WOLF CREEK
NUCLEAR OPERATING CORPORATION

Russell A. Smith
Site Vice President and Chief Nuclear Operating Officer

March 31, 2014

WO 14-0042

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Reference:

1) Letter dated March 12, 2012, from E. J. Leeds and M. R. Johnson, USNRC, to M. W. Sunseri, WCNOC, "Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident"

2) EPRI Report 1025287, "Seismic Evaluation Guidance, Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic"

3) Letter dated February 15, 2013, from D. L. Skeen, USNRC, to J. E. Pollock, NEI, Endorsement of EPRI Final Draft Report 1025287, "Seismic Evaluation Guidance"

4) Letter dated April 9, 2013, from A. R. Pietrangelo, NEI, to D. L. Skeen, USNRC, "Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations"

5) Letter dated May 7, 2013, from E.J. Leeds, USNRC, to J. E. Pollock, NEI, "Electric Power Research Institute Final Draft Report XXXXXX, "Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic," as an Acceptable Alternative to the March 12, 2012, Information Request for Seismic Reevaluations"

Subject: Docket No. 50-482: Wolf Creek Nuclear Operating Corporation's Seismic Hazard and Screening Report (CEUS Sites), Response NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident

Gentlemen:

On March 12, 2012, the Nuclear Regulatory Commission (NRC) issued Reference 1 to Wolf Creek Nuclear Operating Corporation (WCNOC). Enclosure 1 of Reference 1 requested WCNOC to submit a Seismic Hazard Evaluation and Screening Report within 1.5 years from the date of Reference 1.

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In Reference 4, the Nuclear Energy Institute (NEI) requested NRC agreement to delay submittal of the final Central and Eastern United States (CEUS) Seismic Hazard Evaluation and Screening Reports so that an update to the Electric Power Research Institute (EPRI) ground motion attenuation model could be completed and used to develop that information. NEI proposed that descriptions of subsurface materials and properties and base case velocity profiles be submitted to the NRC by September 12, 2013, with the remaining seismic hazard and screening information submitted by March 31, 2014. NRC agreed with that proposed path forward in Reference 5.

Reference 2 contains industry guidance and detailed information to be included in the Seismic Hazard Evaluation and Screening Report submittals. NRC endorsed this industry guidance in Reference 3.

The enclosed Seismic Hazard Evaluation and Screening Report for WCNOC provides the information described in Section 4 of Reference 2 in accordance with the schedule identified in Reference 4.

This letter contains no commitments. If you have any questions concerning this matter, please contact me at (620) 364-4156, or Mr. Michael J. Westman at (620) 364-4009.

Sincerely,

Russell A. Smith

RAS/rlt

Enclosure

cc: M. L. Dapas (NRC), w/e
C. F. Lyon (NRC), w/e
N. F. O'Keefe (NRC), w/e
Senior Resident Inspector (NRC), w/e

STATE OF KANSAS)
) SS
COUNTY OF COFFEY)

Russell A. Smith, of lawful age, being first duly sworn upon oath says that he is Site Vice President and Chief Nuclear Operating Officer of Wolf Creek Nuclear Operating Corporation; that he has read the foregoing document and knows the contents thereof; that he has executed the same for and on behalf of said Corporation with full power and authority to do so; and that the facts therein stated are true and correct to the best of his knowledge, information and belief.

By____________________
Russell A. Smith
Site Vice President and Chief Nuclear Operating Officer

SUBSCRIBED and sworn to before me this 31st day of March, 2014.

STATE OF NOTARY PUBLIC KANSAS
RHONDA L. TIEMEYER
My Appointment Expires
January 11, 2018

Rhonda L. Tiemeyer
Notary Public

Expiration Date January 11, 2018

Enclosure to WO 14-0042

Seismic Hazard and Screening Report for Wolf Creek
(32 pages)

Seismic Hazard and Screening Report for Wolf Creek

Contents

1. Introduction

Following the accident at the Fukushima Daiichi nuclear power plant resulting from the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami, the Nuclear Regulatory Commission (NRC) established a Near-Term Task Force (NTTF) to conduct a systematic review of NRC processes and regulations and to determine if the agency should make additional improvements to its regulatory system. The NTTF developed a set of recommendations intended to clarify and strengthen the regulatory framework for protection against natural phenomena. Subsequently, the NRC issued a 50.54(f) (USNRC, 2012) letter that requests information to assure that these recommendations are addressed by all United States (U.S.) nuclear power plants. The 50.54(f) letter requests that licensees and holders of construction permits under 10 CFR Part 50 to reevaluate the seismic hazards at their sites against present-day NRC requirements. Depending on the comparison between the reevaluated seismic hazard and the current design basis, the result is either no further risk evaluation or the performance of a seismic risk assessment. Risk assessment approaches acceptable to the staff include a seismic probabilistic risk assessment (SPRA), or a seismic margin assessment (SMA). Based upon this information, the NRC staff will determine whether additional regulatory actions are necessary.

This report provides the information requested in items (1) through (7) of the "Requested Information" section and Attachment 1 of the 50.54(f) letter pertaining to NTTF Recommendation 2.1 for the Wolf Creek Generating Station (WCGS), located in Coffey County, Kansas. In providing this information, Wolf Creek Nuclear Operating Corporation (WCNOC) followed the guidance provided in the *Seismic Evaluation Guidance: Screening, Prioritization, and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic* (EPRI, 2013a). The Augmented Approach, Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic (EPRI, 2013c), has been developed as the process for evaluating critical plant equipment as an interim action to demonstrate additional plant safety margin, prior to performing the complete plant seismic risk evaluations.

The original geologic and seismic siting investigations for WCGS were performed in accordance with Appendix A to 10 CFR Part 100 and meet General Design Criterion 2 in Appendix A to 10 CFR Part 50. The Safe Shutdown Earthquake (SSE) Ground Motion was developed in accordance with Appendix A to 10 CFR Part 100 and used for the design of seismic Category I systems, structures and components (SSC).

In response to the 50.54(f) letter and following the guidance provided in the SPID (EPRI, 2013a), a seismic hazard reevaluation for WCGS was performed. For screening purposes, a Ground Motion Response Spectrum (GMRS) was developed.

Based on the results of the screening evaluation, WCGS screens in for a seismic risk assessment, a Spent Fuel Pool evaluation, and a High Frequency Confirmation. WCNOC has elected to perform a SPRA, which is currently in progress.

2. Seismic Hazard Reevaluation

WCGS is located approximately 3.5 miles northeast of Burlington, Kansas. The WCGS site is located in an area with surface bedrock consisting of alternating layers of Pennsylvanian age shales, limestones, sandstones, and a few thin coal seams. Residual soils ranging in thickness from 0 to 16 feet have been developed on the Pennsylvanian strata. Major Category I structures are supported on competent rock.

Refer to Section 2.5.2 of the Updated Safety Analysis Report (USAR) (WCNOC, 2013a). The site is located in a seismically stable region of the central United States. No earthquake epicenter has been reported closer than 40 miles to the site, and the nearest shocks have had intensities no greater than Modified Mercalli Intensity (MMI) III. However, there have been earthquakes of MMI VII at distances of about 90 miles from the site.

The SSE was conservatively defined as an MMI VI earthquake corresponding to a maximum horizontal ground motion of about 0.02g to 0.08g. Non-powerblock safety-related structures, systems, and components (SSC) are conservatively designed for safe shutdown at a horizontal acceleration of 0.12g. However, a seismic evaluation of these SSC using the Lawrence Livermore Laboratories (LLL) spectrum is contained in Appendix 3C (WCNOC, 2013a). This spectrum is enveloped by a Regulatory Guide 1.60 spectrum anchored at 0.15g. Powerblock safety-related SSC are designed for a safe shutdown at a horizontal acceleration of 0.20g based on the envelope of the Standardized Nuclear Unit Power Plant Systems (SNUPPS) sites. A peak ground acceleration of 0.15g and 0.20g in both horizontal and vertical directions thus constitutes the design basis SSE for WCGS non-powerblock SSC and powerblock SSC, respectively.

2.1 Regional and Local Geology

Refer to USAR Section 2.5. The final geological and seismological design of the WCGS powerblock SSC is based on three sites (Callaway, Wolf Creek, and Sterling) per the SNUPPS plant design. The WCGS site is located in an area with surface bedrock consisting of alternating layers of Pennsylvanian age shales, limestones, sandstones, and a few thin coal seams. Residual soils ranging in thickness from 0 to 16 feet have been developed on the Pennsylvanian strata. Quaternary alluvium, which reaches a thickness of approximately 25 feet, is present in the tributary valleys, and scattered Tertiary age deposits of clayey gravel cap some of the higher hills in the site area.

The results of comprehensive geotechnical investigations at the site demonstrate that competent foundation materials are present for establishing conservative design and construction criteria for support of the Category I facilities. Major Category I structures are supported on competent rock. Only minor, localized modification of foundation materials is required to provide uniform support of structures. There are no geologic features at or near the site which would preclude its use for the construction and operation of the nuclear power station.

The detailed geologic and engineering analysis of the site area has shown that there are no hazards due to geologic processes such as subsidence, liquefaction, erosion, landslides, collapse due to cavernous or karst terrain, or to man's activities.

2.2 Probabilistic Seismic Hazard Analysis

2.2.1 Probabilistic Seismic Hazard Analysis Results

In accordance with the 50.54(f) letter and following the guidance in the SPID (EPRI, 2013a), a probabilistic seismic hazard analysis (PSHA) was completed using the recently developed Central and Eastern United States Seismic Source Characterization (CEUS-SSC) for Nuclear Facilities (CEUS-SSC, 2012) together with the updated EPRI Ground-Motion Model (GMM) for the CEUS (EPRI, 2013b). For the PSHA, a lower-bound moment magnitude of 5.0 was used, as specified in the 50.54(f) letter.

For the PSHA, the CEUS-SSC background seismic sources out to a distance of 400 miles (640 km) around Wolf Creek were included. This distance exceeds the 200 mile (320 km) recommendation contained in USNRC (2007) and was chosen for completeness. Background sources included in this site analysis are the following:

1. Extended Continental Crust—Gulf Coast (ECC_GC)
2. Illinois Basin Extended Basement (IBEB)
3. Mesozoic and younger extended prior – narrow (MESE-N)
4. Mesozoic and younger extended prior – wide (MESE-W)
5. Midcontinent-Craton alternative A (MIDC_A)
6. Midcontinent-Craton alternative B (MIDC_B)
7. Midcontinent-Craton alternative C (MIDC_C)
8. Midcontinent-Craton alternative D (MIDC_D)
9. Non-Mesozoic and younger extended prior – narrow (NMESE-N)
10. Non-Mesozoic and younger extended prior – wide (NMESE-W)
11. Oklahoma Aulacogen (OKA)
12. Reelfoot Rift (RR)
13. Reelfoot Rift including the Rough Creek Graben (RR-RCG)
14. Study region (STUDY_R)

For sources of large magnitude earthquakes, designated Repeated Large Magnitude Earthquake (RLME) sources in CEUS-SSC (2012), the following sources lie within 1,000 km of the site and were included in the analysis:

1. Cheraw
2. Commerce
3. Eastern Rift Margin Fault northern segment (ERM-N)
4. Eastern Rift Margin Fault southern segment (ERM-S)
5. Marianna
6. Meers
7. New Madrid Fault System (NMFS)
8. Wabash Valley

For each of the above background and RLME sources, the mid-continent version of the updated CEUS EPRI GMM was used.

2.2.2 Base Rock Seismic Hazard Curves

Consistent with the SPID (EPRI, 2013a), base rock seismic hazard curves are not provided as the site amplification approach referred to as Method 3 has been used. Seismic hazard curves are shown below in Section 3 at the SSE control point elevation.

2.3 Site Response Evaluation

Following the guidance contained in Seismic Enclosure 1 of the March 12, 2012 50.54(f) Request for Information (USNRC, 2012) and in the SPID (EPRI, 2013a) for nuclear power plant sites that are not founded on hard rock (defined as 2.83 km/sec), a site response analysis was performed for WCGS.

2.3.1 Description of Subsurface Material

WCGS is located in Coffey County, Kansas approximately 3.5 miles (5.6 km) northeast of Burlington, Kansas. The site is located in the Central Stable Region. The basic information used to create the site geologic profile at the WCGS was supplied by WCNOC (2013b). The site consists of about 10 ft (3m) of soils overlying about 2,700 ft (823m) of firm sedimentary rock of Pennsylvanian age. The Upper Pennsylvanian Swanee Group is comprised of limestone, shale and some interbedded sandstone. The SSE Control Point was defined to be at the surface at the top of the finished grade at an elevation of 1099.5 ft (335m) (WCNOC, 2013b).

The following description of the Paleozoic sequence is taken directly from WCNOC (2013b):

"The site is located within the Central Stable Region of the North American Continent. The surface bedrock in the site area consists of alternating layers of Pennsylvanian age shales, limestones, sandstones, and a few thin coal seams. These bedrock units dip gently to the west and northwest and have been folded locally into small-scale plunging anticlines and synclines. At the site, the Precambrian surface is at a depth of approximately 2,750 feet. The undifferentiated, clastic/"granite wash" sequence may exceed 1,000 feet in thickness, and appears to rest on a granitic basement complex."

2.3.2 *Development of Base Case Profiles and Nonlinear Material Properties*

Table 2.3.2-1. Summary of Geotechnical Profile Data for WCGS (WCNOC, 2013a)

Depth (feet)	Geologic Unit(s)	Material Description	Compressional Wave Velocity (ft/sec)	Poisson's Ratio	Shear Wave Velocity (ft/sec)	Measured Unit Weight (pcf)	Average Bulk Density (pcf)
0-10	Residual soil and weathered bedrock	Silty clay and weathered shale	2,300	0.463-0.475	500 600	99 113	-
10-36	Heumader Member	Somewhat clayey calcareous shale	6,000	0.467-0.471	1,400-1,500	139	152[b]
36-48	Plattsmouth Member	Dense, fine-grained limestone with shale layers	14,000	0.378	6,200	160 165	166[b]
48-64	Heebner, Leavenworth and Snyderville Members	Interbedded carbonaceous shale, limestone, and clayey calcareous shale	7,000	0.333	3,500[b,d]	-	154[b]
64-82	Toronto Member	Fossiliferous limestone with occasional thin shale layers	11,700	0.305	6,200	147 153	165[b]
82-255	Unnamed Lawrence, Amazonia, Ireland and Robbins Members	Interbedded shale, siltstone and sandstone; a thin coal bed and limestone layer occur in the upper 25 feet; pure shale is present in the basal 60 feet	7,800	0.322	4,000	150-154	160[b]
259-262	Haskell Member	Dense, fine-grained limestone	15,000[b]	0.301[b]	8,000[b,c]	-	166[b]
262-393	Vinland, Tonganoxie and Weston Members	Interbedded siltstone, shale and sandstone; pure shale is present in the basal 30 feet	8,500[b]	0.333[b]	4,250[b,d]	148-154	159[b]
393-402	South Bend and Rock Lake Members	Dense limestone with shale and siltstone	16,500[b]	0.346[b]	8,000[b,c]	-	166[b]

[a]Depths and descriptions based on Boring B-4.

[b]Indicates values obtained from Birdwell Elastic Property Logs, borings B-4, B-5 and B-11.

[c]Shear wave velocity measured by Birdwell.

[d]Shear wave velocity empirically computed by Birdwell.

Table 2.3.2-1 (WCNOC, 2013a) shows the recommended shear-wave velocities and unit weights along with elevations and corresponding stratigraphy. WCNOC (2013b) states that the SSE control point is at the surface on soil. Precambrian basement was estimated to be at a depth of about 2,700 ft (823m). Velocity values listed in Table 2.3.2-1 were obtained from Birdwell Elastic Property logs in three borings and extend to a depth of 402 ft (122.5m) (WCNOC, 2013a).

Velocity measurement extends to a depth below the SSE control point of about 400 ft (122m). The mean base-case profile (P1) was based on the specified shear-wave velocities in Table 2.3.2-1 with the deepest velocity of 8,000 ft/s (2,438m/s) extended to Precambrian basement an assumed shear-wave velocity gradient. Provided the materials to basement depth reflect similar sedimentary rocks and age, the shear-wave velocity gradient for sedimentary rock of 0.5 ft/s/ft (EPRI, 2013a) was assumed to be appropriate for the site. The shear-wave velocity of 8,000 ft/s (2,438m/s) was taken at a depth of 393 ft (120m) of the profile with the velocity gradient applied at that point, resulting in a base-case shear-wave velocity of about 9,075 ft/s (2,766m/s) at a depth of 2,700 ft (823m). The mean or best estimate base-case profile is shown as profile P1 in Figure 2.3.2-1.

Based on the uncertainty in shear-wave velocities due to the age and type of measurement (Table 2.3.2-1), a scale factor of 1.57 was adopted to reflect upper and lower range base-cases. The scale factor of 1.57 reflects a $\sigma_{\mu ln}$ of about 0.35 based on the SPID (EPRI, 2013a) 10th and 90th fractiles which implies a 1.28 scale factor on σ_{μ}. Lower (P2) - and upper (P3) - range profiles were developed with scale factors of 1.57. Depth to Precambrian basement was taken at 2,700 ft (823m) randomized ± 810 ft (247m). Profile P3, the stiffest profile, encountered continuous hard rock shear-wave velocities (9,285 ft/s, 2,890m/s) at a depth below the SSE control point of about 393 ft (120m). The three shear-wave velocity profiles are shown in Figure 2.3.2-1 and listed in Table 2.3.2-2.

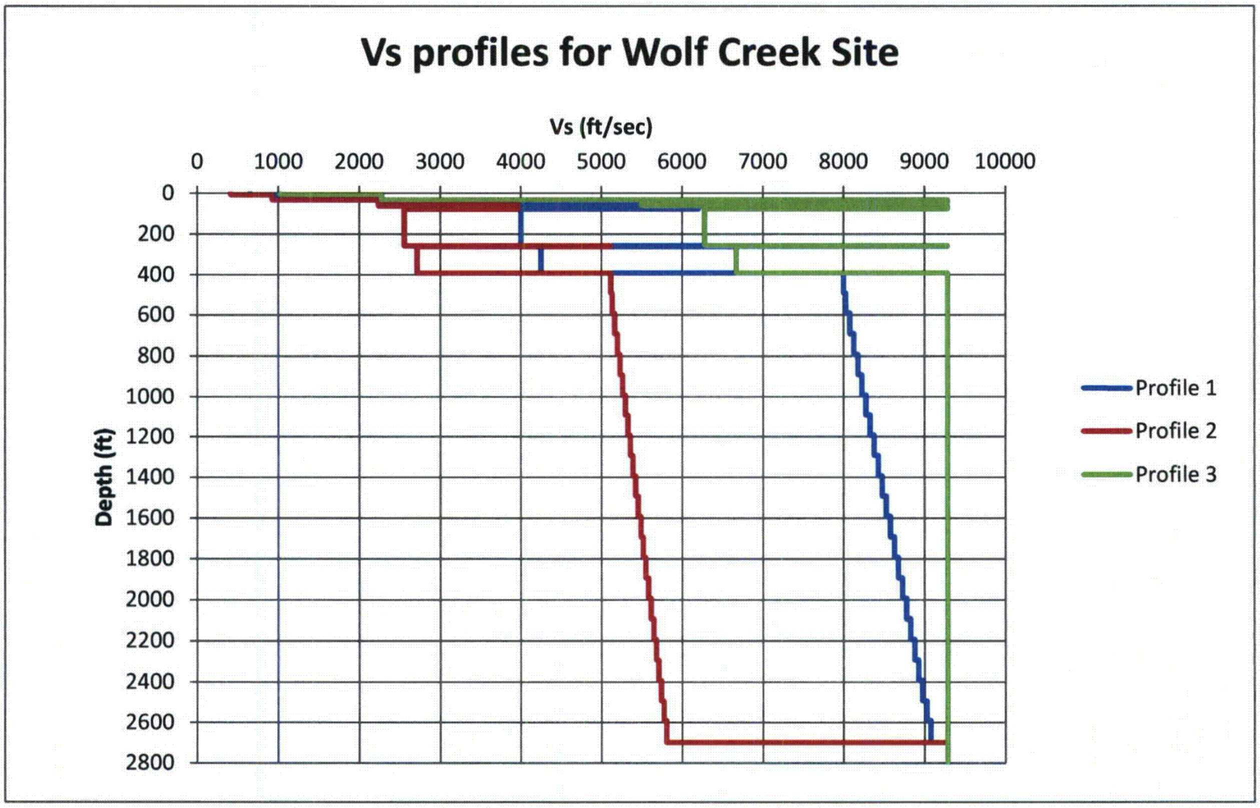

Figure 2.3.2-1. Shear-wave velocity profiles for WCGS site

Table 2.3.2-2. Layer thicknesses, depths, and shear-wave velocities (Vs) for 3 profiles, Wolf Creek site

Profile 1			Profile 2			Profile 3		
Thick-ness(ft)	depth (ft)	Vs(ft/s)	Thick-ness(ft)	depth (ft)	Vs(ft/s)	Thick-ness(ft)	depth (ft)	Vs(ft/s)
	0	550		0	350		0	863
5.0	5.0	550	5.0	5.0	350	5.0	5.0	863
5.0	10.0	550	5.0	10.0	350	5.0	10.0	863
5.0	15.0	1450	5.0	15.0	928	5.0	15.0	2277
5.0	20.0	1450	5.0	20.0	928	5.0	20.0	2277
5.0	25.0	1450	5.0	25.0	928	5.0	25.0	2277
5.0	30.0	1450	5.0	30.0	928	5.0	30.0	2277
6.0	36.0	1450	6.0	36.0	928	6.0	36.0	2277
6.0	42.0	6200	6.0	42.0	3968	6.0	42.0	9285
6.0	48.0	6200	6.0	48.0	3968	6.0	48.0	9285
6.0	54.0	3500	6.0	54.0	2240	6.0	54.0	5495
6.0	60.0	3500	6.0	60.0	2240	6.0	60.0	5495
4.0	64.0	3500	4.0	64.0	2240	4.0	64.0	5495
6.0	70.0	6200	6.0	70.0	3968	6.0	70.0	9285
6.0	76.0	6200	6.0	76.0	3968	6.0	76.0	9285
6.0	82.0	6200	6.0	82.0	3968	6.0	82.0	9285
3.0	85.0	4000	3.0	85.0	2560	3.0	85.0	6280
18.0	103.0	4000	18.0	103.0	2560	18.0	103.0	6280
18.0	121.0	4000	18.0	121.0	2560	18.0	121.0	6280
18.0	139.0	4000	18.0	139.0	2560	18.0	139.0	6280
18.0	157.0	4000	18.0	157.0	2560	18.0	157.0	6280
18.0	175.0	4000	18.0	175.0	2560	18.0	175.0	6280
18.0	193.0	4000	18.0	193.0	2560	18.0	193.0	6280
18.0	211.0	4000	18.0	211.0	2560	18.0	211.0	6280
18.0	229.0	4000	18.0	229.0	2560	18.0	229.0	6280
18.0	247.0	4000	18.0	247.0	2560	18.0	247.0	6280
12.0	259.0	4000	12.0	259.0	2560	12.0	259.0	6280
1.0	260.0	8000	1.0	260.0	5120	1.0	260.0	9285
2.0	262.0	8000	2.0	262.0	5120	2.0	262.0	9285
5.0	267.0	4250	5.0	267.0	2720	5.0	267.0	6672
18.0	285.0	4250	18.0	285.0	2720	18.0	285.0	6672
18.0	303.0	4250	18.0	303.0	2720	18.0	303.0	6672
18.0	321.0	4250	18.0	321.0	2720	18.0	321.0	6672
18.0	339.0	4250	18.0	339.0	2720	18.0	339.0	6672
18.0	357.0	4250	18.0	357.0	2720	18.0	357.0	6672

Profile 1			Profile 2			Profile 3		
Thick-ness(ft)	depth (ft)	Vs(ft/s)	Thick-ness(ft)	depth (ft)	Vs(ft/s)	Thick-ness(ft)	depth (ft)	Vs(ft/s)
18.0	375.0	4250	18.0	375.0	2720	18.0	375.0	6672
18.0	393.0	4250	18.0	393.0	2720	18.0	393.0	6672
100.0	493.0	8000	100.0	493.0	5120	100.0	493.0	9285
100.1	593.0	8025	100.1	593.0	5136	100.1	593.0	9285
100.1	693.1	8075	100.1	693.1	5168	100.1	693.1	9285
100.1	793.2	8125	100.1	793.2	5200	100.1	793.2	9285
100.1	893.2	8175	100.1	893.2	5232	100.1	893.2	9285
100.1	993.3	8225	100.1	993.3	5264	100.1	993.3	9285
100.1	1093.4	8275	100.1	1093.4	5296	100.1	1093.4	9285
100.1	1193.4	8325	100.1	1193.4	5328	100.1	1193.4	9285
100.1	1293.5	8375	100.1	1293.5	5360	100.1	1293.5	9285
100.1	1393.6	8425	100.1	1393.6	5392	100.1	1393.6	9285
100.1	1493.6	8475	100.1	1493.6	5424	100.1	1493.6	9285
100.1	1593.7	8525	100.1	1593.7	5456	100.1	1593.7	9285
100.1	1693.8	8575	100.1	1693.8	5488	100.1	1693.8	9285
100.1	1793.8	8625	100.1	1793.8	5520	100.1	1793.8	9285
100.1	1893.9	8675	100.1	1893.9	5552	100.1	1893.9	9285
100.1	1994.0	8725	100.1	1994.0	5584	100.1	1994.0	9285
100.1	2094.0	8775	100.1	2094.0	5616	100.1	2094.0	9285
100.1	2194.1	8825	100.1	2194.1	5648	100.1	2194.1	9285
100.1	2294.2	8875	100.1	2294.2	5680	100.1	2294.2	9285
100.1	2394.2	8925	100.1	2394.2	5712	100.1	2394.2	9285
100.1	2494.3	8975	100.1	2494.3	5744	100.1	2494.3	9285
100.1	2594.4	9025	100.1	2594.4	5776	100.1	2594.4	9285
105.5	2699.8	9075	105.5	2699.8	5808	105.5	2699.8	9285
3280.8	5980.6	9285	3280.8	5980.6	9285	3280.8	5980.6	9285

2.3.2.1 Shear Modulus and Damping Curves

Results of recent laboratory testing for nonlinear dynamic material properties were not available for the soils or firm rock materials for the WCGS. To reflect epistemic uncertainty in nonlinear dynamic material properties, the firm rock material at the site was assumed to have behavior that could be modeled as either linear or non-linear and a realistic range in soil nonlinearity was accommodated with two sets of modulus reduction and hysteretic damping curves. Consistent with the SPID (EPRI, 2013a), the EPRI soil and rock curves (model M1) were considered to be appropriate to represent the upper range nonlinearity likely in the materials at the site and Peninsular Range (PR) curves for soils combined with linear analyses (model M2) for rock was assumed to represent an equally plausible less nonlinear alternative response across loading level. For the linear firm rock analyses, the low strain damping from the EPRI soil and rock curves were used as the constant damping values in the upper 500 ft (152m) of the profile.

2.3.2.2 Kappa

For the WCGS profile of about 2,700 ft (823m) of soils and firm rock over hard reference rock, the estimates of kappa were based on the low-strain damping in the hysteretic damping curves over the top 500 ft plus the assumption of a constant hysteretic damping of 1.25 (Q_S of 40) for the remaining firm rock profile in addition to a kappa value of 0.006s for hard rock (EPRI, 2013a). For base-case profiles P1, P2, and P3 the kappa contributions from the profiles was 0.014s, 0.023s, and 0.005s respectively. The total kappa values, after adding the hard reference rock value of 0.006s, were 0.020s, 0.029s, and 0.011s respectively (Table 2.3.2-3). The range in kappa about the best estimate base-case value of 0.020s (profile P1) is roughly a factor of 1.5 and this was considered to adequately reflect epistemic uncertainty in low strain damping (kappa) for the profile.

Table 2.3.2-3. Kappa Values and Weights Used for Site Response Analyses

Velocity Profile	Kappa(s)
P1	0.020
P2	0.029
P3	0.011
	Weights
P1	0.4
P2	0.3
P3	0.3
G/G_{max} and Hysteretic Damping Curves	
M1	0.5
M2	0.5

2.3.3 Randomization of Base Case Profiles

To account for the aleatory variability in dynamic material properties that is expected to occur across a site at the scale of a typical nuclear facility, variability in the assumed shear-wave velocity profiles has been incorporated in the site response calculations. For the WCGS site, random shear wave velocity profiles were developed from the base case profiles shown in Figure 2.3.2-1. Consistent with the discussion in Appendix B of the SPID (EPRI, 2013a), the velocity randomization procedure made use of random field models which describe the statistical correlation between layering and shear wave velocity. The default randomization parameters developed in Toro (1997) for United States Geological Survey (USGS) "A" site conditions were used for this site. Thirty random velocity profiles were generated for each base case profile. These random velocity profiles were generated using a natural log standard deviation of 0.25 over the upper 50 ft and 0.15 below that depth. As specified in the SPID (EPRI, 2013a), correlation of shear wave velocity between layers was modeled using the footprint correlation model. In the correlation model, a limit of +/- 2 standard deviations about the median value in each layer was assumed for the limits on random velocity fluctuations.

2.3.4 Input Spectra

Consistent with the guidance in Appendix B of the SPID (EPRI, 2013a), input Fourier amplitude spectra were defined for a single representative earthquake magnitude (M 6.5) using two different assumptions regarding the shape of the seismic source spectrum (single-corner and double-corner). A range of 11 different input amplitudes (median peak ground accelerations (PGA) ranging from 0.01 to 1.5 g) were used in the site response analyses. The characteristics of the seismic source and upper crustal attenuation properties assumed for the analysis of the WCGS site were the same as those identified in Tables B-4, B-5, B-6 and B-7 of the SPID (EPRI, 2013a) as appropriate for typical CEUS sites.

2.3.5 Methodology

To perform the site response analyses for the Wolf Creek site, a random vibration theory (RVT) approach was employed. This process utilizes a simple, efficient approach for computing site-specific amplification functions and is consistent with existing NRC guidance and the SPID (EPRI, 2013a). The guidance contained in Appendix B of the SPID (EPRI, 2013a) on incorporating epistemic uncertainty in shear-wave velocities, kappa, non-linear dynamic properties and source spectra for plants with limited at-site information was followed for the WCGS site.

2.3.6 Amplification Functions

The results of the site response analysis consist of amplification factors (5% damped pseudo absolute response spectra) which describe the amplification (or de-amplification) of hard reference rock motion as a function of frequency and input reference rock amplitude. The amplification factors are represented in terms of a median amplification value and an associated standard deviation (sigma) for each oscillator frequency and input rock amplitude. Consistent with the SPID (EPRI, 2013a) a minimum median amplification value of 0.5 was employed in the present analysis. Figure 2.3.6-1 illustrates the median and +/- 1 standard deviation in the predicted amplification factors developed for the eleven loading levels parameterized by the median reference (hard rock) peak acceleration (0.01g to 1.50g) for profile P1 and EPRI soil and firm rock G/G_{max} and hysteretic damping curves (EPRI, 2013a). The variability in the amplification factors results from variability in shear-wave velocity, depth to hard rock, and modulus reduction and hysteretic damping curves. To illustrate the effects of more linear response at the WCGS site, Figure 2.3.6-2 shows the corresponding amplification factors developed with PR curves for soil and linear site response analyses for firm rock (model M2). Between the more nonlinear and more linear analyses, Figures 2.3.6-1 and Figure 2.3.6-2 respectively show a significant difference across structural frequency as well as loading level. Tabulated values of the amplification factors are provided in Appendix A.

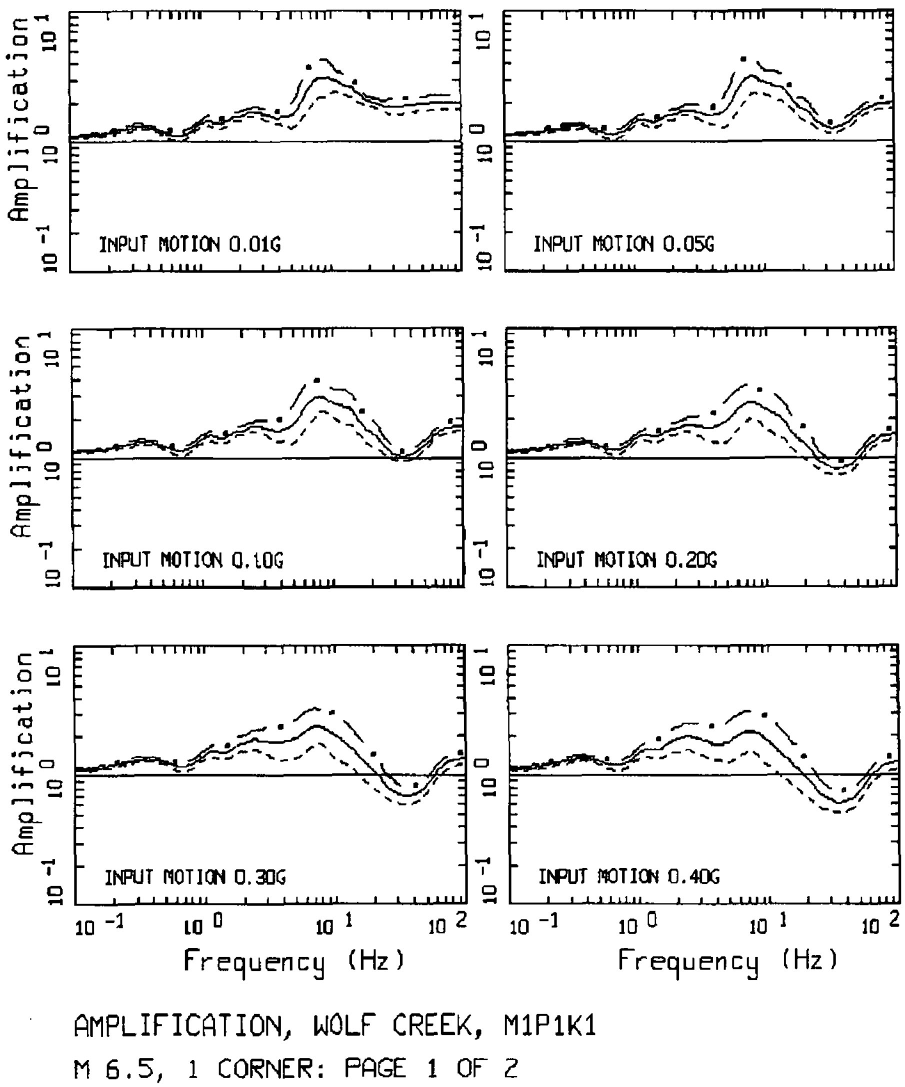

Figure 2.3.6-1. Example suite of amplification factors (5% damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), EPRI rock modulus reduction and hysteretic damping curves (model M1), and base-case kappa (K1) at eleven loading levels of hard rock median peak acceleration values from 0.01g to 1.50g. M 6.5 and single-corner source model (EPRI, 2013a).

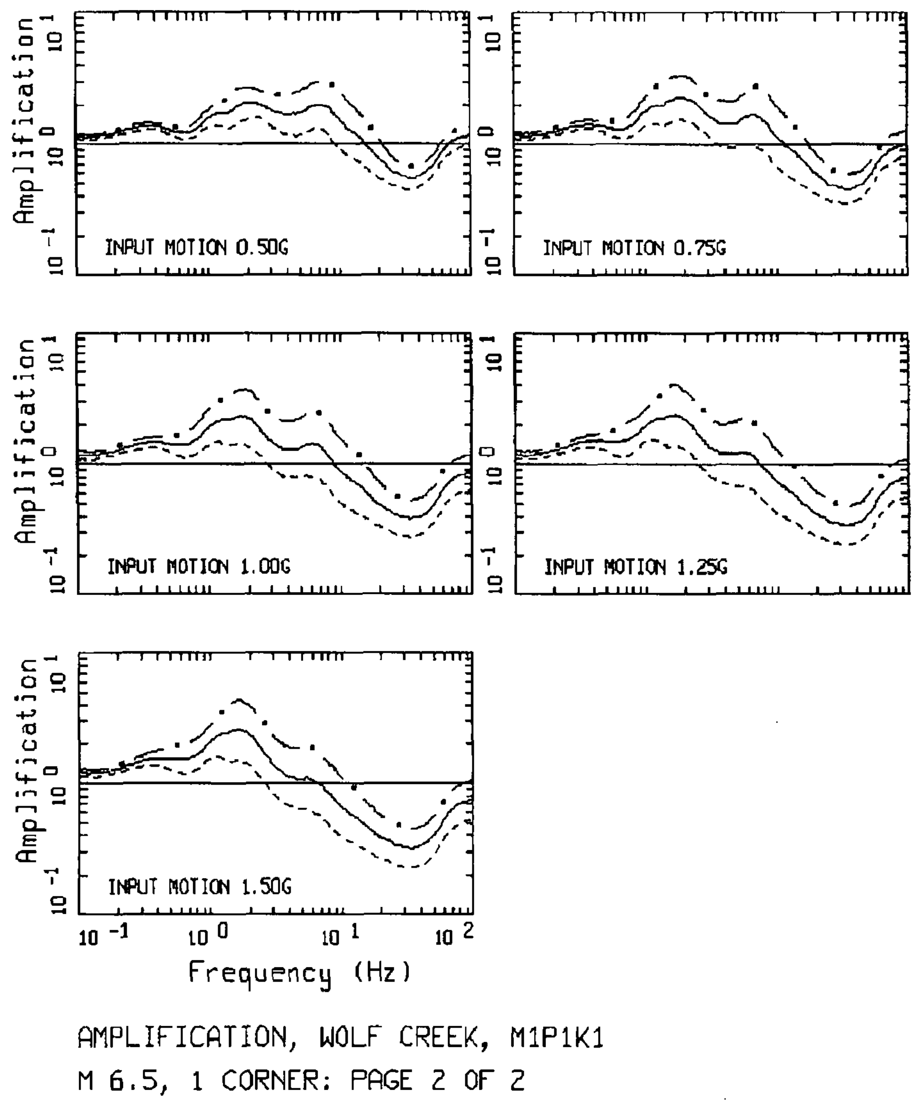

Figure 2.3.6-1. (cont.)

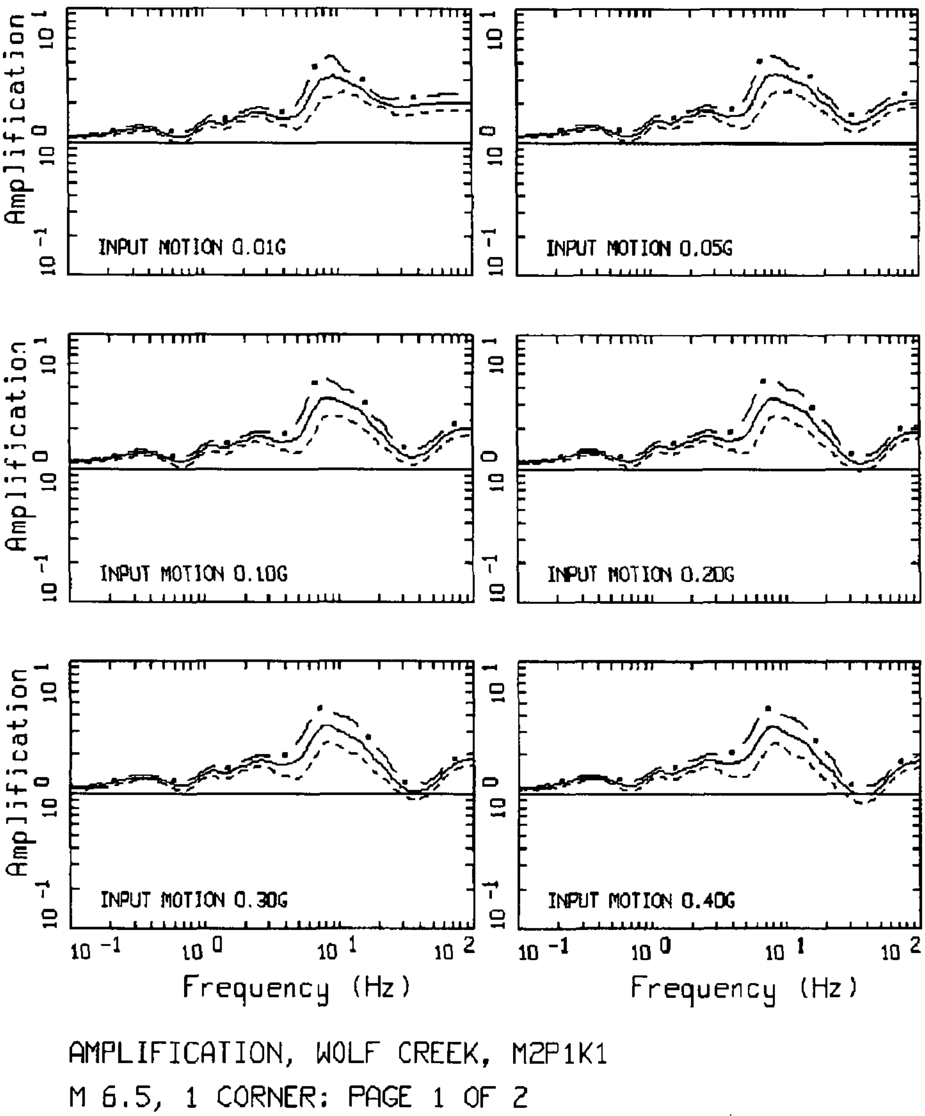

Figure 2.3.6-2. Example suite of amplification factors (5% damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), linear site response (model M2), and base-case kappa (K1) at eleven loading levels of hard rock median peak acceleration values from 0.01g to 1.50g. M 6.5 and single-corner source model (EPRI, 2013a).

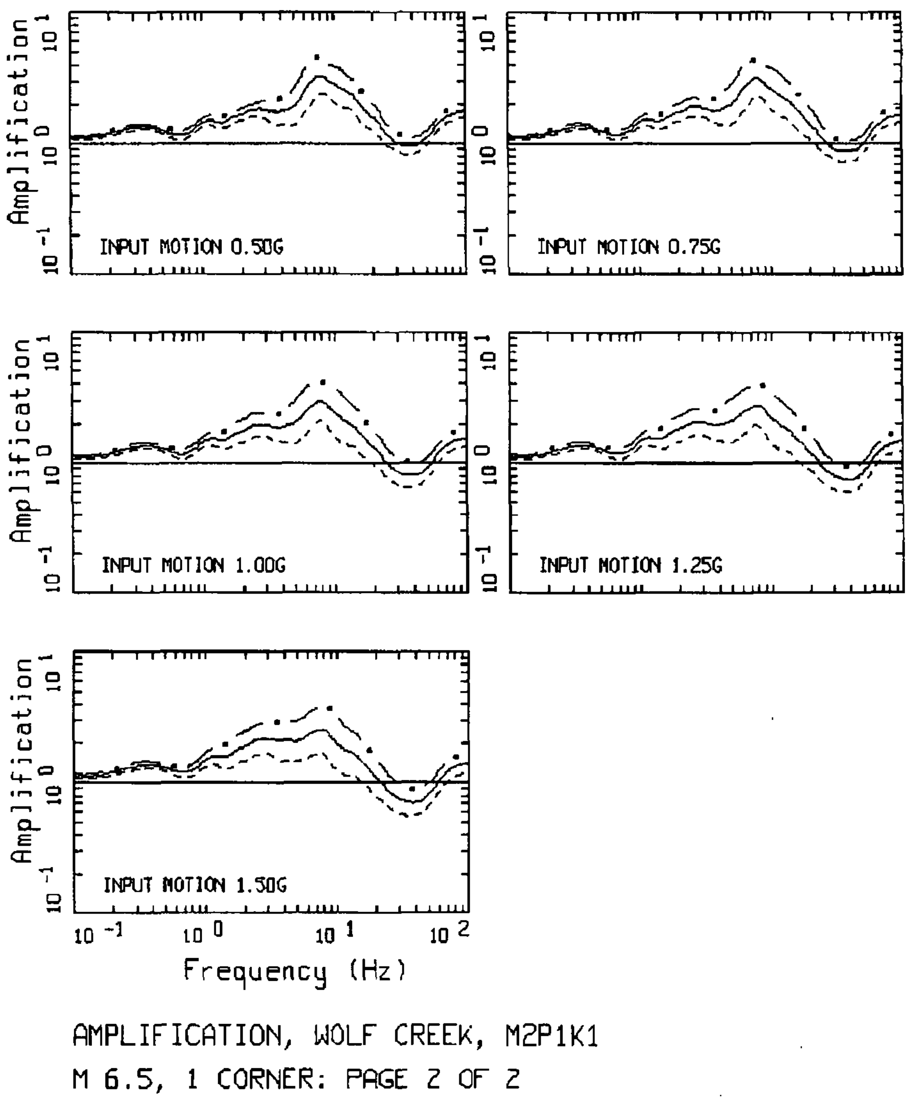

Figure 2.3.6-2. (cont.)

2.3.7 *Control Point Seismic Hazard Curves*

The procedure to develop probabilistic site-specific control point hazard curves used in the present analysis follows the methodology described in Section B-6.0 of the SPID (EPRI, 2013a). This procedure (referred to as Method 3) computes a site-specific control point hazard curve for a broad range of spectral accelerations given the site-specific bedrock hazard curve and site-specific estimates of soil or soft-rock response and associated uncertainties. This process is repeated for each of the seven spectral frequencies for which ground motion equations are available. The dynamic response of the materials below the control point was represented by the frequency- and amplitude-dependent amplification functions (median values and standard deviations) developed and described in the previous section. The resulting control point mean hazard curves for WCGS are shown in Figure 2.3.7-1 for the seven spectral frequencies for which ground motion equations are defined. Tabulated values of mean and fractile seismic hazard curves and site response amplification functions are provided in Appendix A.

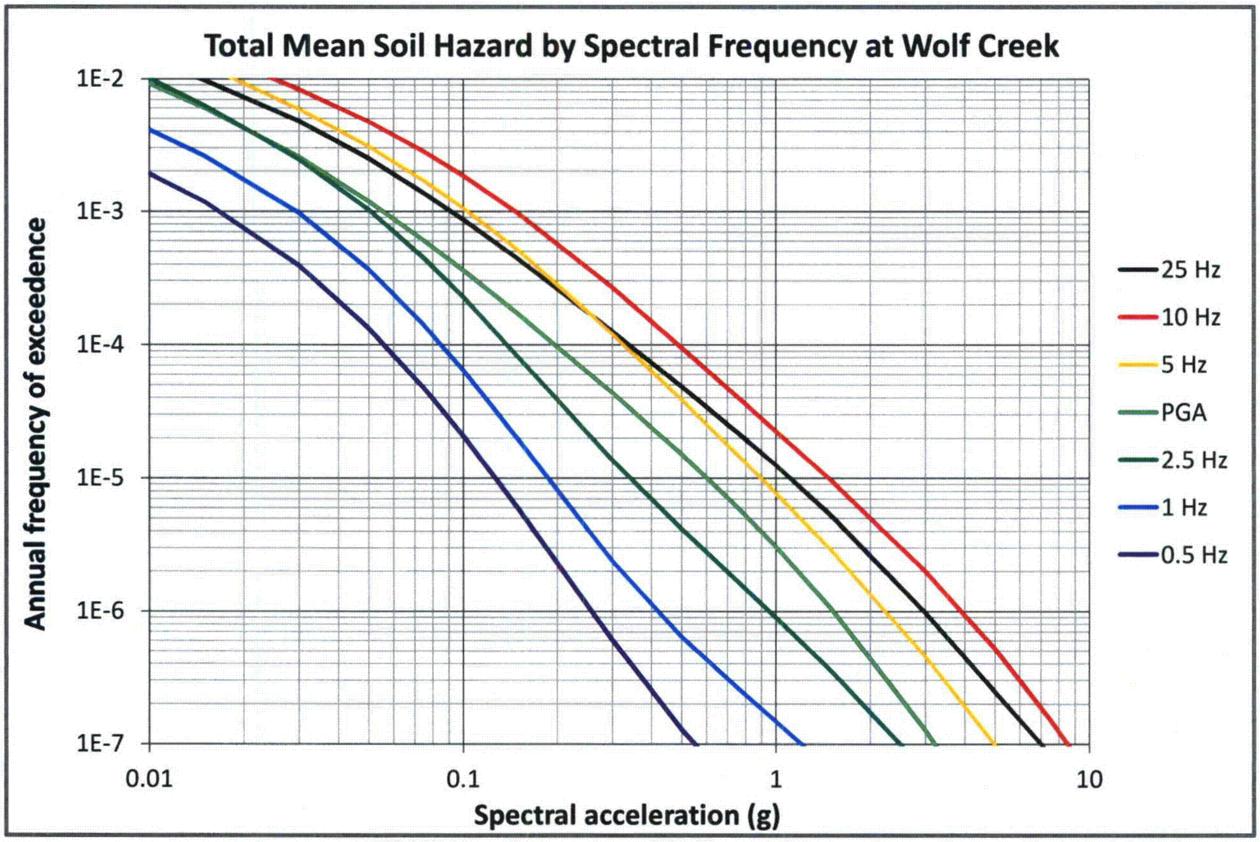

Figure 2.3.7-1. Control point mean hazard curves for spectral frequencies of 0.5, 1, 2.5, 5, 10, 25 and 100 Hz at WCGS

2.4 *Control Point Response Spectra*

The control point hazard curves described above have been used to develop uniform hazard response spectra (UHRS) and the ground motion response spectrum (GMRS). The UHRS were obtained through linear interpolation in log-log space to estimate the spectral acceleration at each oscillator frequency for the 1E-4 and 1E-5 per year hazard levels.

The 1E-4 and 1E-5 UHRS, along with a design factor (DF) are used to compute the GMRS at the control point using the criteria in Regulatory Guide 1.208. Table 2.4-1 shows the UHRS and GMRS spectral accelerations.

Table 2.4-1. UHRS for 10^{-4} and 10^{-5} and GMRS at control point for WCGS

Freq. (Hz)	10^{-4} UHRS (g)	10^{-5} UHRS (g)	GMRS (g)
100	1.95E-01	6.00E-01	2.88E-01
90	1.96E-01	6.07E-01	2.90E-01
80	1.97E-01	6.16E-01	2.94E-01
70	2.00E-01	6.30E-01	3.01E-01
60	2.06E-01	6.59E-01	3.13E-01
50	2.20E-01	7.20E-01	3.41E-01
40	2.43E-01	8.14E-01	3.83E-01
35	2.62E-01	8.88E-01	4.17E-01
30	2.93E-01	9.75E-01	4.60E-01
25	3.39E-01	1.11E+00	5.26E-01
20	3.89E-01	1.24E+00	5.89E-01
15	4.80E-01	1.41E+00	6.83E-01
12.5	5.09E-01	1.50E+00	7.27E-01
10	4.87E-01	1.47E+00	7.06E-01
9	4.70E-01	1.40E+00	6.74E-01
8	4.48E-01	1.29E+00	6.28E-01
7	4.25E-01	1.18E+00	5.79E-01
6	3.75E-01	1.03E+00	5.05E-01
5	3.26E-01	8.93E-01	4.38E-01
4	2.50E-01	6.67E-01	3.29E-01
3.5	2.03E-01	5.37E-01	2.65E-01
3	1.68E-01	4.31E-01	2.14E-01
2.5	1.37E-01	3.41E-01	1.71E-01
2	1.31E-01	3.18E-01	1.60E-01
1.5	1.12E-01	2.66E-01	1.34E-01
1.25	1.01E-01	2.35E-01	1.19E-01
1	8.46E-02	1.86E-01	9.54E-02
0.9	7.72E-02	1.71E-01	8.74E-02
0.8	7.13E-02	1.58E-01	8.10E-02
0.7	6.58E-02	1.47E-01	7.52E-02
0.6	6.04E-02	1.36E-01	6.94E-02
0.5	5.56E-02	1.26E-01	6.43E-02
0.4	4.45E-02	1.01E-01	5.15E-02
0.35	3.89E-02	8.84E-02	4.50E-02
0.3	3.34E-02	7.58E-02	3.86E-02
0.25	2.78E-02	6.32E-02	3.22E-02
0.2	2.22E-02	5.05E-02	2.57E-02
0.15	1.67E-02	3.79E-02	1.93E-02
0.125	1.39E-02	3.16E-02	1.61E-02
0.1	1.11E-02	2.53E-02	1.29E-02

Figure 2.4-1 shows the control point UHRS and GMRS.

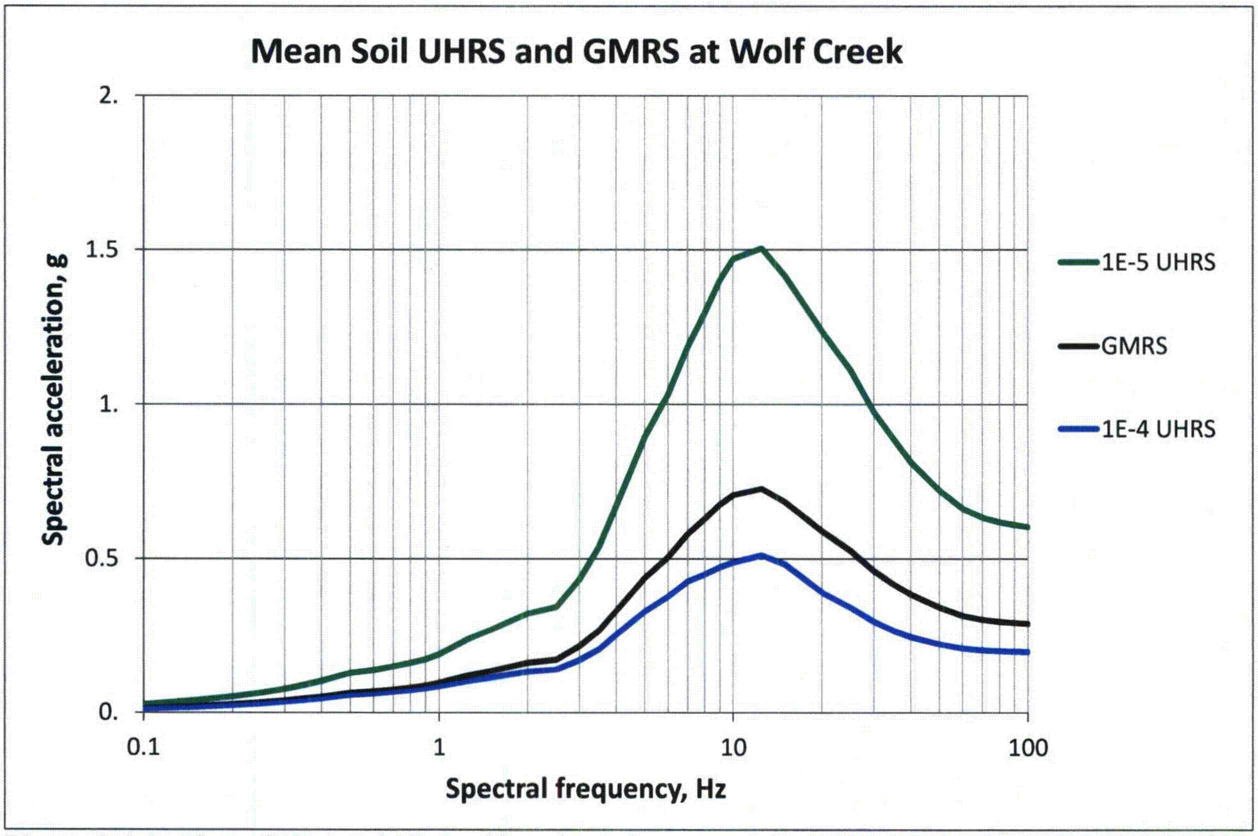

Figure 2.4-1. Plots of 1E-4 and 1E-5 uniform hazard spectra and GMRS at control point for WCGS (5%-damped response spectra)

3. Plant Design Basis

The design basis for WCGS is identified in the Updated Safety Analysis Report (WCNOC, 2013a).

3.1 SSE Description of Spectral Shape

Refer to USAR Sections 2.5.2, 3.7(B), 3.7(S), and Appendix 3C. The SSE is conservatively defined as an MMI VIII earthquake occurring no closer than 75 miles from the site that would generate a maximum ground motion of MMI VI at the site. The maximum horizontal ground motion at the site resulting from the SSE would be about 0.02 to 0.08 times the acceleration of gravity (g) for average foundation conditions.

Non-powerblock safety-related structures, systems, and components (SSC) are conservatively designed for safe shutdown at a horizontal acceleration of 0.12g. However, a seismic evaluation of these SSC using the LLL spectrum is contained in Appendix 3C (WCNOC, 2013a). This spectrum is enveloped by a Regulatory Guide 1.60 spectrum anchored at 0.15g. Powerblock safety-related SSC are designed for a safe shutdown at a horizontal acceleration of 0.20g based on the envelope of the SNUPPS sites. A peak ground acceleration of 0.15g and 0.20g in both horizontal and vertical directions thus constitutes the design basis SSE for WCGS non-powerblock SSC and powerblock SSC, respectively. Wolf Creek conservatively elects to use the SSE anchored at 0.15g for screening.

The two SSEs are defined in terms of a peak ground acceleration (PGA) and a Regulatory Guide 1.60 response spectral shape for both the WCGS powerblock and non-powerblock. The powerblock is anchored to a 0.20g PGA (based on the envelope of SNUPPS sites), and the non-powerblock is anchored to a 0.15g PGA (based upon the evaluation using the LLL SSE spectrum enveloped by a Regulatory Guide 1.60 spectrum). Table 3.1-1 and Figure 3.1-1 show the spectral acceleration values as a function of frequency for the 5% damped horizontal SSE.

Table 3.1-1. SSE for Wolf Creek

Freq (Hz)	Powerblock SA (g)	Non-powerblock SA (g)
0.25	0.09	0.07
2.50	0.63	0.47
9.00	0.52	0.39
33.00	0.20	0.15
100.00	0.20	0.15

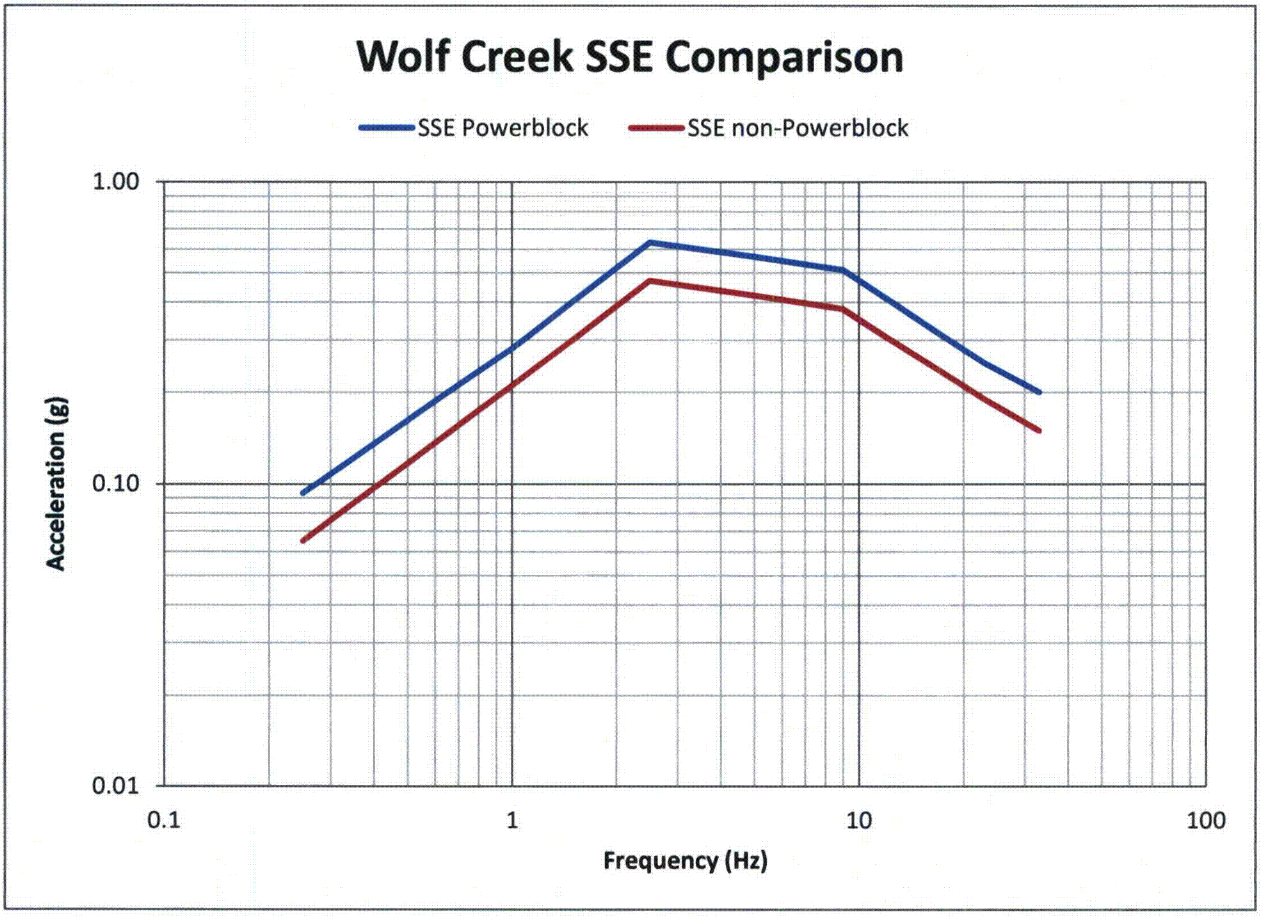

Figure 3.1-1. SSE for WCGS

3.2 Control Point Elevation

The SSE control point elevation is defined at 1099.5 ft National Geodetic Vertical Datum (NGVD) (WCNOC, 2013b). At WCGS this elevation denotes free field at finished grade.

Refer to USAR Sections 3.7(B).1.1 and 3.7(S).1.1. Both the powerblock and non-powerblock design response spectra are stated to be applied in the free field at finished grade.

4. Screening Evaluation

In accordance with SPID Section 3, a screening evaluation was performed as described below.

4.1 Risk Evaluation Screening (1 to 10 Hz)

In the 1 to 10 Hz part of the response spectrum, the GMRS exceeds both the powerblock and non-powerblock SSE. Therefore, the plant screens in for a risk evaluation. WCNOC has elected to perform a SPRA, which is currently in progress.

4.2 High Frequency Screening (>10Hz)

For a portion of the range above 10 Hz, the GMRS exceeds both the powerblock and non-powerblock SSE. As noted in Section 4.1, WCNOC has elected to perform a SPRA which will address the high frequency exceedances.

4.3 Spent Fuel Pool Evaluation Screening (1 to 10Hz)

In the 1 to 10 Hz part of the response spectrum, the GMRS exceeds both the powerblock and non-powerblock SSE. Therefore, the plant screens in for a spent fuel pool evaluation.

5. Interim Actions

Based on the screening evaluation, the expedited seismic evaluation described in the Augumented Approach guidance (EPRI, 2013c) will be performed as proposed in a letter to NRC dated April 9, 2013 (NEI, 2013b) and agreed to by NRC in a letter dated May 7, 2013 (USNRC, 2013).

Consistent with NRC letter dated February 20, 2014, (USNRC, 2014) the seismic hazard reevaluations presented herein are distinct from the current design and licensing bases of WCGS. Therefore, the results do not call into question the operability or functionality of SSCs and are not reportable pursuant to 10 CFR 50.72, "Immediate notification requirements for operating nuclear power reactors," and 10 CFR 50.73, "Licensee event report system."

The NRC letter also requests that licensees provide an interim evaluation or actions to demonstrate that the plant can cope with the reevaluated hazard while the expedited approach and risk evaluations are conducted. In response to that request, NEI letter dated March 12, 2014, (NEI, 2014) provides seismic core damage risk estimates using the updated seismic hazards for the operating nuclear plants in the Central and Eastern United States. These risk estimates continue to support the following conclusions of the NRC GI-199 Safety/Risk Assessment:

> Overall seismic core damage risk estimates are consistent with the Commission's Safety Goal Policy Statement because they are within the subsidiary objective of 10^{-4}/year for core damage frequency. The GI-199 Safety/Risk Assessment, based in part on information from the U.S. Nuclear Regulatory Commission's (NRC's) Individual Plant Examination of External Events (IPEEE) program, indicates that no concern exists regarding adequate protection and that the current seismic design of operating reactors provides a safety margin to withstand potential earthquakes exceeding the original design basis.

WCGS is included in the March 12, 2014 risk estimates. Using the methodology described in the NEI letter, all CEUS plants were shown to be below 10^{-4}/year; thus, the above conclusions apply.

The enclosures to Wolf Creek letters ET 12-0032 (WCNOC, 2012) and ET 13-0021 (WCNOC, 2013c) document the fully completed 2.3 Seismic Walkdown Program performed for WCGS. As a result of the walkdowns, it was reported to the NRC that there were no immediately implemented plant changes warranted as a result of the NTTF 2.3 Seismic Walkdown program. Resolutions of the Condition Reports for seismically insignificant unusual conditions and potentially adverse seismic conditions were identified in the WCGS Corrective Action Program (CAP). Current status and resolutions (where applicable and available) for CRs related to potentially adverse seismic conditions were noted in the enclosures to the letters referenced above.

Prior to the seismic hazard and screening evaluation WCNOC elected to perform a SPRA, which is currently in progress.

6. Conclusions

In accordance with the 50.54(f) request for information, a seismic hazard and screening evaluation was performed for WCGS. A GMRS was developed solely for purpose of screening for additional evaluations in accordance with the SPID. Based on the results of the screening evaluation, the plant screens in for a risk evaluation, a Spent Fuel Pool evaluation, and a High Frequency Confirmation. WCNOC has elected to perform a SPRA, which is currently in progress.

7. References

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Appendix A

Table A-1a. Mean and Fractile Seismic Hazard Curves for PGA at Wolf Creek

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	7.64E-02	3.42E-02	6.17E-02	7.77E-02	9.24E-02	9.93E-02
0.001	5.91E-02	2.16E-02	4.31E-02	6.00E-02	7.77E-02	8.72E-02
0.005	1.77E-02	6.26E-03	1.08E-02	1.62E-02	2.46E-02	3.52E-02
0.01	9.12E-03	2.76E-03	4.90E-03	8.23E-03	1.27E-02	1.98E-02
0.015	5.98E-03	1.57E-03	2.84E-03	5.20E-03	8.60E-03	1.40E-02
0.03	2.55E-03	5.05E-04	8.98E-04	1.92E-03	3.90E-03	7.23E-03
0.05	1.18E-03	1.90E-04	3.33E-04	7.66E-04	1.74E-03	4.01E-03
0.075	5.95E-04	7.89E-05	1.40E-04	3.47E-04	8.47E-04	2.22E-03
0.1	3.57E-04	4.13E-05	7.55E-05	1.98E-04	5.12E-04	1.34E-03
0.15	1.67E-04	1.60E-05	3.09E-05	8.98E-05	2.49E-04	6.09E-04
0.3	4.31E-05	2.96E-06	6.73E-06	2.32E-05	6.93E-05	1.49E-04
0.5	1.50E-05	6.64E-07	1.84E-06	7.34E-06	2.53E-05	5.20E-05
0.75	6.08E-06	1.44E-07	4.98E-07	2.60E-06	1.07E-05	2.25E-05
1.	3.04E-06	3.90E-08	1.64E-07	1.16E-06	5.42E-06	1.20E-05
1.5	1.04E-06	4.63E-09	2.88E-08	3.28E-07	1.82E-06	4.37E-06
3.	1.26E-07	1.87E-10	1.11E-09	2.35E-08	1.98E-07	5.83E-07
5.	2.14E-08	1.53E-10	1.90E-10	2.32E-09	2.84E-08	1.01E-07
7.5	4.60E-09	1.32E-10	1.62E-10	3.95E-10	4.98E-09	2.13E-08
10.	1.43E-09	1.21E-10	1.42E-10	1.87E-10	1.34E-09	6.45E-09

Table A-1b. Mean and Fractile Seismic Hazard Curves for 25 Hz at Wolf Creek

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	8.25E-02	4.63E-02	7.13E-02	8.35E-02	9.65E-02	9.93E-02
0.001	6.84E-02	3.09E-02	5.58E-02	6.93E-02	8.35E-02	9.24E-02
0.005	2.52E-02	1.04E-02	1.69E-02	2.35E-02	3.23E-02	4.90E-02
0.01	1.40E-02	5.42E-03	8.60E-03	1.29E-02	1.82E-02	3.05E-02
0.015	9.75E-03	3.42E-03	5.42E-03	8.72E-03	1.31E-02	2.22E-02
0.03	4.78E-03	1.32E-03	2.16E-03	4.01E-03	7.03E-03	1.16E-02
0.05	2.49E-03	5.35E-04	8.85E-04	1.87E-03	3.90E-03	6.93E-03
0.075	1.37E-03	2.10E-04	3.84E-04	9.24E-04	2.19E-03	4.25E-03
0.1	8.66E-04	9.79E-05	1.98E-04	5.42E-04	1.36E-03	2.84E-03
0.15	4.37E-04	3.19E-05	7.45E-05	2.49E-04	6.83E-04	1.49E-03
0.3	1.26E-04	5.58E-06	1.55E-05	6.26E-05	2.07E-04	4.37E-04
0.5	4.85E-05	1.95E-06	5.50E-06	2.35E-05	8.35E-05	1.74E-04
0.75	2.23E-05	9.24E-07	2.53E-06	1.07E-05	3.90E-05	8.12E-05
1.	1.25E-05	5.35E-07	1.44E-06	6.00E-06	2.22E-05	4.63E-05
1.5	5.26E-06	2.32E-07	6.26E-07	2.53E-06	9.24E-06	1.98E-05
3.	9.74E-07	3.28E-08	1.01E-07	4.43E-07	1.72E-06	3.79E-06
5.	2.46E-07	3.73E-09	1.49E-08	9.65E-08	4.70E-07	9.79E-07
7.5	8.42E-08	5.20E-10	2.22E-09	2.60E-08	1.60E-07	3.57E-07
10.	4.21E-08	2.04E-10	5.66E-10	8.85E-09	7.55E-08	1.95E-07

Table A-1c. Mean and Fractile Seismic Hazard Curves for 10 Hz at Wolf Creek

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	9.01E-02	7.23E-02	7.77E-02	9.11E-02	9.93E-02	9.93E-02
0.001	8.25E-02	6.00E-02	7.03E-02	8.35E-02	9.51E-02	9.93E-02
0.005	4.09E-02	2.10E-02	2.92E-02	4.01E-02	5.27E-02	6.36E-02
0.01	2.37E-02	1.11E-02	1.55E-02	2.25E-02	3.14E-02	4.07E-02
0.015	1.65E-02	7.23E-03	1.02E-02	1.55E-02	2.22E-02	2.96E-02
0.03	8.31E-03	3.09E-03	4.63E-03	7.66E-03	1.16E-02	1.62E-02
0.05	4.69E-03	1.44E-03	2.25E-03	4.13E-03	7.03E-03	9.93E-03
0.075	2.79E-03	7.34E-04	1.16E-03	2.29E-03	4.31E-03	6.64E-03
0.1	1.85E-03	4.31E-04	7.03E-04	1.42E-03	2.92E-03	4.77E-03
0.15	9.61E-04	1.90E-04	3.19E-04	6.83E-04	1.51E-03	2.72E-03
0.3	2.67E-04	4.01E-05	7.23E-05	1.74E-04	4.07E-04	8.00E-04
0.5	9.46E-05	1.13E-05	2.19E-05	6.00E-05	1.53E-04	2.88E-04
0.75	4.08E-05	3.84E-06	8.12E-06	2.53E-05	7.03E-05	1.27E-04
1.	2.24E-05	1.69E-06	3.95E-06	1.34E-05	3.95E-05	7.23E-05
1.5	9.55E-06	5.20E-07	1.34E-06	5.20E-06	1.74E-05	3.33E-05
3.	1.98E-06	6.00E-08	1.84E-07	8.98E-07	3.63E-06	7.55E-06
5.	5.18E-07	1.10E-08	3.84E-08	2.01E-07	9.11E-07	2.13E-06
7.5	1.53E-07	2.60E-09	9.65E-09	5.27E-08	2.60E-07	6.45E-07
10.	5.94E-08	9.11E-10	3.33E-09	1.92E-08	1.01E-07	2.53E-07

Table A-1d. Mean and Fractile Seismic Hazard Curves for 5 Hz at Wolf Creek

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	8.32E-02	5.42E-02	6.73E-02	8.47E-02	9.93E-02	9.93E-02
0.001	7.27E-02	3.73E-02	4.98E-02	7.55E-02	9.24E-02	9.93E-02
0.005	3.37E-02	9.79E-03	1.44E-02	3.14E-02	5.27E-02	6.54E-02
0.01	1.89E-02	4.50E-03	7.03E-03	1.72E-02	3.05E-02	4.01E-02
0.015	1.26E-02	2.64E-03	4.37E-03	1.13E-02	2.10E-02	2.80E-02
0.03	5.85E-03	9.24E-04	1.67E-03	5.05E-03	1.01E-02	1.38E-02
0.05	3.05E-03	3.79E-04	7.13E-04	2.42E-03	5.50E-03	8.00E-03
0.075	1.69E-03	1.79E-04	3.42E-04	1.20E-03	3.09E-03	4.90E-03
0.1	1.05E-03	1.02E-04	1.98E-04	6.83E-04	1.92E-03	3.28E-03
0.15	5.03E-04	4.37E-05	8.72E-05	2.96E-04	8.72E-04	1.64E-03
0.3	1.20E-04	9.37E-06	1.98E-05	6.45E-05	1.95E-04	3.90E-04
0.5	3.83E-05	2.80E-06	6.17E-06	2.10E-05	6.36E-05	1.27E-04
0.75	1.51E-05	9.93E-07	2.32E-06	8.23E-06	2.60E-05	5.12E-05
1.	7.68E-06	4.63E-07	1.13E-06	4.13E-06	1.36E-05	2.68E-05
1.5	2.86E-06	1.46E-07	3.79E-07	1.49E-06	5.20E-06	1.02E-05
3.	4.52E-07	1.51E-08	4.43E-08	2.01E-07	8.00E-07	1.74E-06
5.	9.84E-08	2.19E-09	7.03E-09	3.68E-08	1.69E-07	4.01E-07
7.5	2.64E-08	4.77E-10	1.42E-09	8.12E-09	4.25E-08	1.11E-07
10.	9.81E-09	2.25E-10	4.83E-10	2.57E-09	1.51E-08	4.25E-08

Table A-1e. Mean and Fractile Seismic Hazard Curves for 2.5 Hz at Wolf Creek

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	8.16E-02	5.91E-02	6.83E-02	8.12E-02	9.51E-02	9.93E-02
0.001	6.58E-02	3.90E-02	4.83E-02	6.54E-02	8.35E-02	9.24E-02
0.005	2.10E-02	8.85E-03	1.23E-02	1.95E-02	3.01E-02	3.79E-02
0.01	1.00E-02	3.73E-03	5.50E-03	9.24E-03	1.46E-02	1.87E-02
0.015	6.22E-03	2.01E-03	3.14E-03	5.75E-03	9.24E-03	1.21E-02
0.03	2.44E-03	4.98E-04	8.98E-04	2.04E-03	4.01E-03	5.66E-03
0.05	1.02E-03	1.40E-04	2.72E-04	7.23E-04	1.77E-03	2.92E-03
0.075	4.39E-04	4.56E-05	9.37E-05	2.68E-04	7.45E-04	1.42E-03
0.1	2.23E-04	2.01E-05	4.25E-05	1.27E-04	3.68E-04	7.55E-04
0.15	7.97E-05	6.17E-06	1.36E-05	4.31E-05	1.27E-04	2.72E-04
0.3	1.35E-05	8.35E-07	2.04E-06	7.34E-06	2.29E-05	4.70E-05
0.5	4.11E-06	1.90E-07	5.27E-07	2.13E-06	7.23E-06	1.46E-05
0.75	1.68E-06	5.50E-08	1.74E-07	8.00E-07	3.01E-06	6.26E-06
1.	8.88E-07	2.13E-08	7.45E-08	3.84E-07	1.57E-06	3.37E-06
1.5	3.49E-07	5.20E-09	2.10E-08	1.32E-07	6.00E-07	1.42E-06
3.	6.27E-08	4.19E-10	1.79E-09	1.57E-08	1.01E-07	2.80E-07
5.	1.57E-08	1.67E-10	3.23E-10	2.64E-09	2.25E-08	7.23E-08
7.5	4.76E-09	1.46E-10	1.67E-10	6.36E-10	6.09E-09	2.19E-08
10.	1.91E-09	1.32E-10	1.62E-10	2.84E-10	2.22E-09	8.85E-09

Table A-1f. Mean and Fractile Seismic Hazard Curves for 1 Hz at Wolf Creek

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	5.40E-02	2.49E-02	3.57E-02	5.42E-02	7.13E-02	8.23E-02
0.001	3.51E-02	1.36E-02	2.13E-02	3.42E-02	4.90E-02	5.91E-02
0.005	8.37E-03	2.76E-03	4.43E-03	7.77E-03	1.23E-02	1.60E-02
0.01	4.09E-03	9.37E-04	1.77E-03	3.68E-03	6.45E-03	8.60E-03
0.015	2.58E-03	4.07E-04	8.60E-04	2.19E-03	4.31E-03	6.09E-03
0.03	9.64E-04	7.03E-05	1.74E-04	6.26E-04	1.77E-03	2.96E-03
0.05	3.61E-04	1.51E-05	4.07E-05	1.77E-04	6.64E-04	1.32E-03
0.075	1.38E-04	4.01E-06	1.11E-05	5.27E-05	2.35E-04	5.58E-04
0.1	6.37E-05	1.46E-06	4.19E-06	2.10E-05	1.01E-04	2.60E-04
0.15	1.93E-05	3.19E-07	1.02E-06	5.50E-06	2.76E-05	7.77E-05
0.3	2.36E-06	1.82E-08	7.89E-08	6.09E-07	3.33E-06	9.93E-06
0.5	6.33E-07	1.82E-09	1.13E-08	1.36E-07	9.37E-07	2.84E-06
0.75	2.64E-07	3.33E-10	2.57E-09	4.56E-08	3.79E-07	1.18E-06
1.	1.46E-07	1.79E-10	9.65E-10	2.13E-08	1.98E-07	6.73E-07
1.5	6.29E-08	1.62E-10	3.14E-10	6.93E-09	7.77E-08	2.92E-07
3.	1.25E-08	1.38E-10	1.62E-10	9.37E-10	1.29E-08	5.58E-08
5.	3.17E-09	1.32E-10	1.62E-10	2.68E-10	2.76E-09	1.32E-08
7.5	9.34E-10	1.21E-10	1.42E-10	1.69E-10	7.89E-10	3.63E-09
10.	3.65E-10	1.21E-10	1.32E-10	1.62E-10	3.57E-10	1.40E-09

Table A-1g. Mean and Fractile Seismic Hazard Curves for 0.5 Hz at Wolf Creek

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	2.56E-02	1.15E-02	1.72E-02	2.46E-02	3.37E-02	4.19E-02
0.001	1.48E-02	6.26E-03	9.37E-03	1.40E-02	2.01E-02	2.60E-02
0.005	3.76E-03	8.23E-04	1.57E-03	3.37E-03	5.91E-03	8.00E-03
0.01	1.91E-03	1.90E-04	4.70E-04	1.51E-03	3.37E-03	4.98E-03
0.015	1.17E-03	6.54E-05	1.87E-04	7.66E-04	2.19E-03	3.57E-03
0.03	3.88E-04	7.89E-06	2.72E-05	1.60E-04	7.45E-04	1.55E-03
0.05	1.31E-04	1.36E-06	5.05E-06	3.52E-05	2.22E-04	5.91E-04
0.075	4.67E-05	3.09E-07	1.18E-06	9.11E-06	6.93E-05	2.13E-04
0.1	2.06E-05	1.01E-07	4.01E-07	3.28E-06	2.64E-05	9.24E-05
0.15	5.86E-06	1.87E-08	8.23E-08	7.45E-07	6.26E-06	2.60E-05
0.3	6.00E-07	8.35E-10	4.83E-09	6.00E-08	5.58E-07	2.60E-06
0.5	1.28E-07	1.79E-10	5.20E-10	8.72E-09	1.15E-07	5.58E-07
0.75	4.49E-08	1.62E-10	1.82E-10	1.92E-09	3.52E-08	1.87E-07
1.	2.27E-08	1.32E-10	1.62E-10	7.23E-10	1.53E-08	9.11E-08
1.5	8.85E-09	1.32E-10	1.62E-10	2.53E-10	4.56E-09	3.23E-08
3.	1.57E-09	1.21E-10	1.32E-10	1.62E-10	5.91E-10	4.63E-09
5.	3.67E-10	1.21E-10	1.32E-10	1.62E-10	2.04E-10	9.65E-10
7.5	1.02E-10	1.21E-10	1.32E-10	1.62E-10	1.62E-10	3.28E-10
10.	3.79E-11	1.21E-10	1.32E-10	1.62E-10	1.62E-10	2.01E-10

Table A-2. Amplification Functions for Wolf Creek

PGA	Median AF	Sigma ln(AF)	25 Hz	Median AF	Sigma ln(AF)	10 Hz	Median AF	Sigma ln(AF)	5 Hz	Median AF	Sigma ln(AF)
1.00E-02	2.21E+00	1.56E-01	1.30E-02	2.13E+00	1.38E-01	1.90E-02	2.80E+00	2.72E-01	2.09E-02	2.16E+00	3.41E-01
4.95E-02	2.18E+00	1.26E-01	1.02E-01	1.75E+00	1.87E-01	9.99E-02	2.71E+00	2.64E-01	8.24E-02	2.25E+00	3.04E-01
9.64E-02	2.02E+00	1.16E-01	2.13E-01	1.58E+00	2.10E-01	1.85E-01	2.59E+00	2.81E-01	1.44E-01	2.24E+00	2.93E-01
1.94E-01	1.83E+00	1.14E-01	4.43E-01	1.39E+00	2.36E-01	3.56E-01	2.44E+00	3.13E-01	2.65E-01	2.19E+00	3.20E-01
2.92E-01	1.71E+00	1.18E-01	6.76E-01	1.26E+00	2.50E-01	5.23E-01	2.32E+00	3.38E-01	3.84E-01	2.11E+00	3.35E-01
3.91E-01	1.61E+00	1.27E-01	9.09E-01	1.17E+00	2.60E-01	6.90E-01	2.21E+00	3.55E-01	5.02E-01	2.02E+00	3.45E-01
4.93E-01	1.54E+00	1.37E-01	1.15E+00	1.10E+00	2.69E-01	8.61E-01	2.10E+00	3.72E-01	6.22E-01	1.96E+00	3.56E-01
7.41E-01	1.39E+00	1.63E-01	1.73E+00	9.60E-01	2.89E-01	1.27E+00	1.88E+00	4.00E-01	9.13E-01	1.83E+00	3.78E-01
1.01E+00	1.28E+00	1.86E-01	2.36E+00	8.60E-01	3.08E-01	1.72E+00	1.67E+00	4.34E-01	1.22E+00	1.78E+00	4.07E-01
1.28E+00	1.19E+00	2.07E-01	3.01E+00	7.81E-01	3.25E-01	2.17E+00	1.50E+00	4.61E-01	1.54E+00	1.73E+00	4.22E-01
1.55E+00	1.13E+00	2.17E-01	3.63E+00	7.24E-01	3.41E-01	2.61E+00	1.37E+00	4.73E-01	1.85E+00	1.66E+00	3.92E-01
2.5 Hz	**Median AF**	**Sigma ln(AF)**	**1 Hz**	**Median AF**	**Sigma ln(AF)**	**0.5 Hz**	**Median AF**	**Sigma ln(AF)**			
2.18E-02	1.57E+00	1.25E-01	1.27E-02	1.47E+00	9.25E-02	8.25E-03	1.32E+00	1.09E-01			
7.05E-02	1.63E+00	1.42E-01	3.43E-02	1.51E+00	9.58E-02	1.96E-02	1.35E+00	1.09E-01			
1.18E-01	1.66E+00	1.67E-01	5.51E-02	1.54E+00	1.05E-01	3.02E-02	1.37E+00	1.11E-01			
2.12E-01	1.72E+00	2.03E-01	9.63E-02	1.61E+00	1.58E-01	5.11E-02	1.41E+00	1.18E-01			
3.04E-01	1.74E+00	2.48E-01	1.36E-01	1.70E+00	2.13E-01	7.10E-02	1.44E+00	1.29E-01			
3.94E-01	1.73E+00	2.50E-01	1.75E-01	1.78E+00	2.46E-01	9.06E-02	1.48E+00	1.51E-01			
4.86E-01	1.72E+00	2.56E-01	2.14E-01	1.84E+00	2.83E-01	1.10E-01	1.49E+00	1.68E-01			
7.09E-01	1.74E+00	3.23E-01	3.10E-01	1.90E+00	3.35E-01	1.58E-01	1.53E+00	2.17E-01			
9.47E-01	1.75E+00	3.52E-01	4.12E-01	1.93E+00	3.62E-01	2.09E-01	1.56E+00	2.43E-01			
1.19E+00	1.77E+00	3.64E-01	5.18E-01	1.90E+00	4.22E-01	2.62E-01	1.58E+00	2.95E-01			
1.43E+00	1.81E+00	3.66E-01	6.19E-01	1.91E+00	4.41E-01	3.12E-01	1.59E+00	3.29E-01			

Tables A2-b1 and A2-b2 are tabular versions of the typical amplification factors provided in Figures 2.3.6-1 and 2.3.6-2. Values are provided for two input motion levels at approximately 10^{-4} and 10^{-5} mean annual frequency of exceedance (EPRI, 2014). These factors are unverified and are provided for information only. The figures should be considered the governing information.

Table A2-b1. Median AFs and sigmas for Model 1, Profile 1, for 2 PGA levels.

M1P1K1	Rock PGA=0.0964			M1P1K1	PGA=0.493		
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
100.0	0.172	1.781	0.086	100.0	0.574	1.165	0.159
87.1	0.172	1.753	0.086	87.1	0.575	1.132	0.160
75.9	0.174	1.703	0.086	75.9	0.577	1.076	0.161
66.1	0.175	1.606	0.086	66.1	0.580	0.974	0.164
57.5	0.178	1.438	0.086	57.5	0.585	0.821	0.168
50.1	0.184	1.259	0.089	50.1	0.594	0.684	0.176
43.7	0.193	1.123	0.099	43.7	0.608	0.593	0.189
38.0	0.200	1.049	0.093	38.0	0.626	0.561	0.202
33.1	0.212	1.034	0.101	33.1	0.647	0.555	0.213
28.8	0.228	1.093	0.113	28.8	0.670	0.581	0.220
25.1	0.258	1.210	0.142	25.1	0.708	0.616	0.246
21.9	0.296	1.435	0.200	21.9	0.770	0.713	0.297
19.1	0.329	1.594	0.237	19.1	0.858	0.814	0.359
16.6	0.359	1.785	0.216	16.6	0.955	0.953	0.406
14.5	0.423	2.177	0.257	14.5	1.043	1.100	0.429
12.6	0.464	2.430	0.290	12.6	1.134	1.240	0.452
11.0	0.476	2.529	0.285	11.0	1.228	1.387	0.487
9.5	0.488	2.688	0.246	9.5	1.357	1.617	0.505
8.3	0.497	2.936	0.262	8.3	1.441	1.874	0.467
7.2	0.468	2.928	0.325	7.2	1.427	1.994	0.412
6.3	0.390	2.580	0.377	6.3	1.301	1.947	0.403
5.5	0.307	2.110	0.388	5.5	1.148	1.809	0.394
4.8	0.254	1.776	0.310	4.8	1.045	1.691	0.387
4.2	0.234	1.676	0.216	4.2	1.006	1.688	0.357
3.6	0.222	1.623	0.164	3.6	0.978	1.693	0.328
3.2	0.219	1.687	0.139	3.2	0.970	1.790	0.291
2.8	0.215	1.741	0.106	2.8	0.974	1.902	0.252
2.4	0.201	1.751	0.085	2.4	0.958	2.035	0.241
2.1	0.174	1.659	0.091	2.1	0.874	2.050	0.279
1.8	0.151	1.609	0.083	1.8	0.765	2.014	0.300
1.6	0.123	1.500	0.105	1.6	0.609	1.856	0.300
1.4	0.101	1.431	0.092	1.4	0.479	1.702	0.254
1.2	0.093	1.482	0.096	1.2	0.418	1.693	0.207
1.0	0.083	1.459	0.069	1.0	0.360	1.626	0.160
0.91	0.068	1.316	0.072	0.91	0.289	1.440	0.137
0.79	0.056	1.189	0.079	0.79	0.232	1.283	0.124
0.69	0.048	1.141	0.082	0.69	0.194	1.216	0.114
0.60	0.043	1.158	0.075	0.60	0.169	1.223	0.101
0.52	0.039	1.213	0.058	0.52	0.149	1.272	0.081
0.46	0.034	1.275	0.038	0.46	0.129	1.328	0.063
0.10	0.001	1.131	0.018	0.10	0.005	1.152	0.042

Table A2-b2. Median AFs and sigmas for Model 2, Profile 1, for 2 PGA levels.

M2P1K1	PGA=0.0964			M2P1K1	PGA=0.493		
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
100.0	0.195	2.025	0.119	100.0	0.862	1.750	0.108
87.1	0.196	1.996	0.118	87.1	0.867	1.707	0.108
75.9	0.198	1.942	0.117	75.9	0.874	1.630	0.109
66.1	0.200	1.837	0.116	66.1	0.887	1.489	0.110
57.5	0.205	1.654	0.114	57.5	0.909	1.275	0.115
50.1	0.214	1.465	0.112	50.1	0.952	1.098	0.122
43.7	0.227	1.319	0.119	43.7	1.014	0.988	0.135
38.0	0.238	1.248	0.128	38.0	1.075	0.964	0.154
33.1	0.255	1.242	0.130	33.1	1.131	0.970	0.156
28.8	0.276	1.326	0.137	28.8	1.214	1.053	0.152
25.1	0.314	1.476	0.149	25.1	1.351	1.176	0.181
21.9	0.360	1.750	0.178	21.9	1.536	1.421	0.216
19.1	0.407	1.971	0.177	19.1	1.720	1.632	0.246
16.6	0.461	2.295	0.218	16.6	1.872	1.869	0.277
14.5	0.523	2.692	0.252	14.5	2.107	2.223	0.279
12.6	0.546	2.855	0.258	12.6	2.276	2.488	0.297
11.0	0.571	3.032	0.226	11.0	2.391	2.701	0.331
9.5	0.584	3.219	0.275	9.5	2.465	2.938	0.306
8.3	0.561	3.319	0.300	8.3	2.490	3.239	0.299
7.2	0.506	3.169	0.376	7.2	2.296	3.208	0.351
6.3	0.388	2.563	0.414	6.3	1.824	2.729	0.397
5.5	0.284	1.949	0.331	5.5	1.378	2.170	0.369
4.8	0.239	1.665	0.237	4.8	1.141	1.847	0.296
4.2	0.225	1.613	0.162	4.2	1.056	1.772	0.242
3.6	0.218	1.593	0.127	3.6	0.999	1.729	0.221
3.2	0.217	1.676	0.110	3.2	0.969	1.789	0.182
2.8	0.214	1.735	0.088	2.8	0.935	1.827	0.129
2.4	0.199	1.735	0.076	2.4	0.851	1.807	0.102
2.1	0.171	1.637	0.087	2.1	0.722	1.693	0.108
1.8	0.149	1.588	0.083	1.8	0.621	1.633	0.104
1.6	0.121	1.482	0.106	1.6	0.499	1.519	0.122
1.4	0.100	1.418	0.091	1.4	0.408	1.448	0.100
1.2	0.092	1.472	0.095	1.2	0.370	1.500	0.099
1.0	0.082	1.452	0.070	1.0	0.328	1.478	0.074
0.91	0.068	1.311	0.072	0.91	0.268	1.334	0.075
0.79	0.056	1.186	0.079	0.79	0.218	1.208	0.079
0.69	0.048	1.139	0.082	0.69	0.185	1.160	0.081
0.60	0.043	1.157	0.075	0.60	0.163	1.178	0.073
0.52	0.039	1.213	0.058	0.52	0.145	1.234	0.057
0.46	0.034	1.275	0.038	0.46	0.126	1.295	0.039
0.10	0.001	1.131	0.019	0.10	0.004	1.133	0.024