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MEMORANDUM

MFG PROJECT: 180734

TO: Dr. A. K. Ibrahim, U.S. Nuclear Regulatory Commission

FROM: Roslyn Stern, Clint Strachan

DATE: April 27, 2005

SUBJECT: **Sequoyah Fuels Corporation Site, Seismicity Issues**

COPY: Craig Harlin, Sequoyah Fuels Corporation

This memorandum has been prepared to address outstanding issues regarding the evaluation of the seismicity associated with the Sequoyah Fuels Corporation site. The method used to evaluate the hazard associated with randomly occurring earthquakes has been at issue. Guidance within 10 CFR Part 100, Appendix A section V.1 (ii) is vague and implies that the maximum earthquake associated with a tectonic province should be applied at the site. Two difficulties associated with this method are 1) the attenuation relationships for estimating peak horizontal accelerations require a finite distance from the epicenter of the event to the site, and 2) from a probabilistic standpoint applying the maximum earthquake associated with a tectonic province of hundreds of thousands of square kilometers to a single point at the site is questionable. During a phone conversation on March 7, 2005 we agreed that the Bureau of Reclamation procedure for analyzing the probabilistic seismic hazard for zones of random seismicity (as described by LaForge, 2001) represents the current state of practice to evaluate the random earthquakes generated within the Ozark Uplift.

In April 2005, Mr. LaForge conducted a site-specific evaluation of the seismic hazard using the multiple random sources (mrs) programs. A copy of his report is included as an attachment to this memorandum. As described in MFG (2004) and LaForge (1997, 2001, 2005) the program generates seismic events uniformly distributed within the province at a rate determined from historical seismicity. The events are attenuated to the site using both Atkinson and Boore (1995) and Toro et al. (1997) relationships.

The results show the mean acceleration at a return period of 10,000 years to be 0.16 g. This report further supports that the current design peak horizontal acceleration of 0.27 g is conservative. However, since the current design of the disposal cell, which includes 5H:1V side slopes and a textured synthetic liner in the cover system, can adequately withstand a peak horizontal acceleration of 0.27 g, MFG recommends that the design peak horizontal acceleration remain at its current value.

If you have any further questions or comments, please contact me.

Thank you.

Roslyn Stern

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Attachment

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Probabilistic Hazard Curves for

Peak Horizontal Acceleration

Sequoyah Fuels Nuclear Site

Oklahoma

submitted to MFG, Inc.

Roland C. LaForge,

Seismic Hazard Consulting

April, 2005

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1.0 Introduction

This report presents a mean hazard curve for peak horizontal acceleration, with associated fractile curves, for the Sequoyah Nuclear Repository site. Based on extensive geologic investigations, it has been found that no active faults exist within 100 km of the site. The nearest active fault appears to be the Meers fault, about 300 km to the southwest (e.g., Crone and Luza, 1990; Swan et al., 1993)(Figure 1). The remaining seismic hazard comes from randomly occurring, or "background" earthquakes. The hazard curves presented here assume this hazard consists of uniformly distributed earthquakes occurring at a rate determined from historic seismicity. Two types of fractile curves are presented; one set showing variations in the *mean* hazard due to epistemic uncertaintes, and the other in addition to these including aleatory uncertainties in the expected ground motion as a function of magnitude and distance.

2.0 Historic Seismicity and Catalog Preparation

Because the Oklahoma Geological Survey has operated a microseismic network in the state since the 1970's, it is reasonable to examine state of Oklahoma (excluding the panhandle) as an areal source zone. Although seismograph stations have not been densely deployed, favorable wave propagation characteristics and many quiet sites have allowed for an estimated detection threshold of greater than or equal to magnitude 2.0 since 1977 (J. Lawson, personal comm., 1997).

The methodology presented here extends and modifies to some extent that contained in LaForge (1997). That study presented hazard curves for seven Bureau of Reclamation dam sites within the state. Based on geologic and seismological considerations, the state of Oklahoma was divided into three zones. Figure 1 shows the configuration of the zones, along with earthquakes of magnitude 3 and larger that were used in the recurrence calculations. The zonation was based on the density of small-magnitude seismicity, and the apparent correlation of dense seismicity with the Nemaha Uplift associated with Zone 2.

The Sequoyah site lies within Zone 3 (Figure 1). In LaForge (1997) the calculation of robust recurrence statistics in Zone 3 was problematical, as there were, after filtering for the estimated completeness periods, 114 earthquakes in the magnitude 2 range, and only 7 of magnitude 3 and above. It has been suggested that the overabundance of magnitude 2 events in the state is related to oil and gas extraction activities (Luza, 1985). During a recent reexamination of the seismic hazard to McGee Creek Dam (approximately 100 km to the south of the Sequoyah site), it was decided to raise the minimum magnitude considered to 3.0, in order to eliminate the possibility of induced earthquakes and the clear bias introduced by the large number of these events, and to use a regional recurrence rate for the entire state. Thus the "new" zonation consists of the combination of Zones 1, 2, and 3 on Figure 1.

For the current study the catalog developed in LaForge (1997) was updated through March, 2005. The primary sources of seismicity were the catalog of the Oklahoma Geological Survey Observatory, and the Decade of North American Geology (Engdahl and Rinehart, 1991). Table 1 shows the completeness periods used, and the numbers of events in each magnitude range. These events are plotted in Figure 1. The assumption of spatial randomness does not appear to be grossly violated in this Figure.

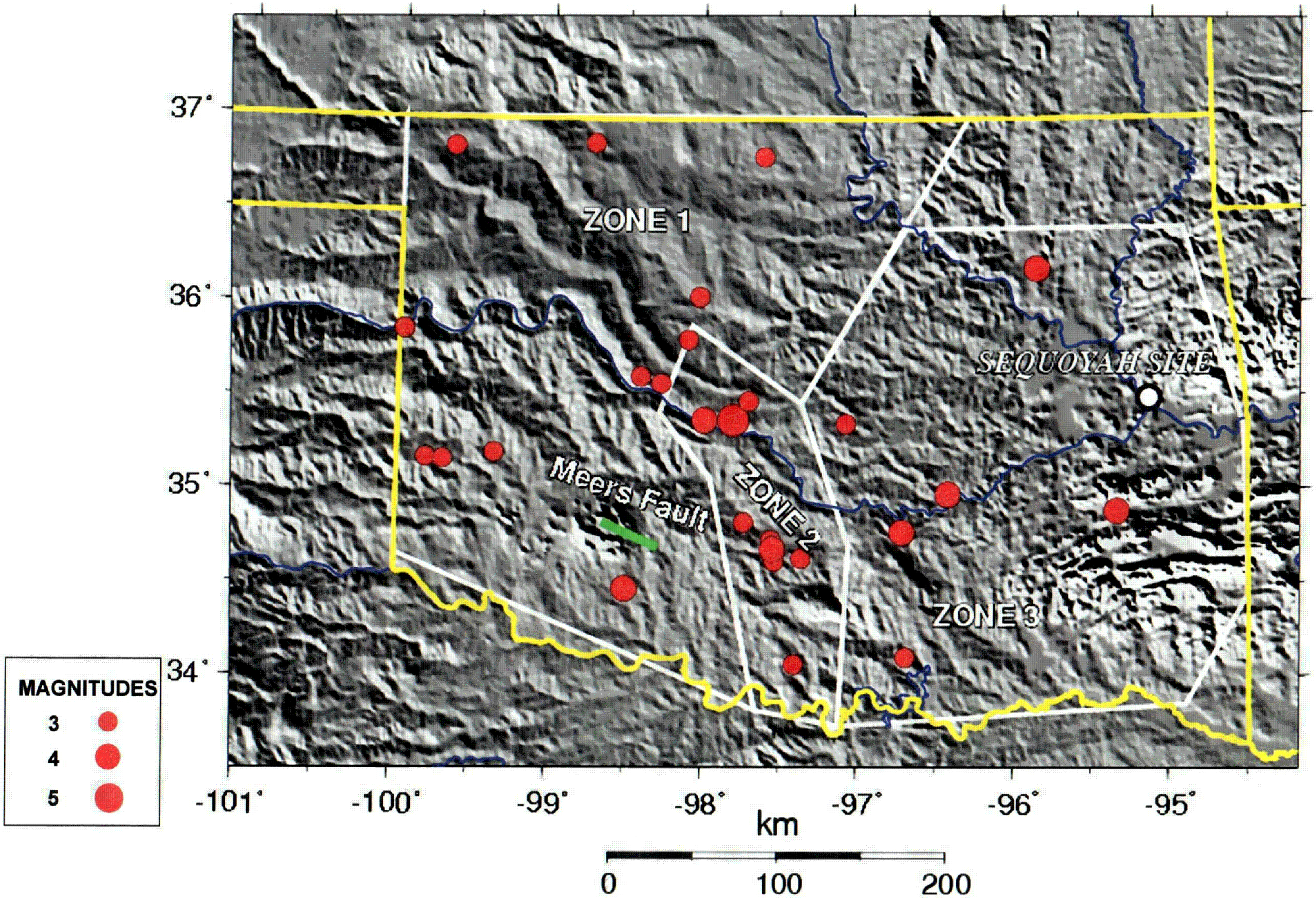

Figure 1. *Map of central Oklahoma, with LaForge (1997) zonation. Meers fault shown as green line.*

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Table 1. Completeness Periods and Event Counts Used in Recurrence Calculations

Magnitude Range	Completeness Period	Number of Earthquakes
3.0 - 4.0	1/1973 - 4/2005	23
4.0 - 5.0	1/1930 - 4/2005	8
5.0 - 6.0	1/1850 - 4/2005	2
6.0 - 7.0	1/1850 - 4/2005	0

Table 2. Recurrence Parameters, Central Oklahoma

Parameter	
a (σ)	-2.623 (.468)
b (σ)	0.878 (.120)

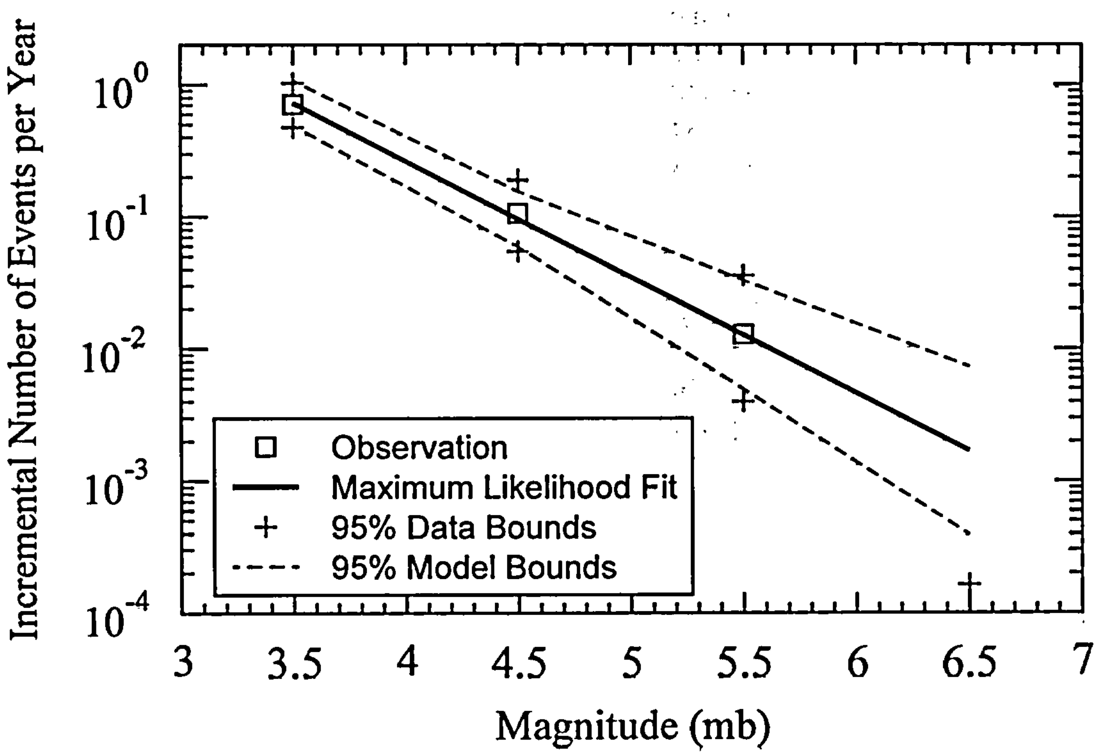

Figure 2. Incremental recurrence curve for Central Oklahoma.

An incremental recurrence curve was fit to the data, using the maximum likelihood method as outlined in Weichert (1980). Rate uncertainties were computed as described in Bollinger et al. (1989). Parameter values in the Gutenberg-Richter relation, Log(N) = a - b (M) (where a is the number of events greater than or equal to magnitude M), and their uncertainties are shown in Table 2. The incremental curve is shown in Figure 2. The a values have been normalized to km^2/yr. The areal zone encompasses 151,495 km.

3.0 Probabilistic Seismic Hazard Analysis

The probabilistic seismic hazard analysis (PSHA) conducted follows the basic precepts outlined in Cornell (1968). The calculations were performed with the *mrs* (*multiple random sources*) programs, developed by the U.S. Bureau of Reclamation (LaForge, 2001). Two attenuation functions were used; Toro et al. (1997), and Boore and Atkinson (1995). Both were developed for eastern North America crustal conditions. A third relation developed by Frankel (1996) gives results very similar to Toro et al. (1997). Because there appears to be no basis for choosing one relation over the other, the Toro et al. (1997) relation was weighted .67, and the Boore and Atkinson (1995) relation .33. At the site, shear wave velocites in the upper 10 m were measured to be greater than 670 m/s, and greater than 1330 m/s at deeper depths, placing the site conditions at NEHRP B and A, respectively (R. Stern, MFG, Inc., personal comm., 2005). The attenuation functions used are appropriate for these conditions.

The resulting curves are shown in Figures 3 and 4. In Figure 3, the fractile curves indicate the variation in the *mean* hazard for peak horizontal acceleration, due to differences in the mean ground motion values as a function of magnitude and distance from the two attenuation relations, and the uncertainty in seismicity rates as indicated by the dashed lines in Figure 2. In Figure 4 the fractiles also incorporate the log-normal variation in the ground motion as specified in each attenuation function. These fractiles thus reflect the uncertainty in the *estimated* hazard, as described in LaForge (2001).The mean curves are identical in each figure.

4.0 Conclusions

A probabilistic seismic hazard analysis for peak horizontal acceleration was performed for the Sequoyah site, based on modified and updated methodologies described in LaForge (1997), and using software developed at the U.S. Bureau of Reclamation (LaForge, 2001). The results show the mean acceleration at return periods of 5,000, 10,000, and 50,000 years to be 0.11, 0.16, and 0.35 g, respectively (Table 3).

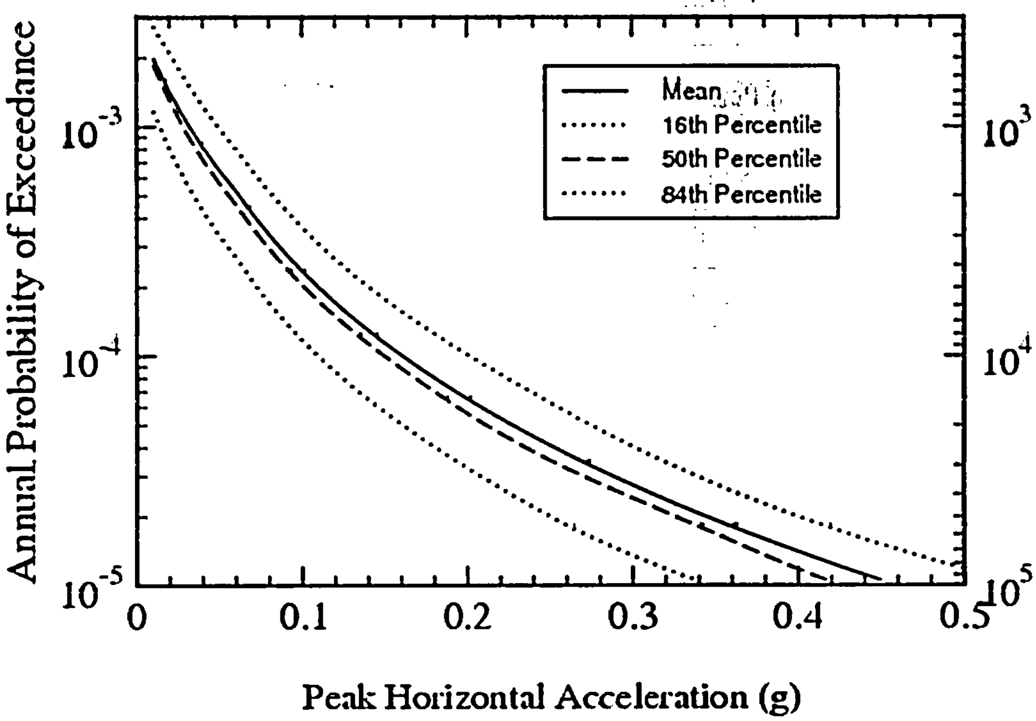

Figure 3. Mean hazard curve for the Sequoyah Site, with fractile curves reflecting the variation in the mean hazard.

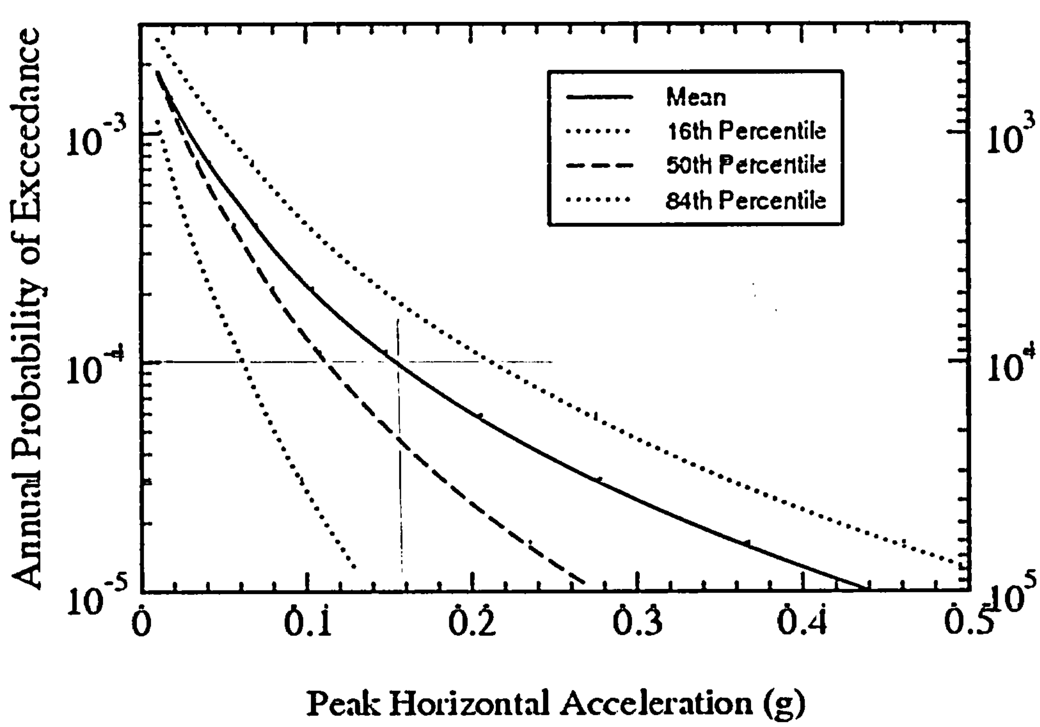

Figure 4. Mean hazard curve for the Sequoyah Site, with fractile curves reflecting the variation in the estimated hazard.

Table 3. Values of Peak Horizontal Acceleration for Various Return Periods

Return Period (years)	Peak Horizontal Acceleration (g)
5,000	0.11
10,000	0.16
50,000	0.35

5.0 References

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