Notes on seismic hazard sensitivity studies for Eastern Tennessee Seismic Zone

3 March 2008—R. McGuire

Maximum magnitude values

The TIP study (Ref. 1) and TVA Dam Safety study (Ref. 2) used distributions of maximum magnitude $\mathbf{M}_{max}$ that are somewhat higher than values used in the EPRI-SOG study. Figure 1 shows distributions of values used in the TIP and TVA studies, on the moment magnitude (**M**) scale.

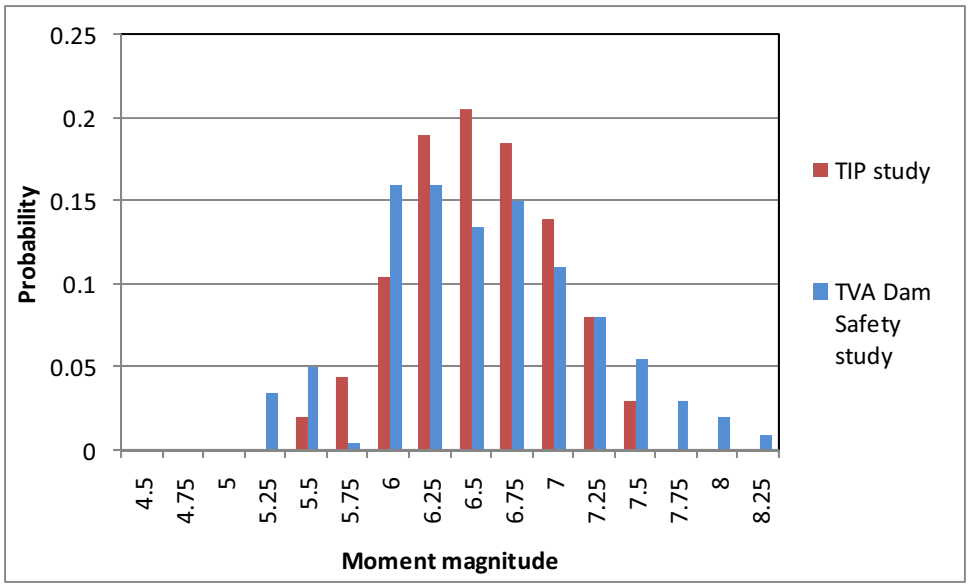

Figure 1: Distributions of $\mathbf{M}_{max}$ (on the moment magnitude scale) for the TIP and TVA studies.

These distributions have the following means and standard deviations (σ):

	mean **M**	**σ**
TIP study:	6.55	0.202
TVA Dam Safety study:	6.58	0.411
Composite:	6.56	0.307

Values for the composite distribution were determined by equally weighting the TIP and TVA distributions in Figure 1 and calculating the mean and σ.

For sensitivity studies on seismic hazard, the composite distribution can be represented with three magnitude values with weights, as follows:

M value	equivalent m_b value	weight
6.2	6.4	0.28
6.6	6.7	0.44

	7.0	6.9	0.28
Mean	6.60	6.67	
σ	0.299	0.190	

where the equivalent body-wave magnitude (m_b) values are computed by equally weighting the conversion equations from Atkinson and Boore (1995), Frankel et al. (1996), and EPRI (1993). The 3-point **M** distribution is one of many that could be chosen to represent the mean and σ of the composite distribution; the chosen values of **M** and m_b are on even tenths of a magnitude unit and will be consistent with the numerical integrations used for seismic hazard calculations. The distribution of **M** above (and the equivalent values of m_b) are referred to as the "composite distribution" in the next section.

EPRI-SOG source representations

The six EPRI-SOG teams represented seismicity in the region of eastern Tennessee with a range of seismic sources. These sources are summarized in Figure 2. They range from very localized sources capturing the seismicity in the eastern Tennessee region, to broad tectonic sources reflecting the geologic and tectonic structure, to large background sources that represent non-tectonic, "none-of-the-above" sources.

The specific EPRI-SOG interpretations, and the manner which they can be modified to determine the sensitivity to changes in m_{max} and seismicity for the eastern Tennessee region, are as follows. For sources that represent a tectonic explanation for the eastern Tennessee region, the m_{max} distribution will be modified to reflect the composite distribution described above. For sources that represent a background interpretation that is applicable when the tectonic sources are not active, the team's original m_{max} distribution will not be modified to reflect the composite distribution. As summarized below, this occurs with a combined probability of about 0.21.

For these sensitivity studies, seismicity parameters will be updated using an extension of the EPRI-SOG catalog through 2007.

Bechtel team. Bechtel used 3 sources with mutually exclusive activity to represent seismicity in eastern Tennessee, as follows. (The original m_{max} values listed below are for the m_b magnitude scale, as published in the EPRI-SOG documents).

Source	Name	P[activity]	Seismicity	Orig. m_{max}	Modified m_{max}
BEC-24	Bristol Trends	0.25	Updated (2007)	5.7-6.6	Composite
BEC-25	NY-AL lineament	0.30	Updated (2007)	5.4-6.6	Composite
BEC-25A	Altern. geom. for 25	0.45	Updated (2007)	5.4-6.6	Composite
	Total:	1.00			

The Bechtel team's sources will be represented as 3 mutually exclusive sources with updated seismicity parameters (using the catalog extended through 2007) and the composite m_{max} distribution.

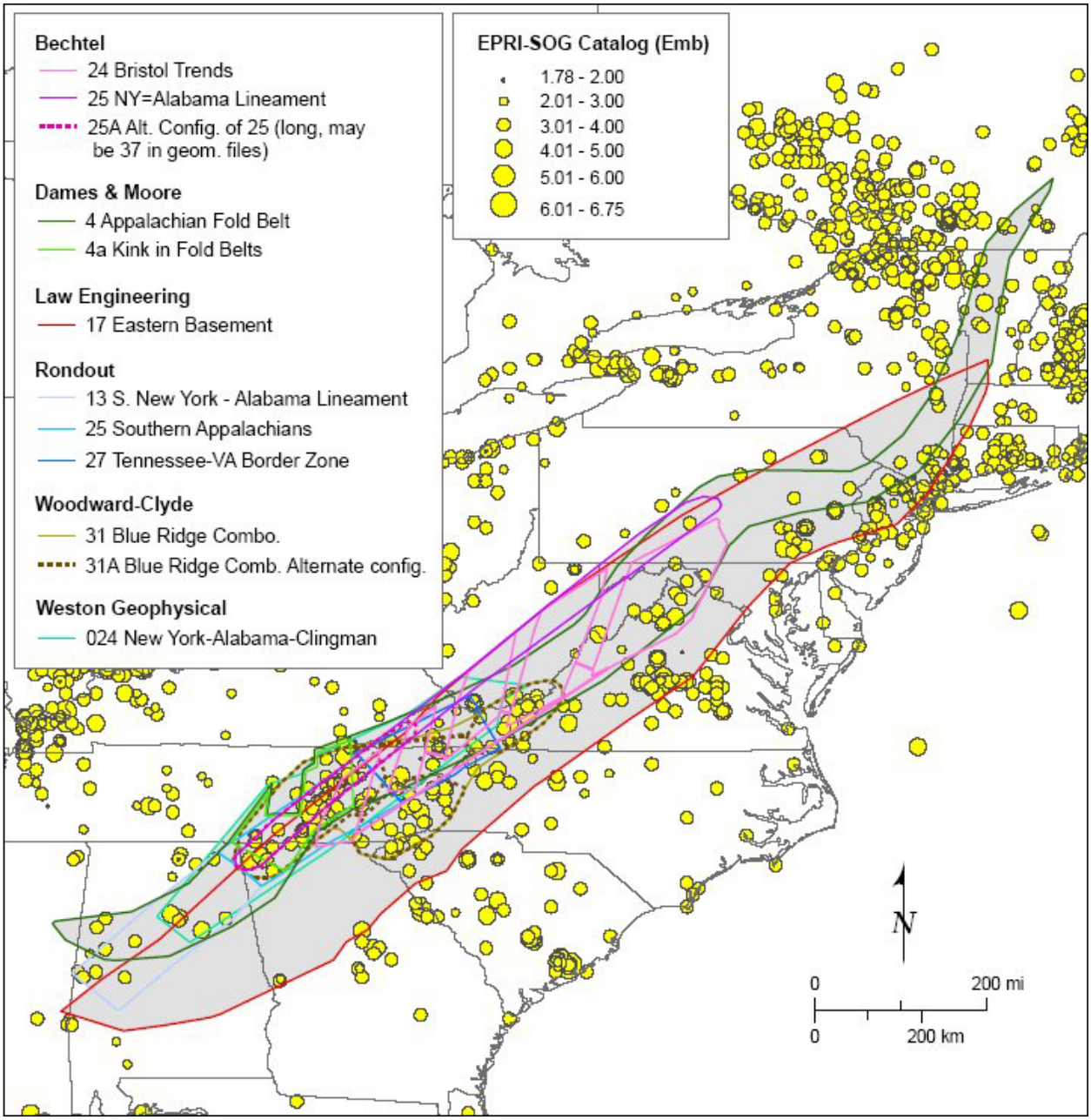

Figure 2: EPRI-SOG sources used to represent ETSZ, plotted with historical earthquakes from the EPRI-SOG catalog (figure courtesy of WLA).

Dames & Moore team. Dames & Moore used 2 sources with mutually exclusive activity to represent seismicity in eastern Tennessee, as follows.

Source	Name	P[activity]	Seismicity	Orig. m_{max}	Modified m_{max}
DAM-04	Appal. fold belts	0.35	Updated (2007)	6.0-7.2	Composite
DAM-4A	Kink in fold belts	0.65	Updated (2007)	6.8-7.2	Composite
	Total:	1.00			

The Dames & Moore team's sources will be represented as 2 mutually exclusive sources with updated seismicity parameters (using the catalog extended through 2007) and the composite m_{max} distribution. Note that for the area covered by source DAM-4A, the combined probability of activity is 1.0, so that for a site in the center of the ETSZ there is not an issue of missing seismicity.

Law Engineering team. The Law team used one source plus a background source to represent seismicity in eastern Tennessee, as follows.

Source	Name	P[activity]	Seismicity	Orig. m_{max}	Modified m_{max}
LAW-17	Eastern basement	0.62	Updated (2007)	5.7-6.8	Composite
LAW-217	Eastern base. BG	1.0 (P_b=0.29)*	Updated (2007)	4.9-5.7**	(not modified)

*--modified to P_a=0.38 and P_b=1.0 per nearby hazard studies

**--modified to 5.2-5.7 per nearby hazard studies

The LAW-217 source has the same geometry as the LAW-17 source and is identified as a background source with probability of background P_b=0.29. Both the LAW-17 and LAW-217 sources use spatial smoothing of seismicity. The difference between the two sources is in the m_{max} values. As done in hazard studies at a site in the vicinity of the ETSZ, the P_a of LAW-217 will be changed to 0.38 (with P_b=1.0), and the original m_{max} distribution will be modeled as 5.2-5.7. Thus there will be a total P_a=1.0 for the LAW sources.

Rondout team. Rondout used 3 separate sources with non-overlapping geometries to represent seismicity in eastern Tennessee, as follows.

Source	Name	P[activity]	Seismicity	Orig. m_{max}	Modified m_{max}
RND-25	So. Appalachians	0.99*	Updated (2007)	6.6-7.0	Composite
RND-13	So. NY-AL lineament	1.00	Updated (2007)	5.2-6.5	Composite
RND-27	TN-VA border zone	0.99*	Updated (2007)	5.2-6.5	Composite

*--will be changed to 1.00

The RND-25 source is centered on the ETSZ, and the RND-13 and RND-27 sources represent seismicity to the southwest and northeast, respectively. All 3 sources will be used to compute hazard sensitivity with updated seismicity parameters (using the catalog extended through 2007) and the composite m_{max} distribution.

Weston Geophysical team. Weston used one source plus a background source to represent seismicity in eastern Tennessee, as follows.

Source	Name	P[activity]	Seismicity	Orig. m_{max}	Modified m_{max}
WGC-24	NY-AL Clingman	0.90	Updated (2007)	5.4-6.6	Composite
WGC-C17	So. Appalachians BG	0.10	Updated (2007)	5.4-6.6	(not modified)
	Total:	1.00			

Source WGC-24 is the Weston tectonic interpretation that incorporates the ETSZ. Background source C17 represents the remaining probability of 0.1 that earthquakes occur with some other explanation.

Woodward-Clyde team. Woodward-Clyde used 2 sources with mutually exclusive activity to represent seismicity in eastern Tennessee. The total probability of activity of these sources is 0.235. The remaining activity is represented by a Woodward-Clyde background source.

Source	Name	P[activity]	Seismicity	Orig. m_{max}	Modified m_{max}
WCC-31	Blue Ridge Comb.	0.024	Updated (2007)	5.9-7.0	Composite
WCC-31A	Blue Ridge Comb. Alt.	0.211	Updated (2007)	5.9-7.0	Composite
WCC-BG	Local background	0.765	Updated (2007)	5.8-6.6	(not modified)
	Total:	1.00			

The Woodward-Clyde team sources will be represented as 3 mutually exclusive sources with updated seismicity parameters (using the catalog extended through 2007). Two of these are tectonic sources and will be modified with the composite m_{max} distribution. The last source is a background source that will maintain the original m_{max} distribution. The total P[activity] for these sources is 1.0.

Summary. All of the six EPRI-SOG teams have interpretations of seismicity in the ETSZ with a total P[activity] of 1.0. Three of the six teams have alternative tectonic sources representing seismicity, and all of those sources will have m_{max} distributions modified to reflect the composite distribution. The remaining three teams have some sources representing tectonic interpretations, and alternative background sources representing the possibility that there is no specific tectonic basis in eastern Tennessee to explain historical seismicity there or to localize it there. These alternative background sources will not have their m_{max} distributions modified. These background sources have P[activity] of 0.38 (Law), 0.1 (Weston), and 0.765 (Woodward-Clyde), or a total probability (weighted by all team interpretations) of 0.2075.

The proposed seismic hazard sensitivity study using revised seismicity parameters and m_{max} value reflects the combined probability over all EPRI-SOG teams that seismicity in eastern Tennessee can be explained tectonically with about 79% confidence. For these interpretations, the m_{max} distribution will be modified to reflect the composite distribution. When tectonic interpretations do not apply (with about 21% confidence), the original EPRI-SOG m_{max} distributions will be used to represent the distributions of earthquake magnitudes in the eastern Tennessee region.

References

1. LLNL (2002). *Guidance for Performing Probabilistic Seismic Hazard Analysis for a Nuclear Plant Site: Example Application to the Southeastern United States*, USNRC Rept. NUREG/CR-6607, Oct.
2. Geomatrix Consultants (2004). *Dam Safety Seismic Hazard Assessment*, report prepared for Tennessee Valley Authority, 2 vol, September.