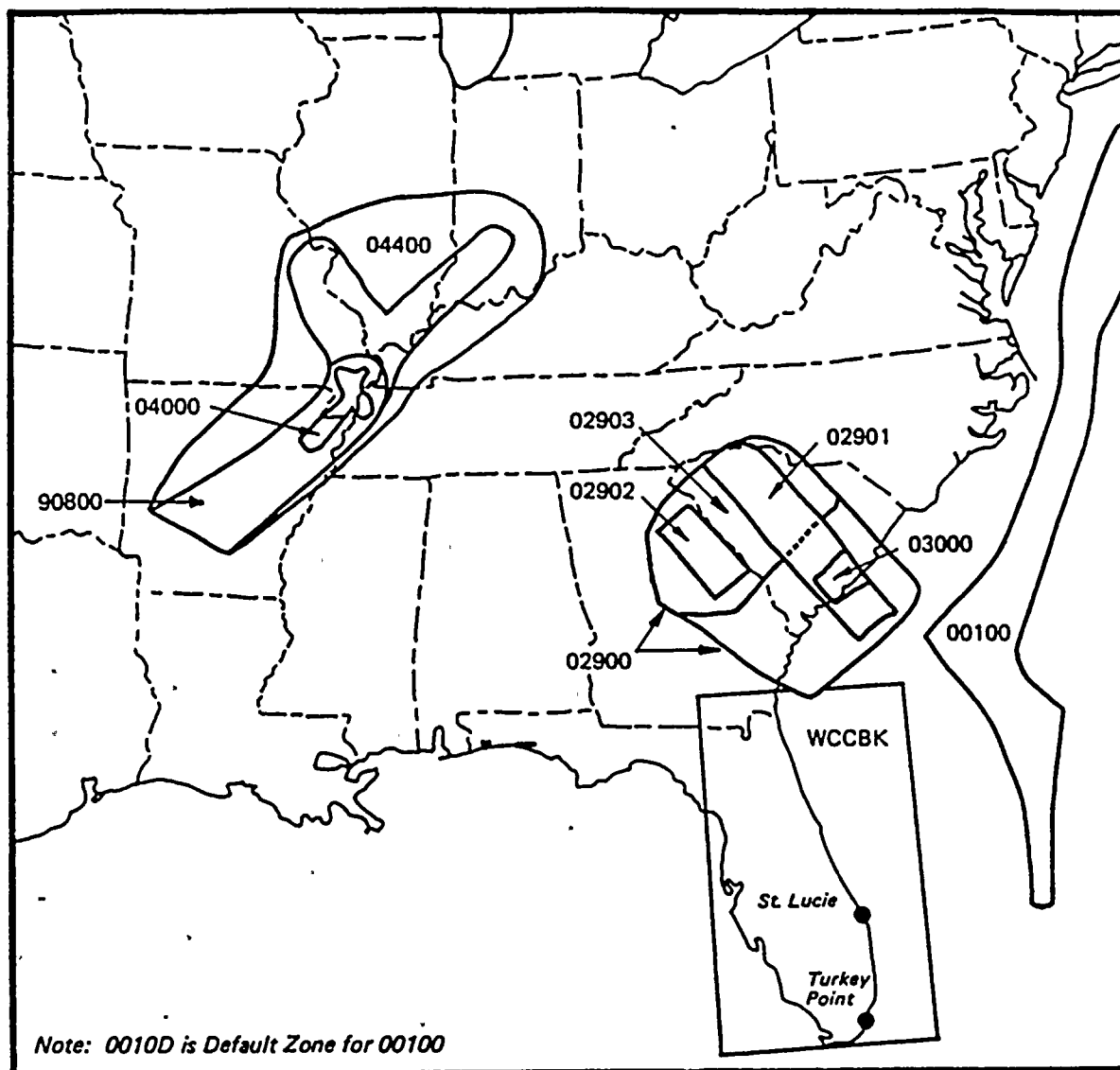
Source Zone Contributing to Hazard

<u>St. Lucie</u>	<u>Turkey Point</u>
02500	
02600	
05400	
05700	05700
92000 to 92400	
92700	
92800	

\*Geometry of Combination Sources Given in Table 1.

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 Seismic Source Zones Considered for  
 the Florida Power and Light Company  
 (Weston Geophysical Corp. Model)

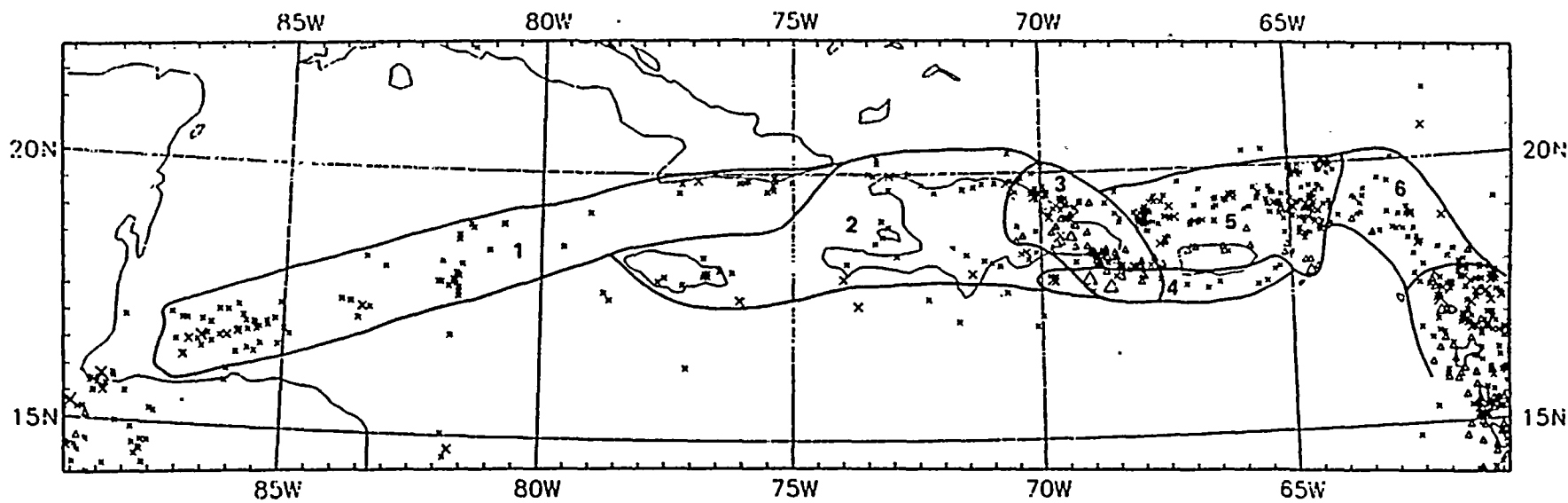
FIGURE 6



<u>Source Zone</u>		<u>Source Zone Contributing to Hazard</u>	
<u>Number</u>	<u>Name</u>	<u>St. Lucie</u>	<u>Turkey Point</u>
00100	Continental Shelf Edge		
02900	South Carolina, Option 1	02900	
02901	South Carolina, Option 2	02901	
02902	South Carolina, Option 2	02902	
02903	South Carolina, Option 3	02903	
03000	Charleston NOTA		
04000	Central Reelfoot Rift		
90800	Reelfoot Rift		
04400	New Madrid Loading Zone		
WCCBK	Background	WCCBK	WCCBK

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Seismic Source Zones Considered for the Florida Power and Light Company (Woodward Clyde Consultants Model)

FIGURE 7



Source Zone

Number

Name

- |   |   |
|---|---|
| 1 | Cayman Trough                               |
| 2 | Jamaica-Western Hispaniola                  |
| 3 | Eastern Hispaniola                          |
| 4 | Puerto Rico Trench                          |
| 5 | Muertos Trench                              |
| 6 | Greater Antilles-Lesser Antilles Transition |

Source Zone Contributing to Hazard

St. Lucie

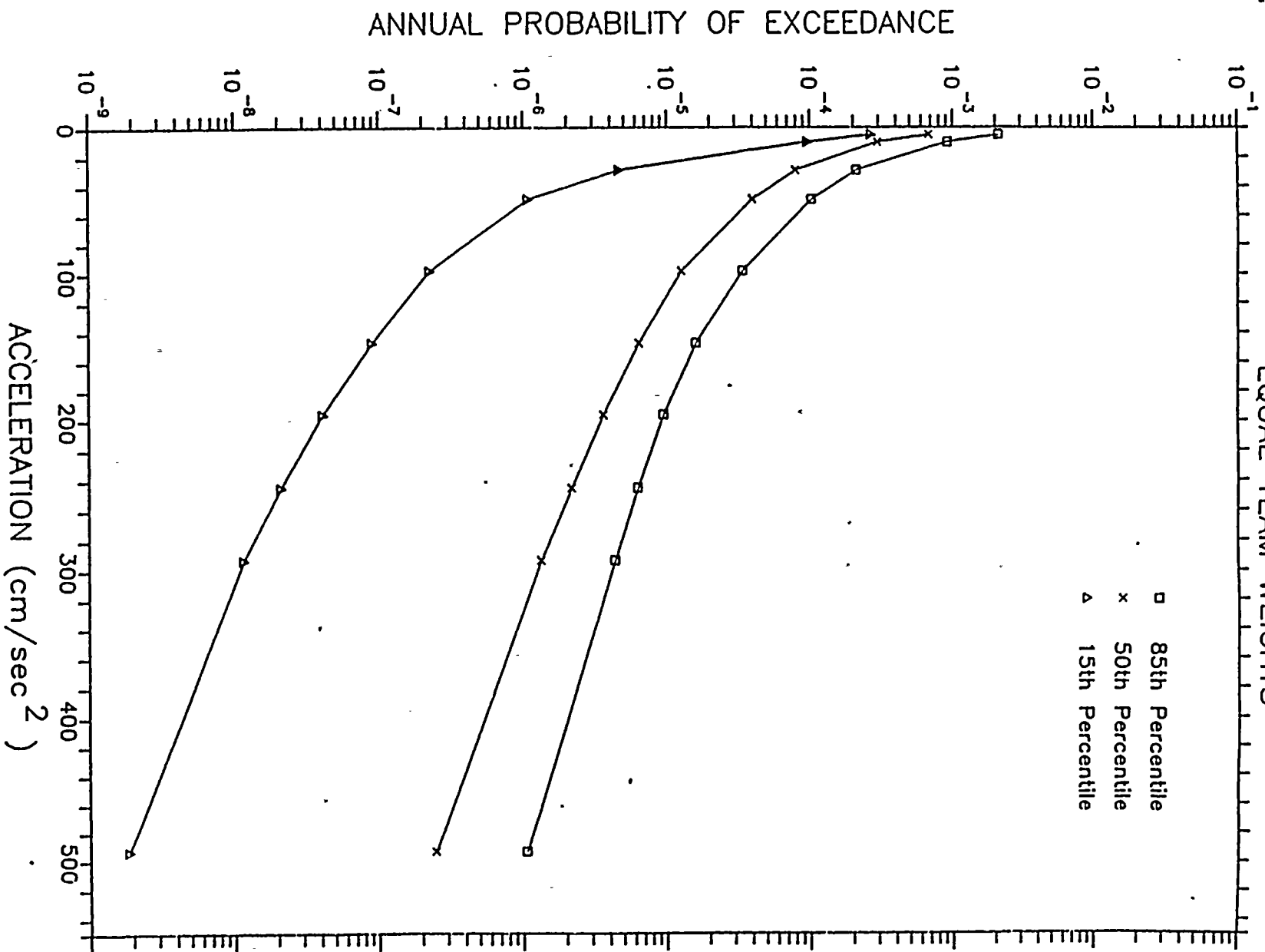
Turkey Point

- |      |   |
|------|---|
|      | 1 |
| None | 2 |

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 Seismic Source Zones Considered for  
 the Florida Power and Light Company  
 in the Northern Caribbean

FIGURE 8

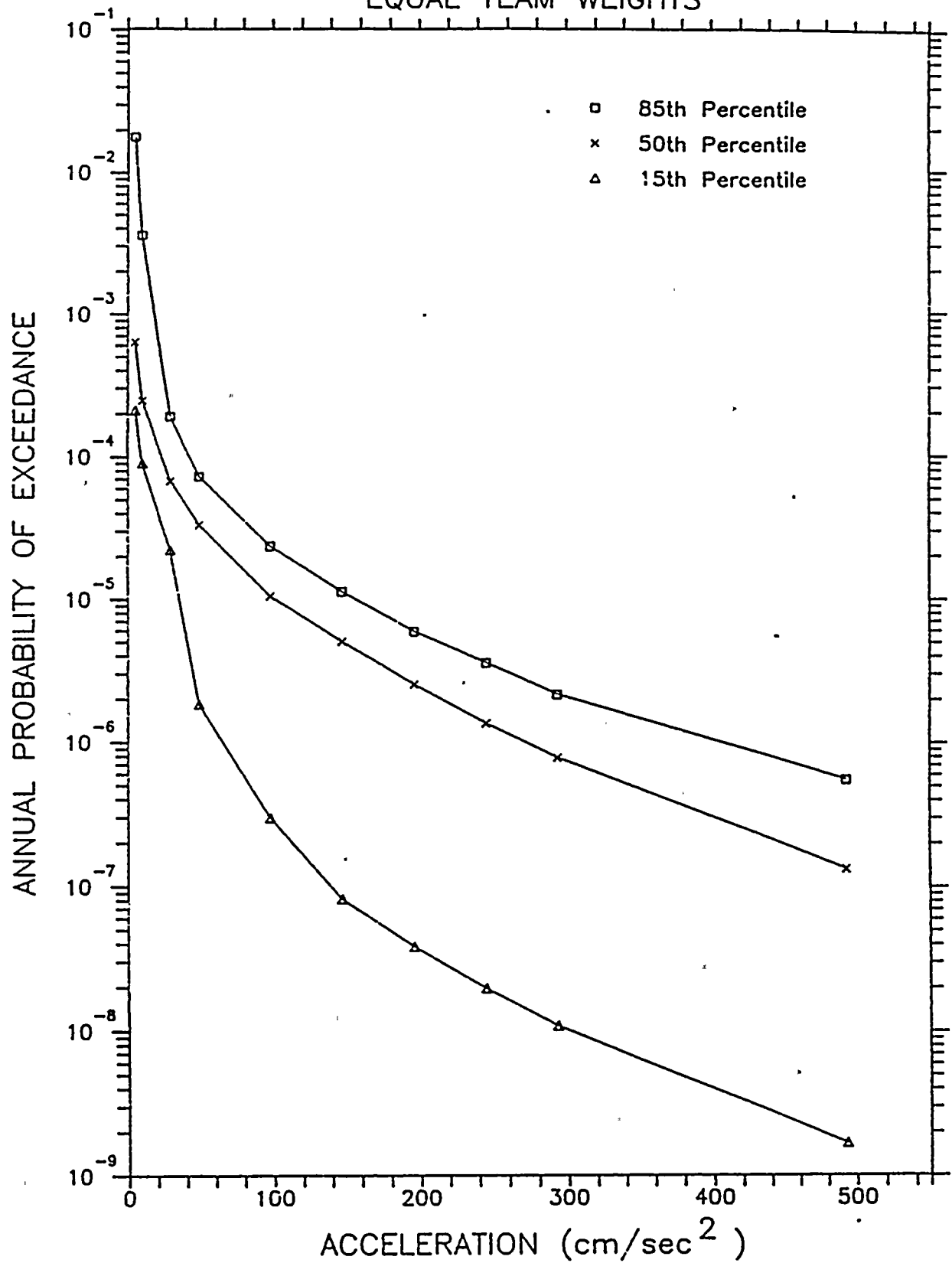
# HAZARD RESULTS AT ST. LUCIE EQUAL TEAM WEIGHTS



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FIGURE 9

# HAZARD RESULTS AT TURKEY POINT EQUAL TEAM WEIGHTS



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FIGURE 10