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Task G1.1
ASCE 43-05 Performance-Based Method for Determining Site Ground Motion

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EPRI

Task G1.1 Scope:

- Computed updated PSHA for 28 NPP sites, compute design basis response spectra using ASCE 43-05 approach, and evaluate ASCE 43-05 approach

Updates:

Seismic sources:	Charleston source New Madrid source Illinois sources Saline River sources Gulf Coast sources
Ground motion	EPRI 2003
Sources of Information:	Clinton ESP application (2003) Grand Gulf ESP application (2003) North Anna ESP application (2003) TVA seismic hazard study (2004)

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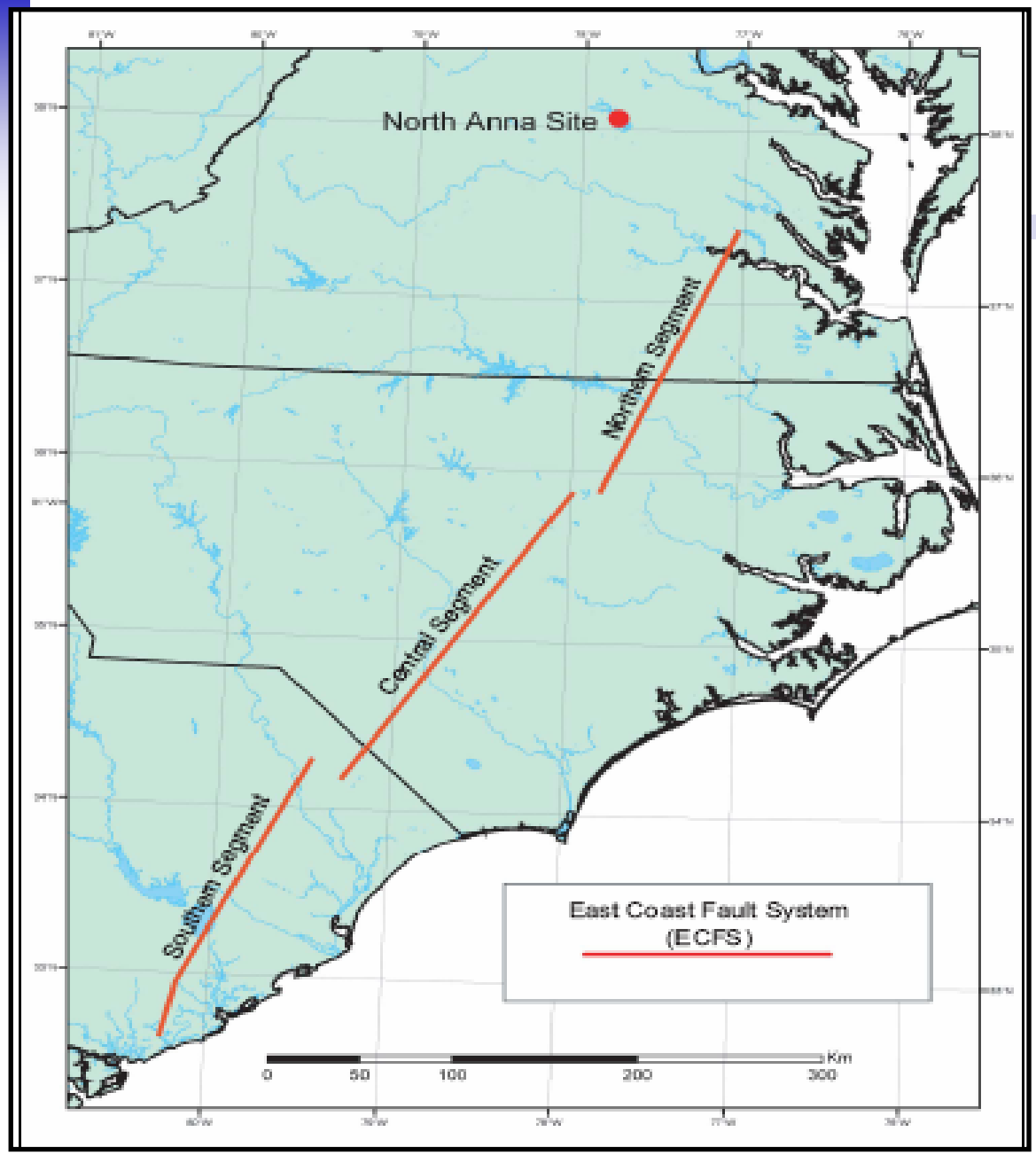

Figure 3.5-13
Northern, Central, and Southern Segments of the East Coast Fault System

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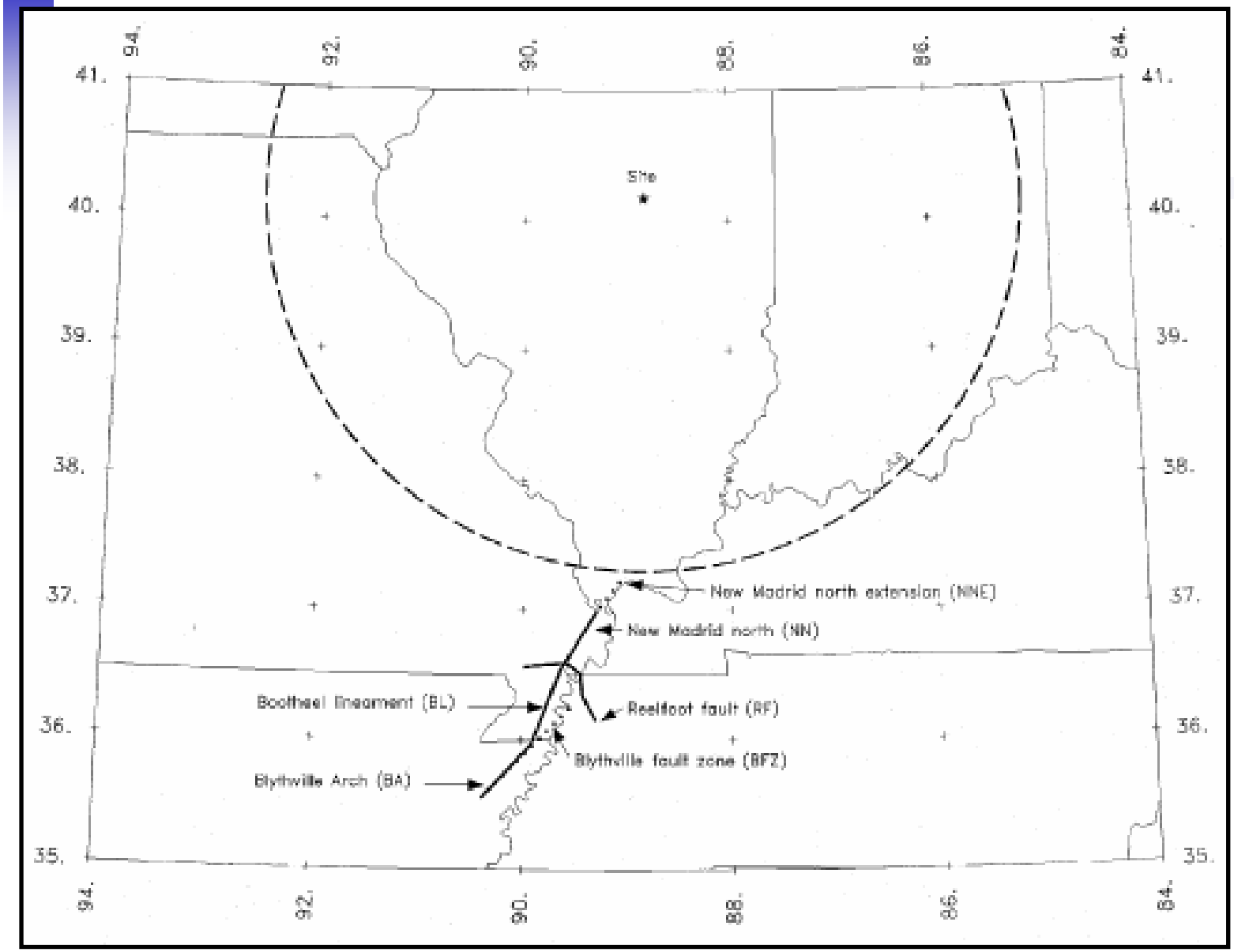

Figure 4.1-2 Seismic Hazards Report for the EGC ESP Site: Locations of Fault Sources for Characteristic New Madrid Earthquakes

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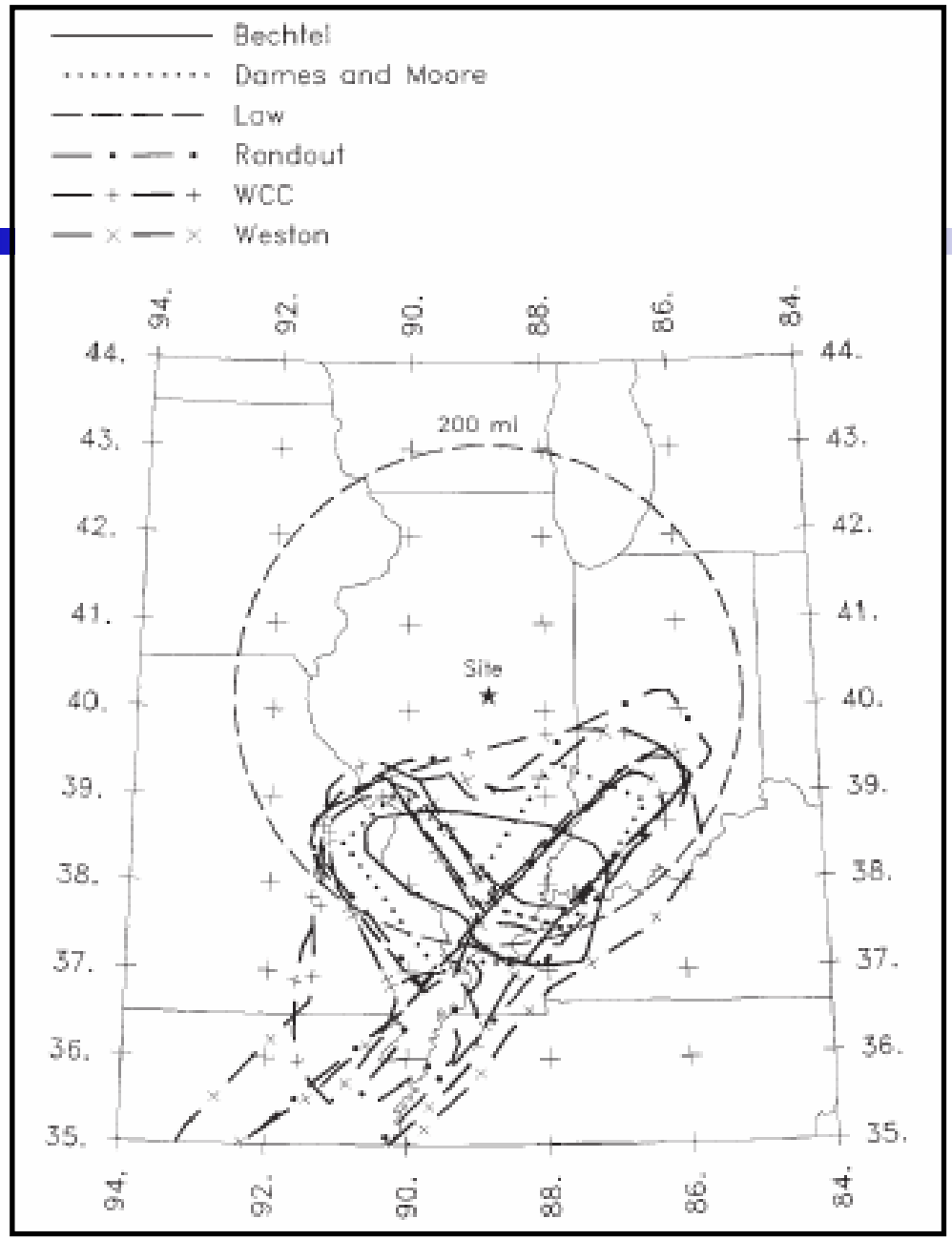

Figure 3.1-1
Alternative Southern Illinois-Wabash Valley Source Configurations used in EPRI-SOG

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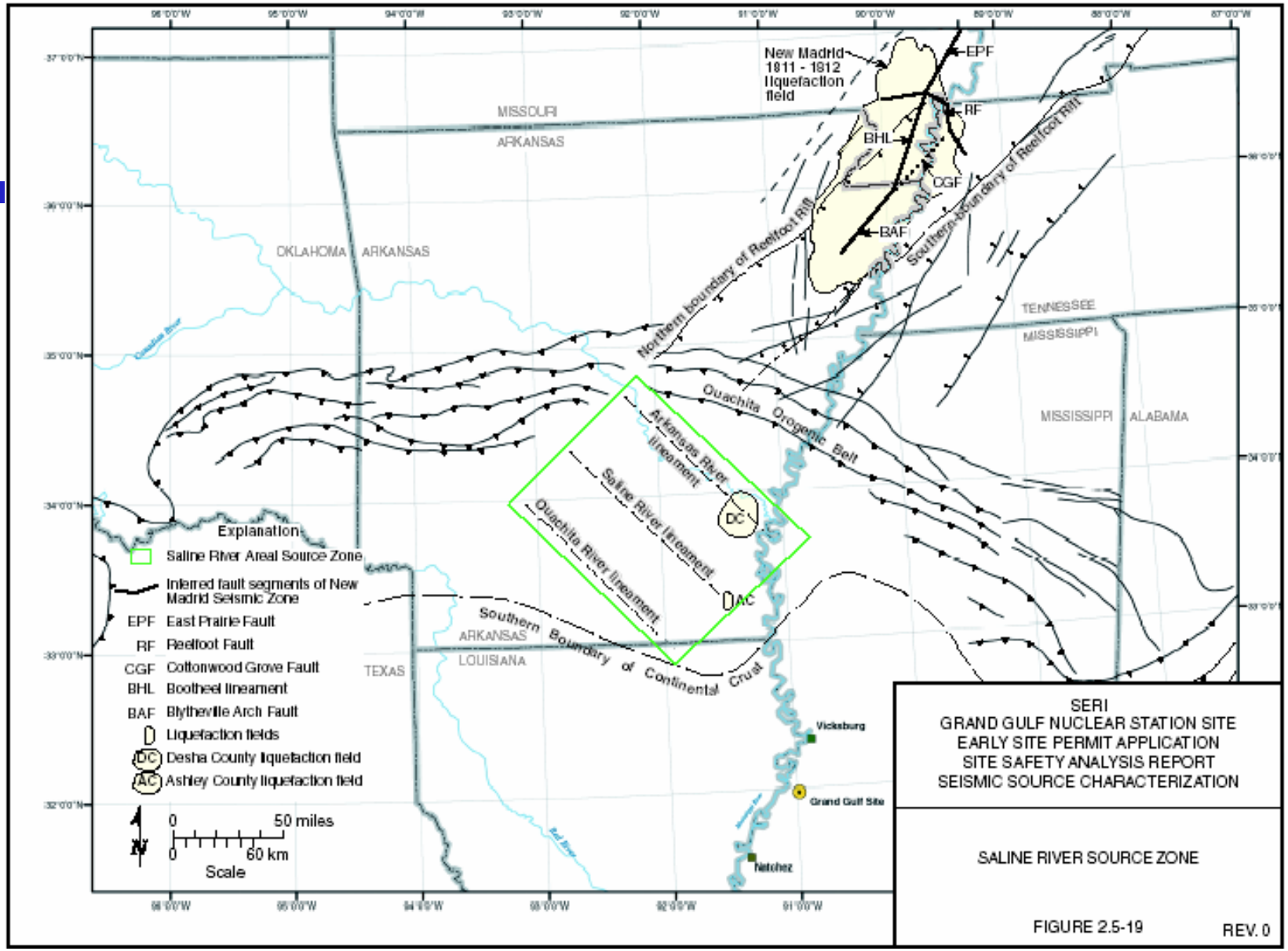

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Changes in seismic sources:

Charleston:	▪ mean recurrence interval ~ 550 years for large earthquakes (**M** • 6.8 to 7.3)
New Madrid:	▪ mean recurrence interval ~ 500 years for large earthquakes (**M** • 7.5 to 8.2) ▪ cluster model used for earthquake occurrence
Wabash Valley/ Illinois sources:	▪ Wabash Valley/Southern Illinois: **M** • 7.3 to 7.5 ▪ Central Illinois: **M** • 6.3 to 7.0
Saline River source: (new source)	▪ **M** • 6 to 7 ▪ recurrence interval 1,000 to 125,000 years
Gulf Coast sources:	▪ raised minimum m_{max} to m_b 5.4 (**M** 5.0)

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Changes in ground motion models:

- High frequencies: EPRI 2003 similar to EPRI 1989 in mean, σ larger
- Low frequencies: EPRI 2003 lower than EPRI 1989, σ larger

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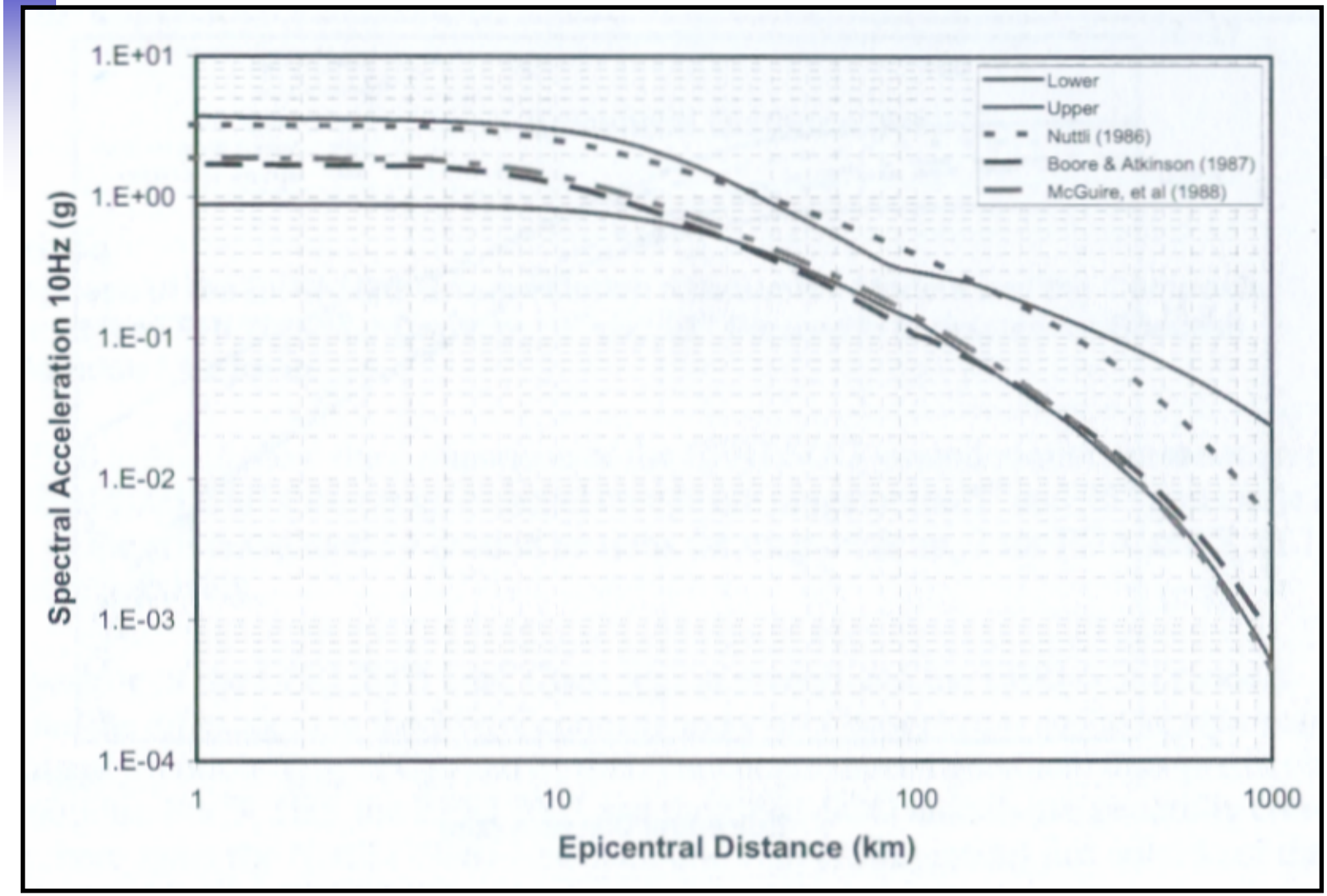

EPRI 2003 10 Hz SA for m_b 7, compared to EPRI-SOG equations

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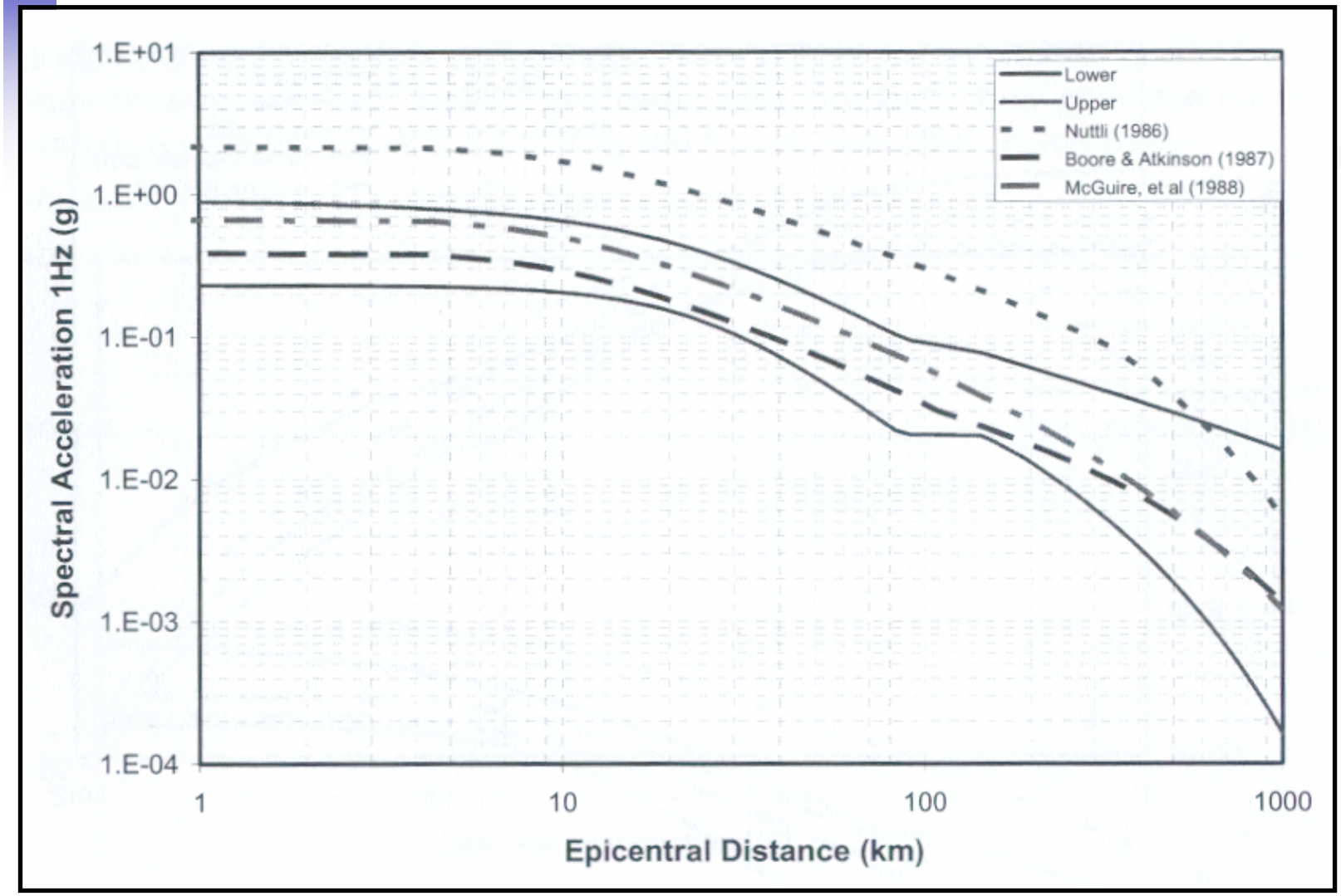

EPRI 2003 1 Hz SA for m_b 7, compared to EPRI-SOG equations

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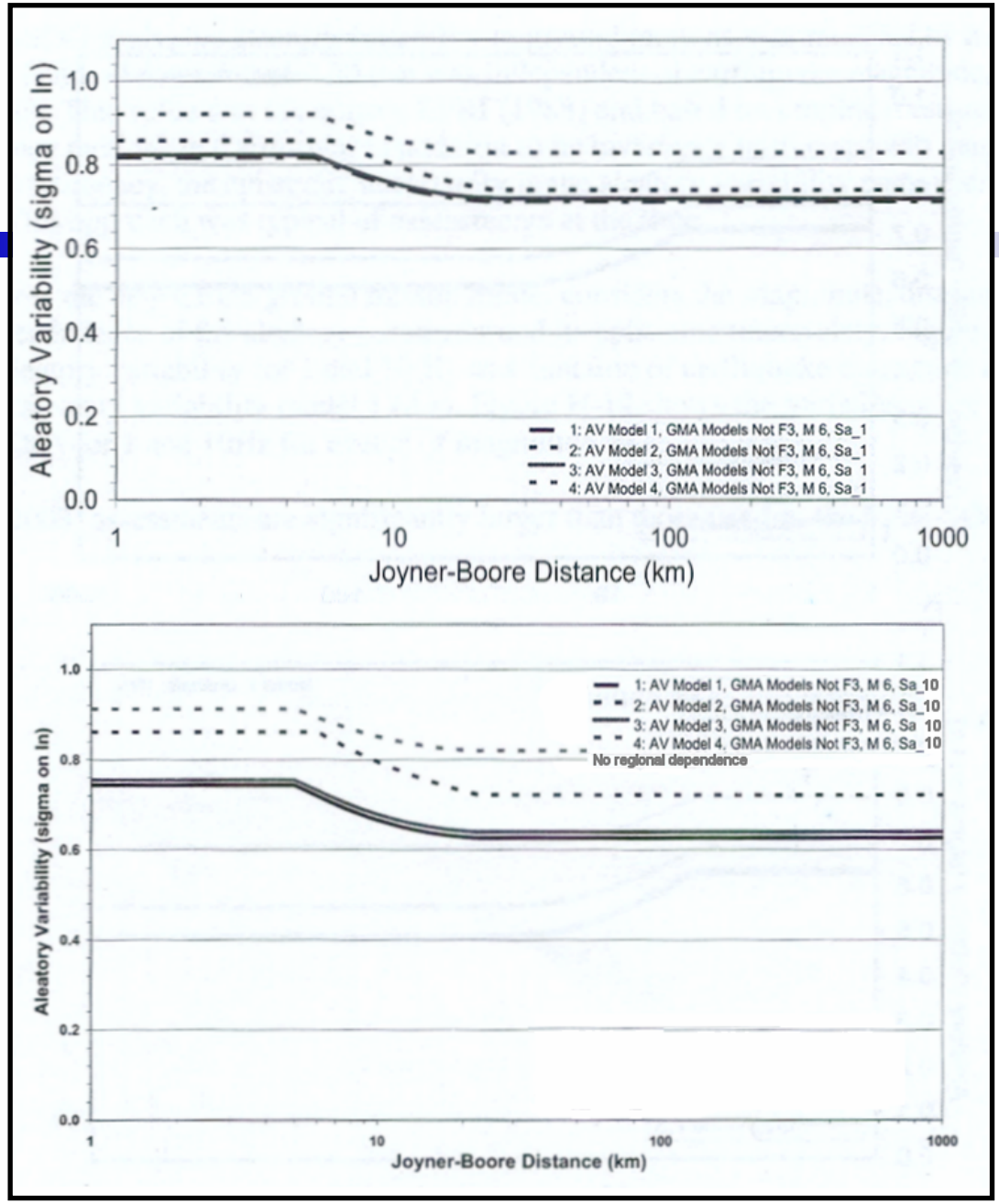

EPRI σ for M 6, 1 Hz (top) and 10 Hz (bottom)

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Figure 1.1 Map Showing 28 Plant Sites Where Hazard Curves were Calculated

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Verification Studies:

- Replicated EPRI 1989 rock hazard calculations at 4 test sites (verifies FRISK88 software, EPRI-SOG sources)
- Replicated ESP application rock hazard calculations at 3 ESP sites (verifies updates to seismic sources, EPRI 2003 ground motion model)

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Assumptions for seismic hazard analysis:

- Minimum magnitude = m_b 5.0 (follows EPRI-SOG and 2 of 3 ESP applications)
- Cluster model used for New Madrid earthquakes (follows Clinton ESP application)

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Site specific amplification model for soil and soft-rock sites:

- equivalent linear vertically propagating shear-wave model
- site properties (shear-wave velocity, K, G/G_{max}, hysteretic damping) modeled to basement rock (Vs = 9200 ft/s)
- site properties and depth to basement were randomized using correlation model
- site information taken from FSAR publications
- rock hazard curves were integrated with amplification factors to calculate site-specific hazard curves, accounting for epistemic uncertainties

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Calculations:

- Focus on 5 and 10 Hz spectral response (following Reg. Guide 1.165)
- Develop recommended design response spectra following ASCE (2005):
  - DRS = DF • UHRS

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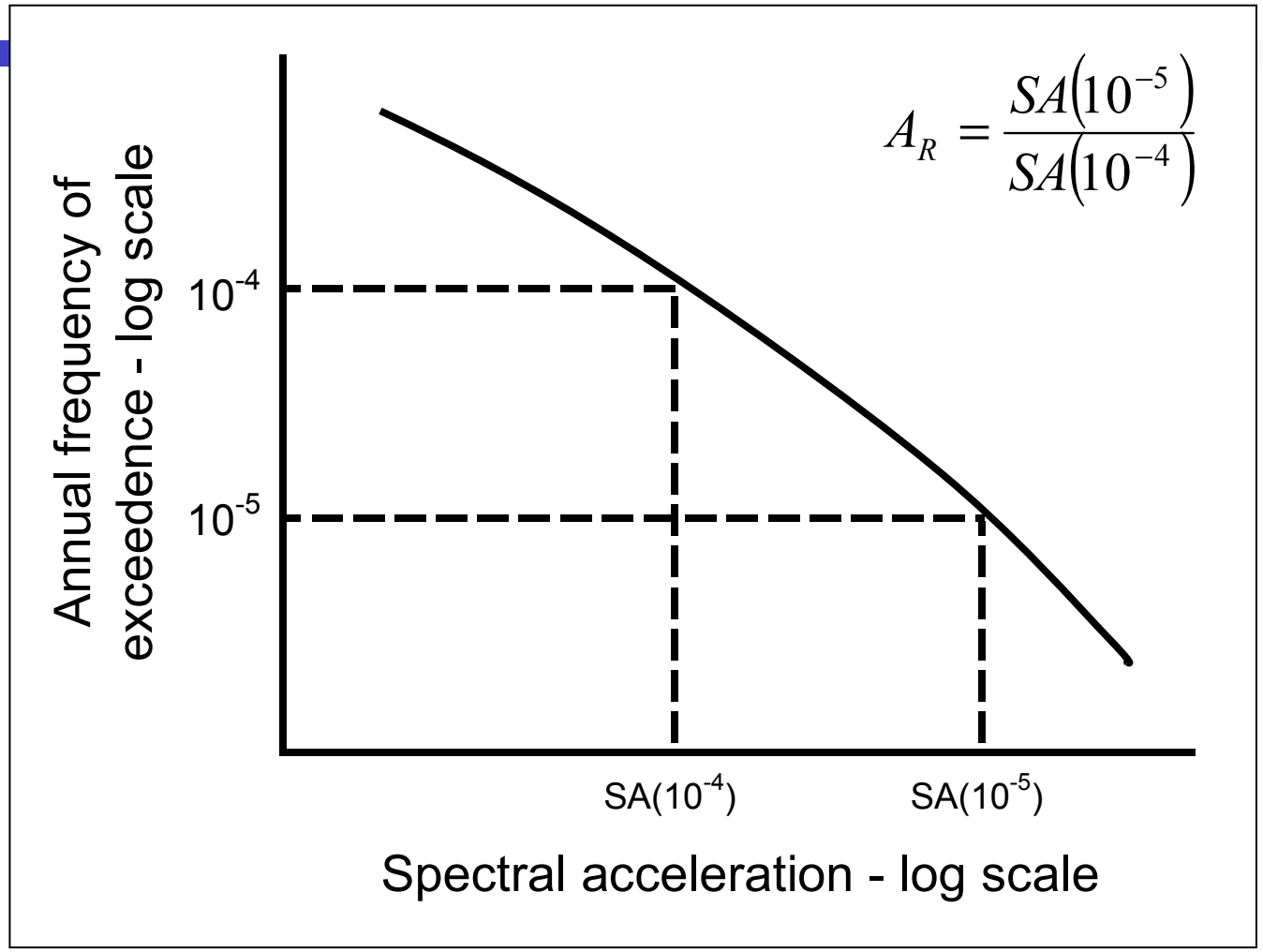
1 Calculate ground motion ratio A_R



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2 Establish design basis earthquake response spectrum DRS:

$$UHRS = \text{mean } 10^{-4} \text{ spectrum}$$

$$DF = \max (1.0, 0.6A_R^{0.8})$$

$$DRS = DF * UHRS$$

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Range of AR, DF, and P[exceedance] for 28 sites in study

	Min	16th	50th	84th	Max
10 Hz, AR	1.50	2.26	3.01	3.67	4.36
10 Hz, DF	1	1.15	1.45	1.70	1.95
10 Hz, PE/1E-4	0.37	0.40	0.48	0.68	1
5 Hz, AR	1.64	2.17	2.63	3.33	4.05
5 Hz, DF	1	1.11	1.30	1.57	1.84
5 Hz, PE/1E-4	0.38	0.43	0.54	0.75	1
2.5 Hz, AR	1.54	2.19	2.42	3.23	3.81
2.5 Hz, DF	1	1.13	1.22	1.53	1.75
2.5 Hz, PE/1E-4	0.4	0.45	0.62	0.76	1
1 Hz, AR	1.58	2.24	2.49	3.40	3.77
1 Hz, DF	1	1.14	1.24	1.60	1.74
1 Hz, PE/1E-4	0.39	0.44	0.61	0.73	1

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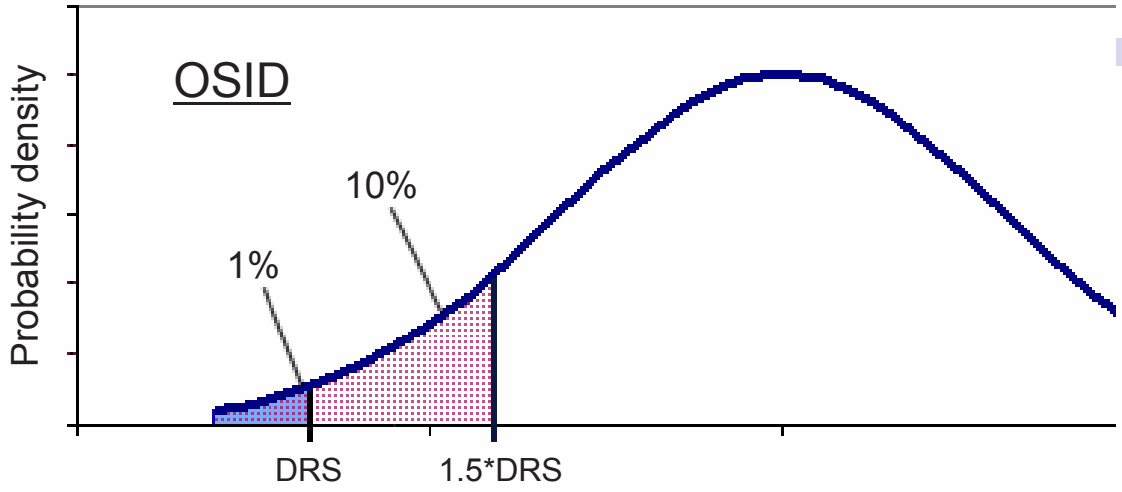
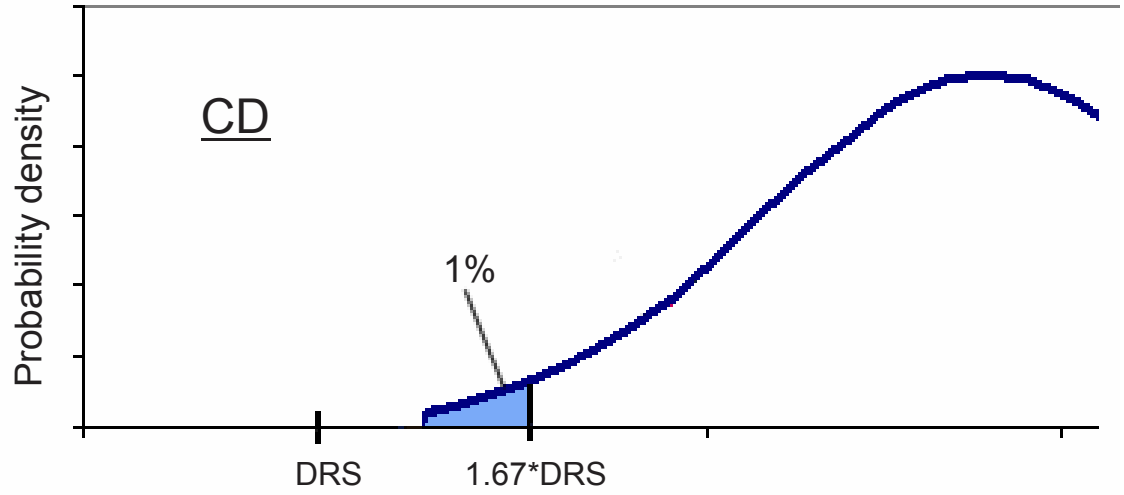
3 Estimate plant resistance to:



A. Onset of significant inelastic deformation



B. Core damage

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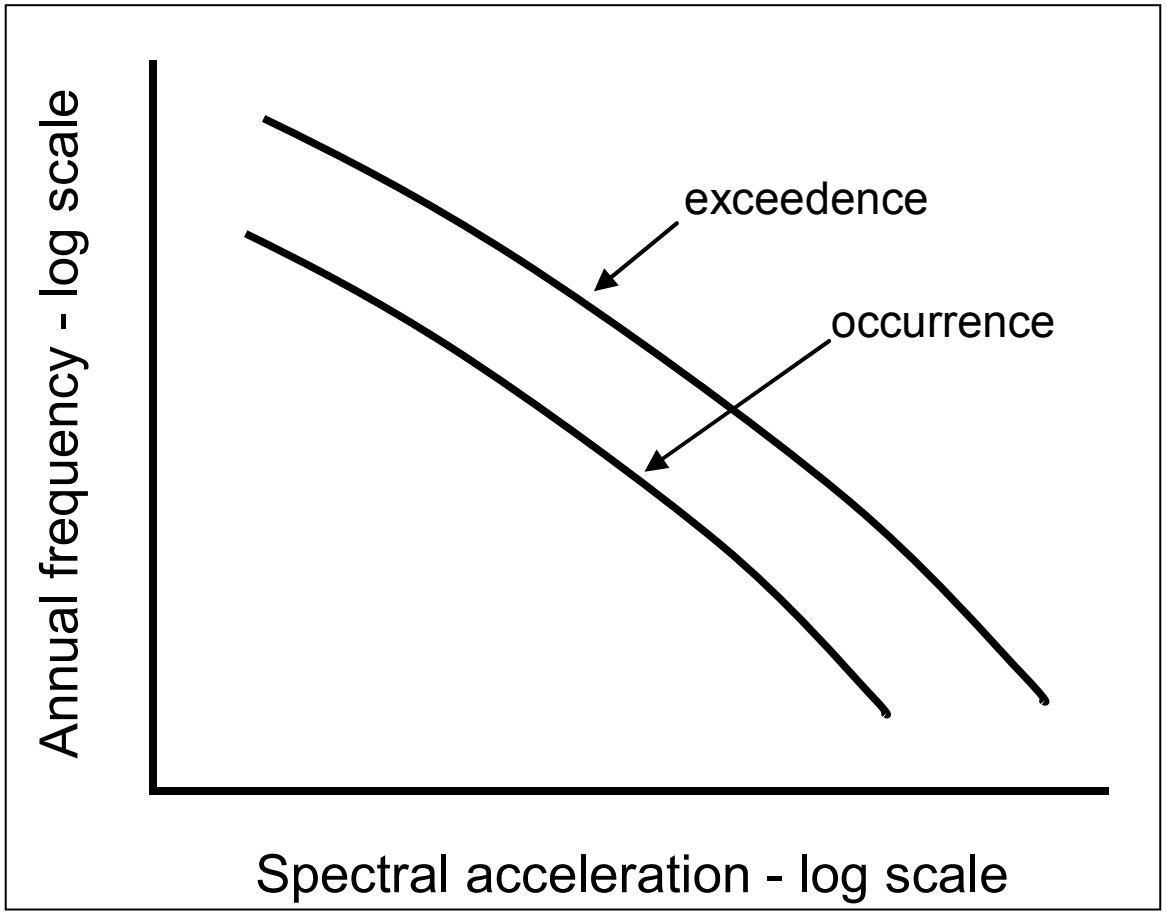
4 Derive P[occurrence] from P[exceedence]



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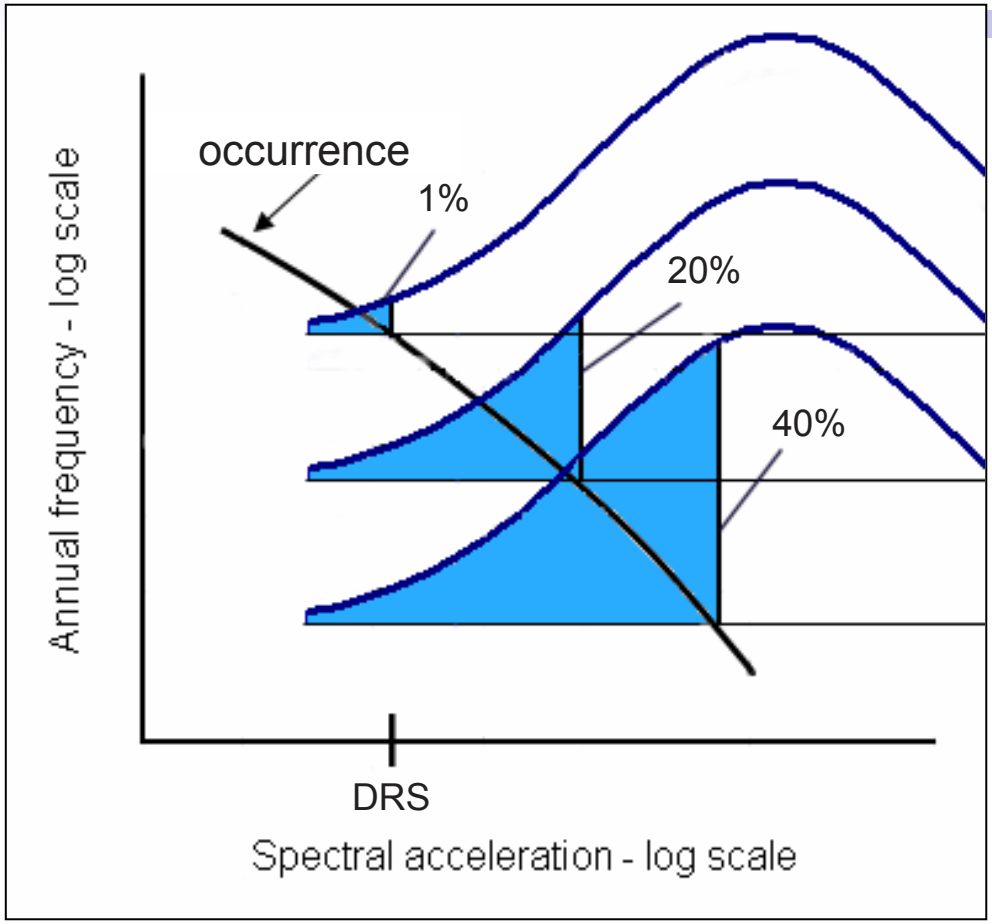
5 Convolution



$$FOSID = \sum_{SA} f(SA) * P[OSID|SA]$$

$$SCDF = \sum_{SA} f(SA) * P[CD|SA]$$

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Calculations:

- Comparison 1: Recommended design response spectra vs. SSE spectra used for existing plants:
  - average of DRS/SSE at 5 and 10 Hz
  - minimum DRS is RG 1.60 spectrum anchored to 0.1g (ASCE, 2005)

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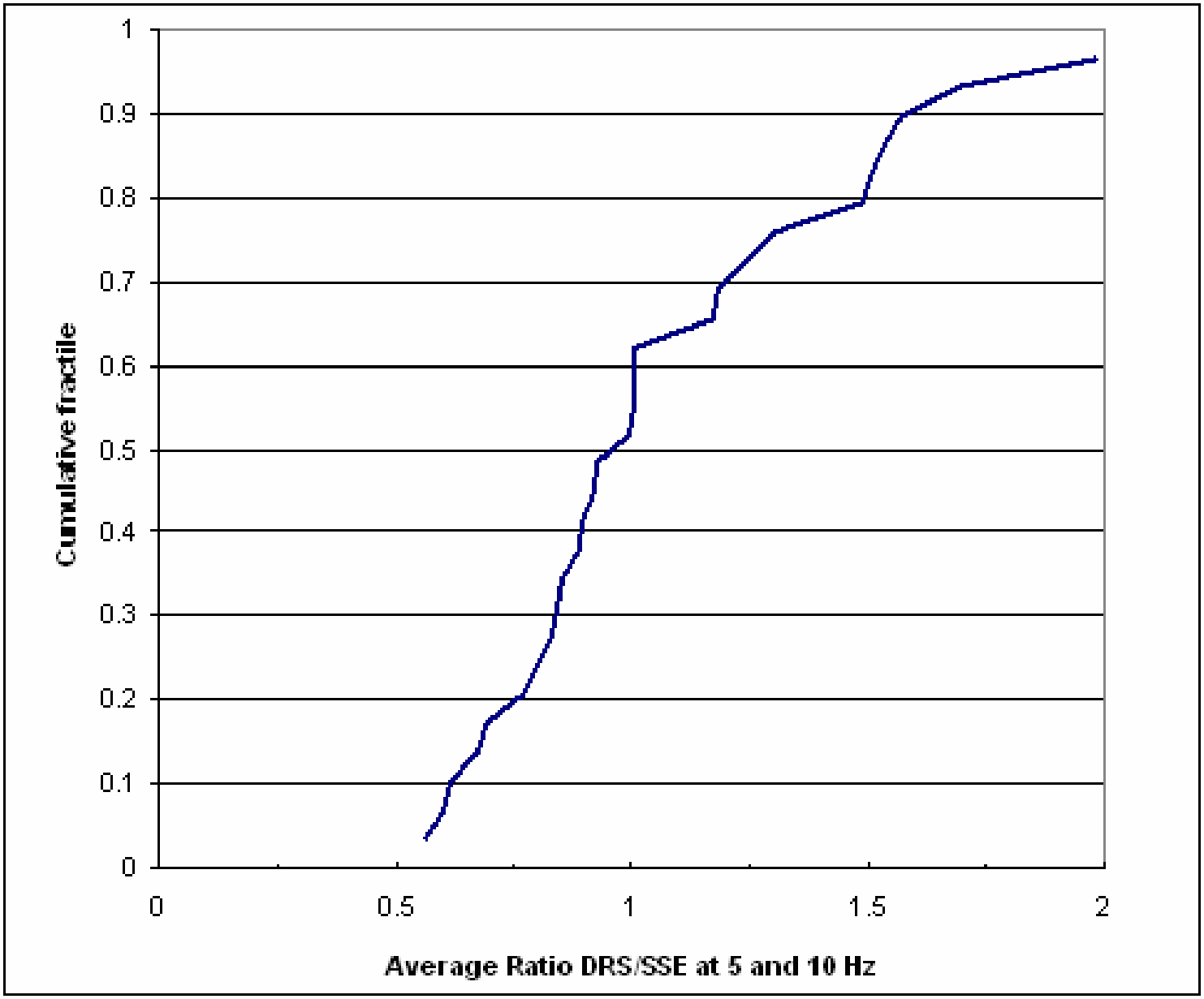

Figure 3.1 Cumulative Distribution of DRS/SSE Ratio at 5 and 10 Hz

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Calculations:

- Comparison 2: Component-level behavior:
  - calculate Frequency of Onset of Significant Inelastic Deformation (FOSID), compare to distribution of Seismic Core Damage Frequency (SCDF) from 25 seismic PRAs

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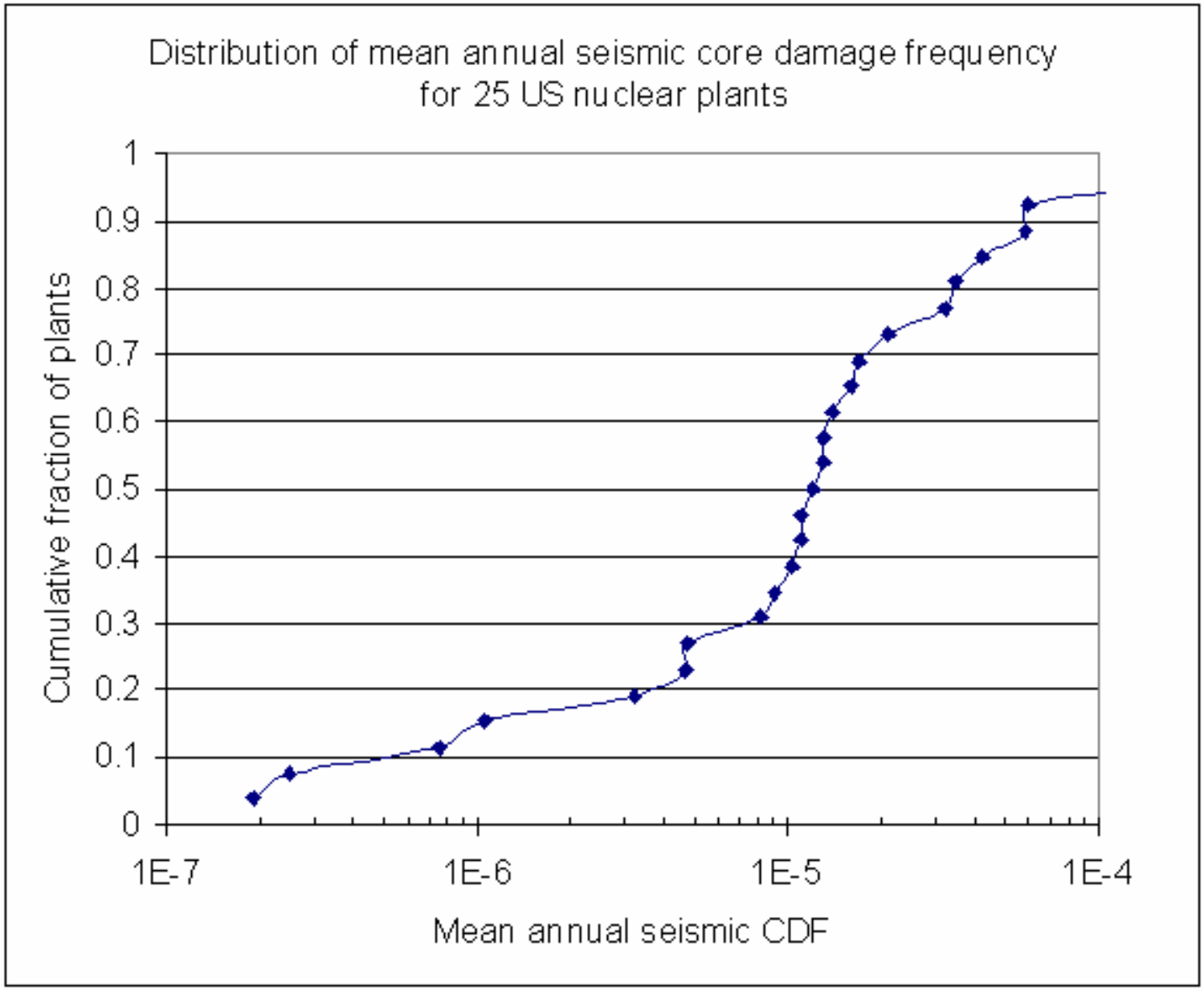

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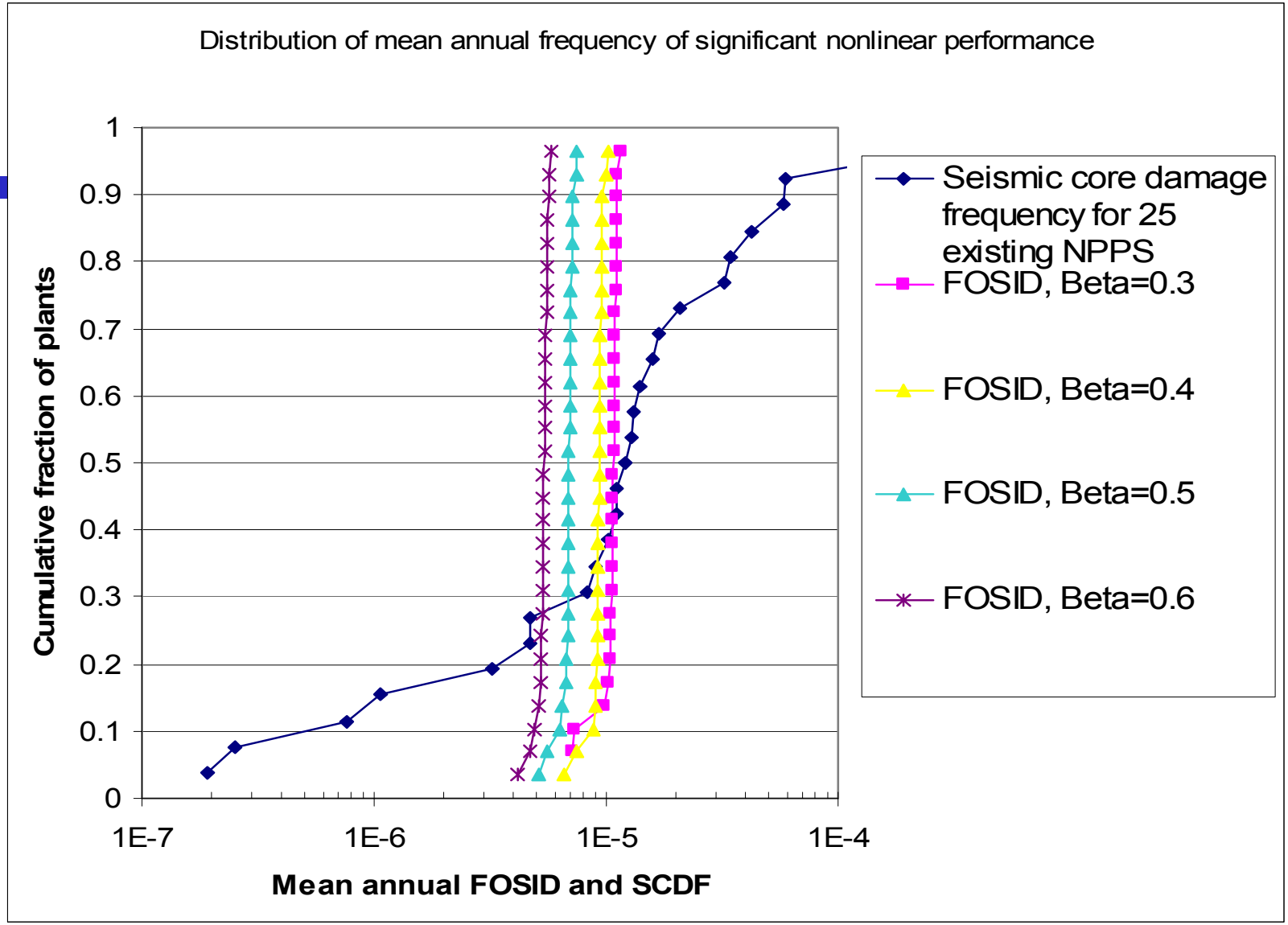

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Calculations:

- Comparison 3: Plant-level behavior:
  - calculate frequency of plant-level damage, compare to distribution of Seismic Core Damage Frequency (SCDF) from 25 seismic PRAs

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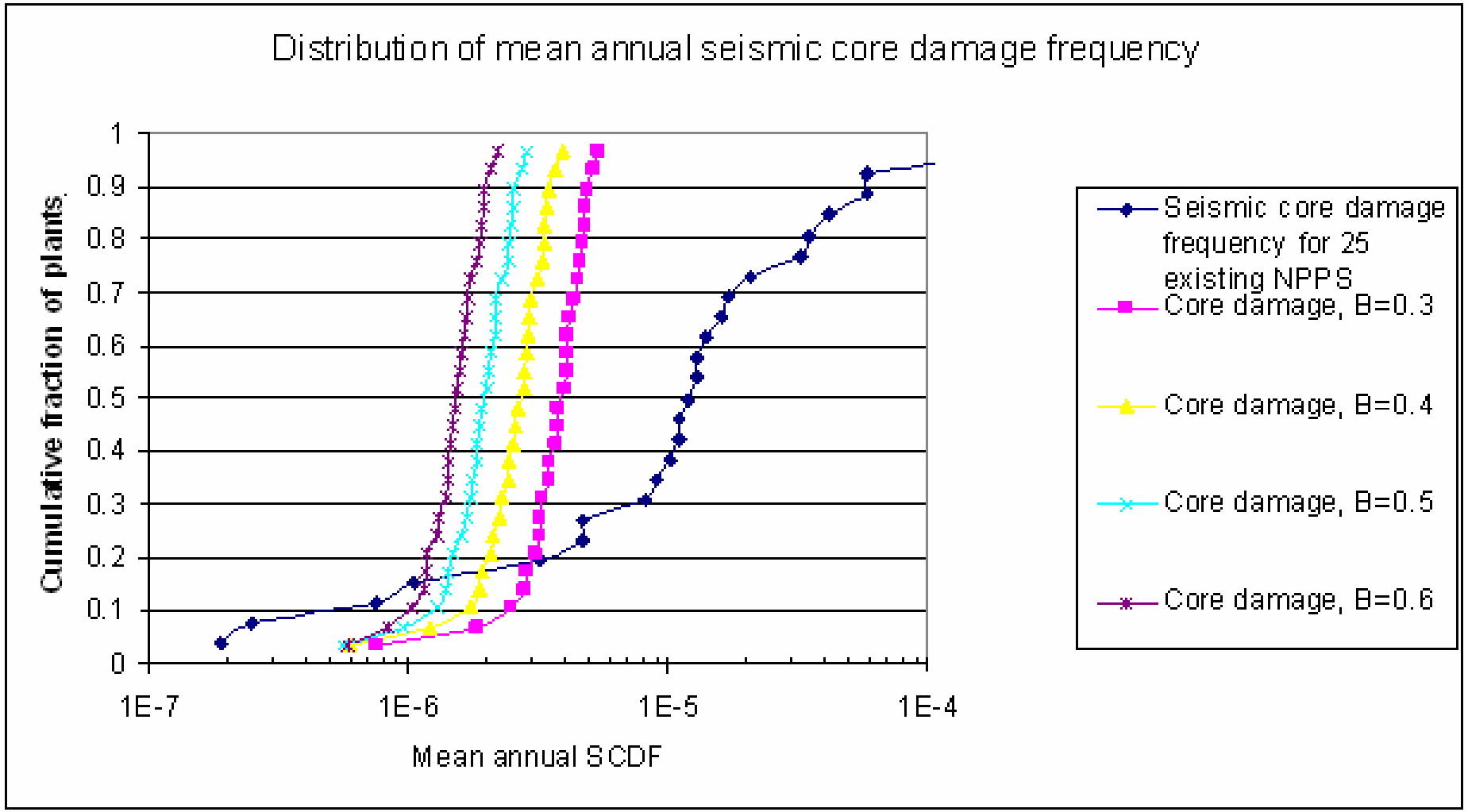

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Conclusions:

- ASCE DRS method leads to recommended design response spectra at 5 and 10 Hz that, as a whole, are equivalent to those used at 28 existing NPPs
- ASCE DRS method leads to recommended site-specific design response spectra that achieve a performance goal of 1 x 10^{-5} per year, for individual components at 5 and 10 Hz
- ASCE DRS method leads to plant-level performance estimates that are safer against seismic initiated core damage than 80% of existing nuclear plants (based on 5 and 10 Hz)

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