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Donald C. Cook Nuclear Plant Units 1 and 2

Seismic Hazard and Screening Report for the Cook Nuclear Plant (CNP)

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Seismic Hazard and Screening Report for the Cook Nuclear Plant (CNP)

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1.0 Introduction

Following the accident at the Fukushima Daiichi nuclear power plant resulting from the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami, the NRC Commission 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) letter [Ref. 1] that requests information to assure that these recommendations are addressed by all U.S. nuclear power plants. The 50.54(f) letter requests that licensees and holders of construction permits under 10 CFR Part 50 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) [Ref. 1] letter pertaining to NTTF Recommendation 2.1 for the Cook Nuclear Plant Units 1 and 2 (CNP1 and CNP2), located in Lake Township, Berrien County, Michigan. In providing this information, the Cook Nuclear Plant (CNP) 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 1025287, 2012) [Ref. 2]. The Augmented Approach, Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic (EPRI 3002000704, 2013) [Ref. 3], has been developed as the process for evaluating critical plant equipment prior to performing the complete plant seismic risk evaluations.

CNP was designed and constructed to meet the intent of the Proposed General Design Criteria, published July 11, 1967 [Ref. 4]. The Final Safety Analysis Report had been filed with the Atomic Energy Commission (AEC) when revisions of the General Design Criteria were published in February 1971 and July 7, 1971. In 1973, the AEC reviewed the plant design against the most recent General Design Criteria and concluded that the design meets these criteria. As described in Section 1.4 of the CNP Updated Final Safety Analysis Report (UFSAR) [Ref. 13] subsequently an evaluation was performed that determined the original geologic and seismic siting investigations for the CNP 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. It is noted that the CNP referred to their higher earthquake level as the Design Basis Earthquake (DBE). Shortly after CNP was licensed the terminology for this earthquake was changed to the Safe Shutdown Earthquake (SSE). To be consistent with industry terminology for the

Fukushima recommendations, the DBE will be referred to as the SSE throughout this report. The Safe Shutdown Earthquake Ground Motion (SSE) was determined to be in accordance with Appendix A to 10 CFR Part 100 and used for the design of seismic Category I systems, structures and components.

In response to the 50.54(f) letter [Ref. 1] and following the guidance provided in the SPID [Ref. 2], a seismic hazard reevaluation for CNP was performed. For screening purposes a Ground Motion Response Spectrum (GMRS) was developed.

Based on the results of the screening evaluation, the CNP screens in for risk evaluation and a Spent Fuel Pool evaluation.

2.0 Seismic Hazard Reevaluation

The CNP is located along the eastern shore of Lake Michigan in Lake Township, Berrien County, Michigan about 11 miles south-southwest of Benton Harbor (UFSAR 1.1.1, [Ref. 13]). The site consists of about 650 acres along the eastern shore of Lake Michigan, with approximately 4350 feet of Lake Michigan frontage and extends about one and one quarter miles eastward from the lake (UFSAR 2.1.2, [Ref. 13]).

The site consists of heavily wooded rugged sand dunes. A sandy beach sloped gently upwards for about 200 feet from the lake before rising sharply into the dunes. The peaks of the highest dunes reach an elevation of about 120 feet above the lake's surface; depressions between the dunes are as low as 10 feet above lake level (FSAR 2.1.3, [Ref. 13]).

The original geologic and seismic siting investigations for CNP indicated that the site was in a region which had experienced very little earthquake activity. No major earthquakes had epicenters closer than about 400 miles to the plant site. There had been some minor earthquake activity closer to the site; however, no shocks within 50 miles of the site had been large enough to cause significant structural damage.

As discussed in Section 2.5.2 of the CNP UFSAR [Ref. 13] based on the history of previous earthquake activity in the area, it was estimated that the maximum ground motion which the site may be subjected to during its life would be due to a shock similar to the 1947 south-central Michigan earthquake. It is estimated that the magnitude of this shock was no greater than about 4½ on the Richter Scale. This earthquake possibly may be related to a postulated fault structure trending northwest-southeast through southwest Michigan. The closest approach of this postulated structure to the site is about 50 miles to the northeast. There was an earthquake in 1943 with its epicenter in Lake Erie that may have had a magnitude as great as 5. The geology of Lake Erie is similar to that of southwest Michigan in that the bedrock is essentially a stable platform with little or no seismic history and no known faulting. Shocks in the Lake Erie area are probably related to glacial rebound, as potential shocks would likely be in the area of the site.

The original selection of the maximum potential earthquake conservatively assumed that it could be as large as Magnitude 5 and might occur relative to some yet unknown geologic structure in the bedrock near the site, perhaps triggered by glacial rebound. Assuming such a shock might have a focal depth as shallow as 10 kilometers, it was estimated that the maximum ground acceleration at foundation level (within the lake or beach sand deposits) at the site would be about 15 percent of gravity. However, as discussed in Section 2.5.2 of the CNP UFSAR [Ref. 13] additional margin was provided for by designing the engineered safety features to be operative under a SSE, maximum horizontal ground acceleration of 20 percent of gravity and maximum vertical acceleration of 13.33 percent of gravity.

2.1 Regional and Local Geology

As described in Section 2.3.1 of the CNP UFSAR [Ref. 13] the CNP lies within the southern peninsula of Michigan within the Central Lowland Physiographic Province. The topography is typical of areas of regional glaciations. As a consequence of glaciation, land forms are low to moderate relief and generally smoothly contoured. Bedrock exposures are rare. Reaches of the Lake Michigan shoreline are characterized by extensive sand dunes and ancient shoreline features of Glacial Lake Chicago. Regional drainage in southwest Michigan is toward Lake Michigan on the west.

Bedrock consists of a mixed sequence of sedimentary strata including shale, limestone, sandstone and dolomite. The strata range in age from Cambrian to Pennsylvanian. This sequence is underlain by a basement complex of Precambrian igneous and metamorphic rocks.

Bedrock formations in the vicinity of the site include shale and sandstones of Devonian and Mississippian age. The Precambrian basement is estimated to occur at a depth of 3,500 feet (UFSAR Section 2.3.2 [Ref. 13]).

The CNP site is located within a local physiographic area known as the Grand Marais Embayment (UFSAR Section 2.3.2 [Ref. 13]). The area, 16 miles long and with an average width of about one mile, lies adjacent and parallel to the shore line of Lake Michigan in the western Berrien County. The area adjacent to the beach is characterized by high sand dunes of Pleistocene and Recent origin.

2.2 Probabilistic Seismic Hazard Analysis

2.2.1 Probabilistic Seismic Hazard Analysis Results

The CNP specific Probabilistic Seismic Hazard Analysis [Ref. 14] has been completed in accordance with the 50.54(f) letter [Ref. 1]. Following the guidance in the SPID [Ref. 2], 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 [Ref. 7] together with the updated EPRI Ground-Motion Model (GMM) for the CEUS [Ref. 8]. 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 the CNP were included. This distance exceeds the 200 mile (320 km) recommendation contained in [Ref. 10] and was chosen for completeness. Background sources included in this site analysis are the following:

1. Illinois Basin Extended Basement (IBEB)
2. Mesozoic and younger extended prior – narrow (MESE-N)
3. Mesozoic and younger extended prior – wide (MESE-W)

4. Midcontinent-Craton alternative A (MIDC_A)
5. Midcontinent-Craton alternative B (MIDC_B)
6. Midcontinent-Craton alternative C (MIDC_C)
7. Midcontinent-Craton alternative D (MIDC_D)
8. Non-Mesozoic and younger extended prior – narrow (NMESE-N)
9. Non-Mesozoic and younger extended prior – wide (NMESE-W)
10. Paleozoic Extended Crust narrow (PEZ_N)
11. Paleozoic Extended Crust wide (PEZ_W)
12. Reelfoot Rift (RR)
13. Reelfoot Rift including the Rough Creek Graben (RR-RCG)
14. St. Lawrence Rift, including the Ottawa and Saguenay Grabens (SLR)
15. Study region (STUDY_R)

For sources of large magnitude earthquakes, designated Repeated Large Magnitude Earthquake (RLME) sources in [Ref. 7], the following sources lie within 1,000 km of the site and were included in the analysis:

1. Commerce
2. Eastern Rift Margin Fault northern segment (ERM-N)
3. Eastern Rift Margin Fault southern segment (ERM-S)
4. Marianna
5. New Madrid Fault System (NMFS)
6. 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 [Ref. 2], 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 included in Section 3 at the SSE control point elevation.

2.3 Site Response Evaluation

Following the guidance contained in Seismic Enclosure 1 of the 50.54(f) Request for Information [Ref. 1] and in the SPID [Ref. 2] 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 the CNP.

2.3.1 Description of Subsurface Material

The CNP is located along the eastern shore of Lake Michigan in Berrien County Michigan. The information used to create the site geologic profile is shown in Table 2.3.1-1 [Ref. 6]. As indicated in Table 2.3.1-1, the SSE Control Point is at an elevation of 587.4 ft. The CNP site

consists of about 34 ft (10m) of dune sand overlying 137 ft (42m) of lake deposit with about 3,200 ft (975m) of sedimentary rock followed by Precambrian basement (Table 2.3.1-1). The SSE Control Point at elevation 587.4 ft (Table 2.3.1-1) places it about 9 ft (3m) into the lake deposits with about 127 ft (39m) of lake deposit soils overlying the sedimentary rock section.

The site properties at CNP from Reference 6 are as follows:

> "The southern peninsula of Michigan lies within the Central Lowland Physiographic Province. The topography is typical of areas of regional glaciation. As a consequence of glaciation, land forms are of low to moderate relief and generally smoothly contoured. Bedrock exposures are rare. Reaches of the Lake Michigan shoreline are characterized by extensive sand dunes and ancient shoreline features of Glacial Lake Chicago. Regional drainage in southwest Michigan is toward Lake Michigan on the west.
>
> **Stratigraphy:** The regional bedrock geology is relatively simple. The southwest part of Michigan is located on the flank of a very large synclinal basin, the Michigan Basin. Bedrock consists of a mixed sequence of sedimentary strata including shale, limestone, sandstone and dolomite. The strata range in age from Cambrian to Pennsylvanian. This sequence is underlain by a basement complex of Precambrian igneous and metamorphic rocks.
>
> Bedrock formations in the vicinity of the site include shale and sandstones of Devonian and Mississippian age. The Precambrian basement is estimated to occur at a depth of 3,500 feet. In southwest Michigan, the surficial glacial deposits exceed 350 feet in thickness in places and overlie a moderately irregular bedrock surface. Valleys in the bedrock surface represent pre-glacial stream channels modified to a certain extent by glacial erosion. In the site area, the bedrock surface slopes generally north or northwest.
>
> **Structure:** The Michigan Basin is a remarkably symmetrical dish-shaped structure bounded on the north by the Canadian Shield and on the west by the La Salle Anticline and Wisconsin Arch. On the south side, it is bounded by the Cincinnati-Kankakee-Findlay Arch System. A number of large faults have been mapped in areas surrounding the Michigan Basin. All but one lies well beyond the borders of the state.
>
> **Local Geology:** The site is located within a local physiographic area known as the Grand Marais Embayment. This area, 16 miles long and with an average width of about 1 mile, lies adjacent and parallel to the shore-line of Lake Michigan in western Berrien County. The area adjacent to the beach is characterized by high sand dunes of Pleistocene and Recent origin, and shore features of several glacial lake stages. The area is bounded on the east by a glacial moraine which parallels the shoreline and is known as Covert Ridge. The area east of this ridge is a glacial plain, with morainic ridges."

Table 2.3.1-1 provides a brief description of the subsurface material in terms of the geologic units and layer thicknesses.

Table 2.3.1-1 [Ref. 6]
Geologic Profile and Estimated Layer Thicknesses for CNP

FORMATION SYMBOL	DESCRIPTION	COMPRESSION WAVE VELOCITY (FT/SEC)	ASSUMED POISSON RATIO	SHEAR WAVE VELOCITY (FT/SEC)	UNIT WEIGHT (LBS/CU. FT.)
+761, +622, +597	DUNE SAND	ABOVE WATER TABLE 600 ± 200 (MEASURED) BELOW WATER LINE 5400 ± 200 (MEASURED)	0.35 (ESTIMATED)	800 (CALCULATED)	110 (MEASURED); 130 (MEASURED)
+460	LAKE DEPOSITS (CLAYS AND SILTS)	5400 ± 200 (MEASURED)	0.45 (ESTIMATED)	1600 (CALCULATED)	130 (MEASURED)
	PALEOZOIC SEDIMENTARY ROCKS LIMESTONE DOLOMITE SHALE SANDSTONE	17,000 ± 1,000 (ESTIMATED)	0.20 (ESTIMATED)	10,000 (CALCULATED)	150 TO 170 (ESTIMATED)
-2600	CRYSTALLINE BASEMENT	18,000 ± 1,000 (ESTIMATED)	0.15 (ESTIMATED)	12,000 (CALCULATED)	170 (ESTIMATED)

EL 580 LAKE MICHIGAN
EL 570
EL 554 BEACH SAND

SSE Turbine Bldg Control Point El 565'
Aux Bldg Control Point El 573
SSE Containment Control Point, EL 587.4'

TABLE EPRI-2. GEOTECHNICAL COLUMN
(REFERENCE: D&M REPORT, PLATE IIC-1)

2.3.2 Development of Base Case Profiles and Nonlinear Material Properties

Table 2.3.1-1 that is from Reference 14 and originally transmitted to EPRI from CNP in Reference 6 includes the recommended shear-wave velocities and unit weights along with depths and corresponding stratigraphy. The SSE control point is at an elevation of 587.4 ft and about 9 ft (3m) within the lake deposits at an estimated mean base-case (P1) shear-wave velocity of 1,600 ft/s (488m/s) and thickness of about 127 ft (39m). The shear-wave velocity was based on uphole testing for compressional-waves with an assumed Poisson ratio. As a result a scale factor of 1.57 was selected to reflect lower (P2) and upper (P3) range velocities. The scale factor of 1.57 reflect σ_{ln} of about 0.35, based on the SPID [Ref. 2] 10th and 90th fractiles which implies a 1.28 scale factor on σ_{μ}.

To characterize hard reference rock conditions, shear-wave velocity at or exceeding 9,285 ft/s (2,830m/s), based on an estimated compressional-wave velocity and assumed Poisson ratio, Table 2.3.1-1 indicates an assumed shear-wave velocity of 10,000 ft/s (3,048m/s) for the 3,260 ft (994m) thick sedimentary rock section. To accommodate epistemic uncertainty in the sedimentary rock column, two shear-wave velocities were assumed: hard reference rock velocity of 9,285 ft/s (2,830m/s) and 5,000 ft/s (1,524m/s). The latter shear-wave velocity of 5,000 ft/s (1,524m/s) was selected to address the possibility of thick sections of the sedimentary rock column comprised of softer shales and sandstone. The two cases of sedimentary rock shear-wave velocity resulted in two sets of lower, mean, and upper base-case profiles: P1, P2, and P3 with sedimentary rock shear-wave velocity of 9,285 ft/s (2,830m/s) and P4, P5, and P6 reflecting a velocity of 5,000 ft/s (1,524m/s) for the sedimentary rock column.

The base-case shear wave velocity profiles (P1, P2, P3, and P4, P5, P6) are provided in Tables 2.3.2-2a and 2.3.2-2b and are shown in Figures 2.3.2-2a and b respectively. Depth to Precambrian basement was taken as 3,387 ft (1,032m) randomized ± 1,016 ft (310m). The depth randomization reflects ± 35% of the depth and was included to provide a realistic broadening of the fundamental resonance at deep sites in addition to reflect actual random variations in depth to basement shear-wave velocities across a footprint.

Table 2.3.2-2a
Geologic Profile and Estimated Layer Thickness for CNP (P1, P2,and P3)

Profile 1			Profile 2			Profile 3		
thickness(ft)	depth (ft)	Vs(ft/s)	thickness(ft)	depth (ft)	Vs(ft/s)	thickness(ft)	depth (ft)	Vs(ft/s)
	0	1600		0	1024		0	2512
6.4	6.4	1600	6.4	6.4	1024	6.4	6.4	2512
6.4	12.7	1600	6.4	12.7	1024	6.4	12.7	2512
6.4	19.1	1600	6.4	19.1	1024	6.4	19.1	2512
6.4	25.5	1600	6.4	25.5	1024	6.4	25.5	2512
6.4	31.8	1600	6.4	31.8	1024	6.4	31.8	2512
6.4	38.2	1600	6.4	38.2	1024	6.4	38.2	2512
6.4	44.6	1600	6.4	44.6	1024	6.4	44.6	2512
6.4	50.9	1600	6.4	50.9	1024	6.4	50.9	2512
6.4	57.3	1600	6.4	57.3	1024	6.4	57.3	2512
6.4	63.6	1600	6.4	63.6	1024	6.4	63.6	2512
6.4	70.0	1600	6.4	70.0	1024	6.4	70.0	2512
6.4	76.4	1600	6.4	76.4	1024	6.4	76.4	2512
6.4	82.7	1600	6.4	82.7	1024	6.4	82.7	2512
6.4	89.1	1600	6.4	89.1	1024	6.4	89.1	2512
6.4	95.5	1600	6.4	95.5	1024	6.4	95.5	2512
6.4	101.8	1600	6.4	101.8	1024	6.4	101.8	2512
6.4	108.2	1600	6.4	108.2	1024	6.4	108.2	2512
6.4	114.6	1600	6.4	114.6	1024	6.4	114.6	2512
6.4	120.9	1600	6.4	120.9	1024	6.4	120.9	2512
6.4	127.3	1600	6.4	127.3	1024	6.4	127.3	2512
9.6	136.9	9285	9.6	136.9	9285	9.6	136.9	9285

Table 2.3.2-2b
Geologic Profiles and Estimated Layer Thickness for CNP (P4, P5, and P6)

Profile 4			Profile 5			Profile 6		
thickness(ft)	depth (ft)	Vs(ft/s)	thickness(ft)	depth (ft)	Vs(ft/s)	thickness(ft)	depth (ft)	Vs(ft/s)
	0	1600		0	1024		0	2512
6.4	6.4	1600	6.4	6.4	1024	6.4	6.4	2512
6.4	12.7	1600	6.4	12.7	1024	6.4	12.7	2512
6.4	19.1	1600	6.4	19.1	1024	6.4	19.1	2512
6.4	25.5	1600	6.4	25.5	1024	6.4	25.5	2512
6.4	31.8	1600	6.4	31.8	1024	6.4	31.8	2512
6.4	38.2	1600	6.4	38.2	1024	6.4	38.2	2512
6.4	44.6	1600	6.4	44.6	1024	6.4	44.6	2512
6.4	50.9	1600	6.4	50.9	1024	6.4	50.9	2512
6.4	57.3	1600	6.4	57.3	1024	6.4	57.3	2512
6.4	63.6	1600	6.4	63.6	1024	6.4	63.6	2512
6.4	70.0	1600	6.4	70.0	1024	6.4	70.0	2512
6.4	76.4	1600	6.4	76.4	1024	6.4	76.4	2512
6.4	82.7	1600	6.4	82.7	1024	6.4	82.7	2512
6.4	89.1	1600	6.4	89.1	1024	6.4	89.1	2512
6.4	95.5	1600	6.4	95.5	1024	6.4	95.5	2512
6.4	101.8	1600	6.4	101.8	1024	6.4	101.8	2512
6.4	108.2	1600	6.4	108.2	1024	6.4	108.2	2512
6.4	114.6	1600	6.4	114.6	1024	6.4	114.6	2512
6.4	120.9	1600	6.4	120.9	1024	6.4	120.9	2512
6.4	127.3	1600	6.4	127.3	1024	6.4	127.3	2512
9.6	136.9	5000	9.6	136.9	3200	9.6	136.9	7850
10.0	146.9	5000	10.0	146.9	3200	10.0	146.9	7850
10.0	156.9	5000	10.0	156.9	3200	10.0	156.9	7850
10.0	166.9	5000	10.0	166.9	3200	10.0	166.9	7850
10.0	176.9	5000	10.0	176.9	3200	10.0	176.9	7850
10.0	186.9	5000	10.0	186.9	3200	10.0	186.9	7850
10.0	196.9	5000	10.0	196.9	3200	10.0	196.9	7850
10.0	206.9	5000	10.0	206.9	3200	10.0	206.9	7850
10.0	216.9	5000	10.0	216.9	3200	10.0	216.9	7850
20.0	236.9	5000	20.0	236.9	3200	20.0	236.9	7850
13.4	250.3	5000	13.4	250.3	3200	13.4	250.3	7850
26.6	276.9	5000	26.6	276.9	3200	26.6	276.9	7850
20.0	296.9	5000	20.0	296.9	3200	20.0	296.9	7850
20.0	316.9	5000	20.0	316.9	3200	20.0	316.9	7850
20.0	336.9	5000	20.0	336.9	3200	20.0	336.9	7850

Table 2.3.2-2b
Geologic Profiles and Estimated Layer Thickness for CNP (P4, P5, and P6)

Profile 4			Profile 5			Profile 6		
thickness(ft)	depth (ft)	Vs(ft/s)	thickness(ft)	depth (ft)	Vs(ft/s)	thickness(ft)	depth (ft)	Vs(ft/s)
20.0	356.9	5000	20.0	356.9	3200	20.0	356.9	7850
20.0	376.9	5000	20.0	376.9	3200	20.0	376.9	7850
20.0	396.9	5000	20.0	396.9	3200	20.0	396.9	7850
20.0	416.9	5000	20.0	416.9	3200	20.0	416.9	7850
20.0	436.9	5000	20.0	436.9	3200	20.0	436.9	7850
20.0	456.9	5000	20.0	456.9	3200	20.0	456.9	7850
43.1	500.0	5000	43.1	500.0	3200	43.1	500.0	7850
103.4	603.4	5000	103.4	603.4	3200	103.4	603.4	7850
146.5	749.9	5000	146.5	749.9	3200	146.5	749.9	7850
146.5	896.4	5000	146.5	896.4	3200	146.5	896.4	7850
146.5	1042.9	5000	146.5	1042.9	3200	146.5	1042.9	7850
146.5	1189.5	5000	146.5	1189.5	3200	146.5	1189.5	7850
146.5	1336.0	5000	146.5	1336.0	3200	146.5	1336.0	7850
146.5	1482.5	5000	146.5	1482.5	3200	146.5	1482.5	7850
146.5	1629.0	5000	146.5	1629.0	3200	146.5	1629.0	7850
146.5	1775.5	5000	146.5	1775.5	3200	146.5	1775.5	7850
146.5	1922.0	5000	146.5	1922.0	3200	146.5	1922.0	7850
146.5	2068.5	5000	146.5	2068.5	3200	146.5	2068.5	7850
146.5	2215.0	5000	146.5	2215.0	3200	146.5	2215.0	7850
146.5	2361.6	5000	146.5	2361.6	3200	146.5	2361.6	7850
146.5	2508.1	5000	146.5	2508.1	3200	146.5	2508.1	7850
146.5	2654.6	5000	146.5	2654.6	3200	146.5	2654.6	7850
146.5	2801.1	5000	146.5	2801.1	3200	146.5	2801.1	7850
146.5	2947.6	5000	146.5	2947.6	3200	146.5	2947.6	7850
146.5	3094.1	5000	146.5	3094.1	3200	146.5	3094.1	7850
146.5	3240.6	5000	146.5	3240.6	3200	146.5	3240.6	7850
146.5	3387.1	5000	146.5	3387.1	3200	146.5	3387.1	7850
3280.8	6668.0	9285	3280.8	6668.0	9285	3280.8	6668.0	9285

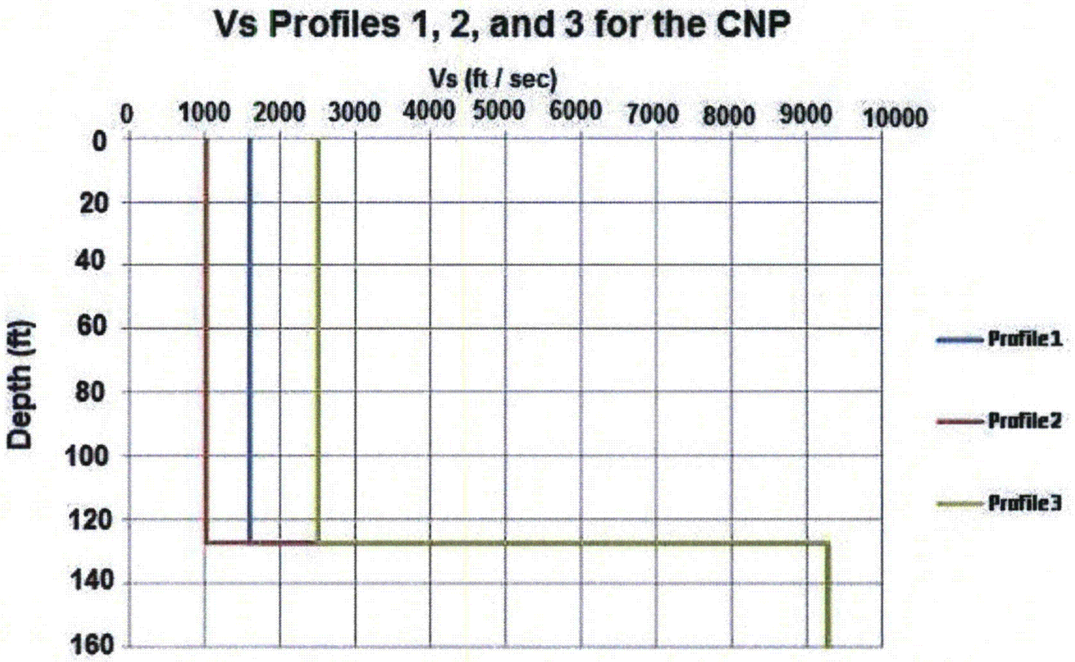


Figure 2.3.2-2a. Shear-Wave Velocity Profiles (P1, P2, P3) Used in Site Response Calculations for CNP

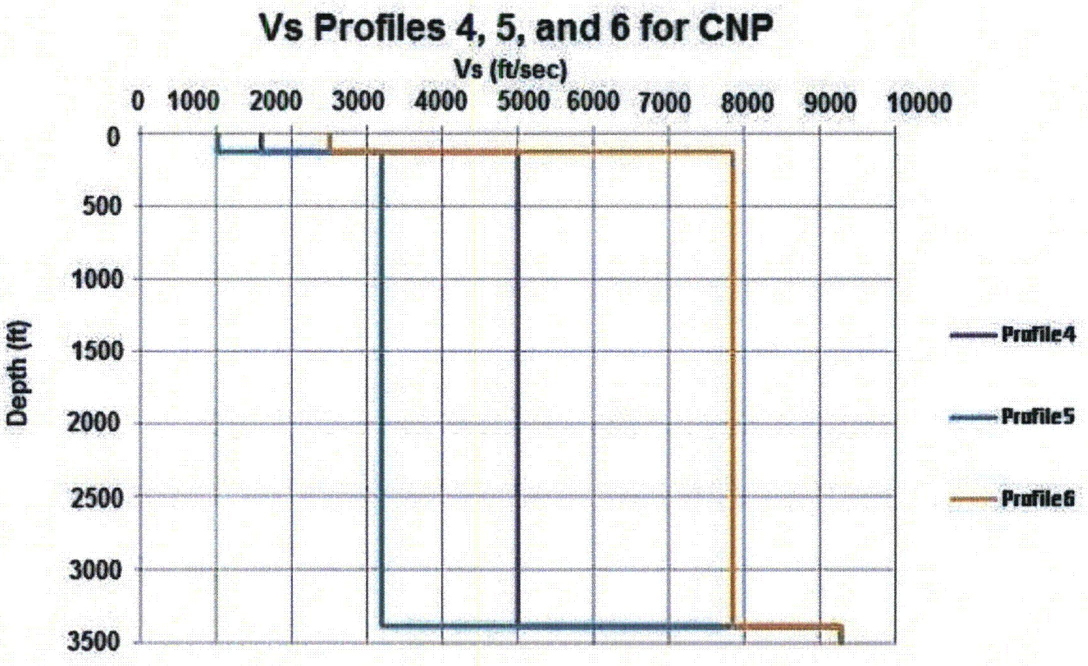


Figure 2.3.2-2b. Shear-Wave Velocity Profiles (P4, P5, P6) Used in Site Response Calculations for CNP

2.3.2.1 Shear Modulus and Damping Curves

As discussed in Reference 14, no site-specific nonlinear dynamic material properties were available for CNP for the soils or firm rock. The firm soil material over the upper 500 ft (150 m) was assumed to have behavior that could be modeled with either EPRI cohesionless soil or Peninsular Range G/G_{max} and hysteretic damping curves while the firm rock was assumed to reflect either EPRI firm rock curves or linear response per the SPID [Ref. 2]. Consistent with the SPID, the EPRI soil and firm rock curves (model M1) were considered to be appropriate to represent the more nonlinear response likely to occur in the materials at this site. The Peninsular Range (PR) curves for soils combined with linear analysis for firm rock (model M2) [Ref. 2] was assumed to represent an equally plausible alternative more linear response across loading level.

2.3.2.2 Kappa

As documented in Reference 14 for shallow, less than about 3,000 ft (1,000m), soil/firm rock sites, kappa may be estimated based on the small strain damping contributed by the profile with the addition of the hard basement rock value of 0.006s, conditioned with an upper bound of 0.04s [Ref. 2]. For the CNP site, with about 127 ft (39m) of soil overlying hard rock (base case profiles P1, P2, and P3) the kappa contributed by the soil low strain damping was about 0.002s, resulting in total kappa values of about 0.008s (Table 2.3.2-3). For the base-case profiles with an assumed shear-wave velocity of 5,000 ft/s (1,524m/s) underlying soils to a depth of 3,387 ft (1,032m), base-case profiles P4, P5, and P6, the kappa contribution from the profiles was 0.018s, 0.028s, and 0.010s respective. The corresponding total kappa estimates were 0.024s, 0.034s, and 0.016s and are listed in Table 2.3.2-3. Epistemic uncertainty in profile damping (kappa) ranges from 0.007s to about 0.034s and is also accommodated at design loading levels by the multiple (2) sets of G/G_{max} and hysteretic damping curves.

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

Velocity Profile	Kappa(s)
P1	0.008
P2	0.009
P3	0.007
P4	0.024
P5	0.034
P6	0.016
	Weights
P1	0.20
P2	0.15
P3	0.15
P4	0.20
P5	0.15
P6	0.15
G/G_{max} and Hysteretic Damping Curves	
M1	0.5
M2	0.5

2.3.3 Randomization of Base Case Profiles

As documented in Reference 14, 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. Random shear wave velocity profiles were developed for the CNP site from the base case profiles shown in Figures 2.3.2-2a and 2.3.2-2b. Consistent with the discussion in Appendix B of the SPID [Ref. 2], 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 [Ref. 9] for 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 [Ref. 2], correlation of shear wave velocity between layers was modeled using the footprint correlation model. A limit of +/- 2 standard deviations about the median value in each layer was assumed in the correlation model, for the limits on random velocity fluctuations.

2.3.4 Input Spectra

As discussed in Reference 14, consistent with the guidance in Appendix B of the SPID [Ref. 2], 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 CNP site were the same as those identified in Tables B-4, B-5, B-6 and B-7of the SPID [Ref. 2] as appropriate for typical CEUS sites.

2.3.5 Methodology

As documented in Reference 14, to perform the site response analyses for the CNP 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 [Ref. 2]. The guidance contained in Appendix B of the SPID [Ref. 2] 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 CNP site.

2.3.6 Amplification Functions

The results of the site response analysis from Reference 14 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 [Ref. 2] 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 G/G_{max} and hysteretic damping curves. 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 an assumed shear-wave velocity of 5,000 ft/s (1,524m/s) for the sedimentary rock column (profile P4), Figure 2.3.6-2 shows the corresponding amplification factors developed for profile P4 with EPRI soil and firm rock G/G_{max} and hysteretic damping curves (model M1). Figures 2.3.6-1 and Figure 2.3.6-2 show differences across frequency as well as loading levels. Tabulated values of the amplification factors are provided in Appendix A.

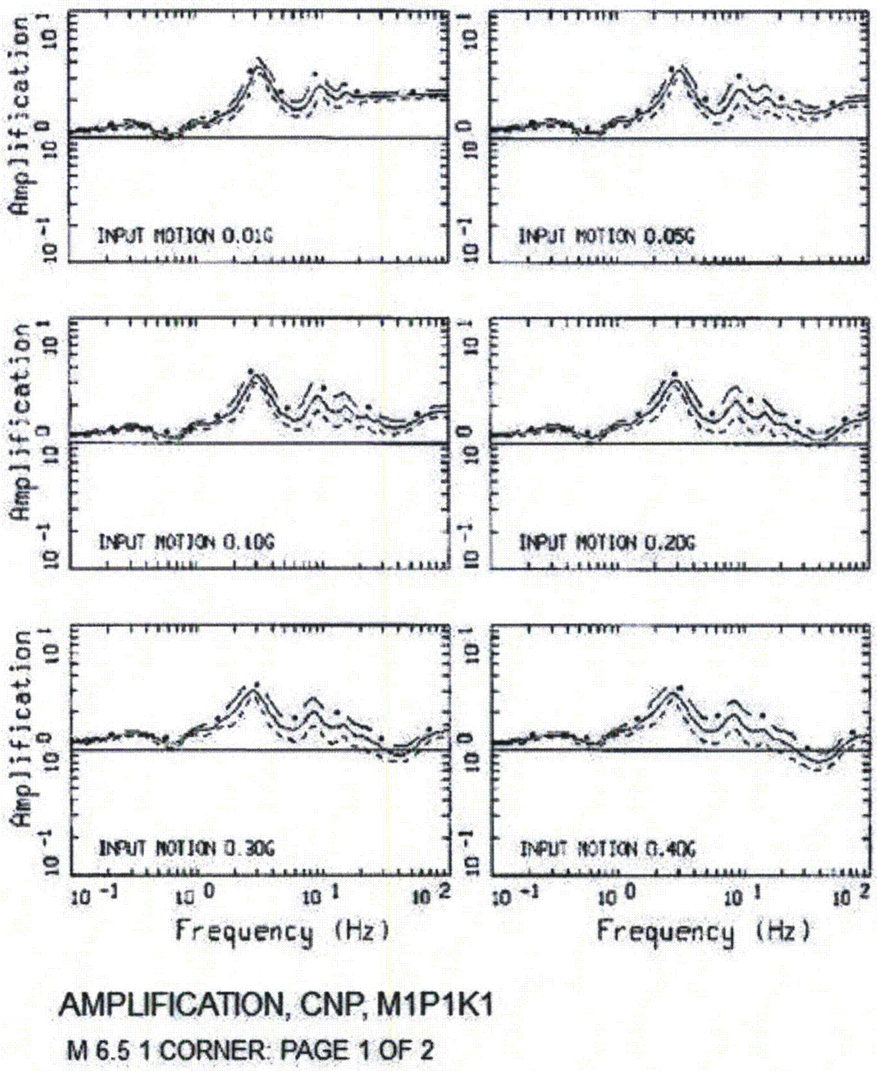
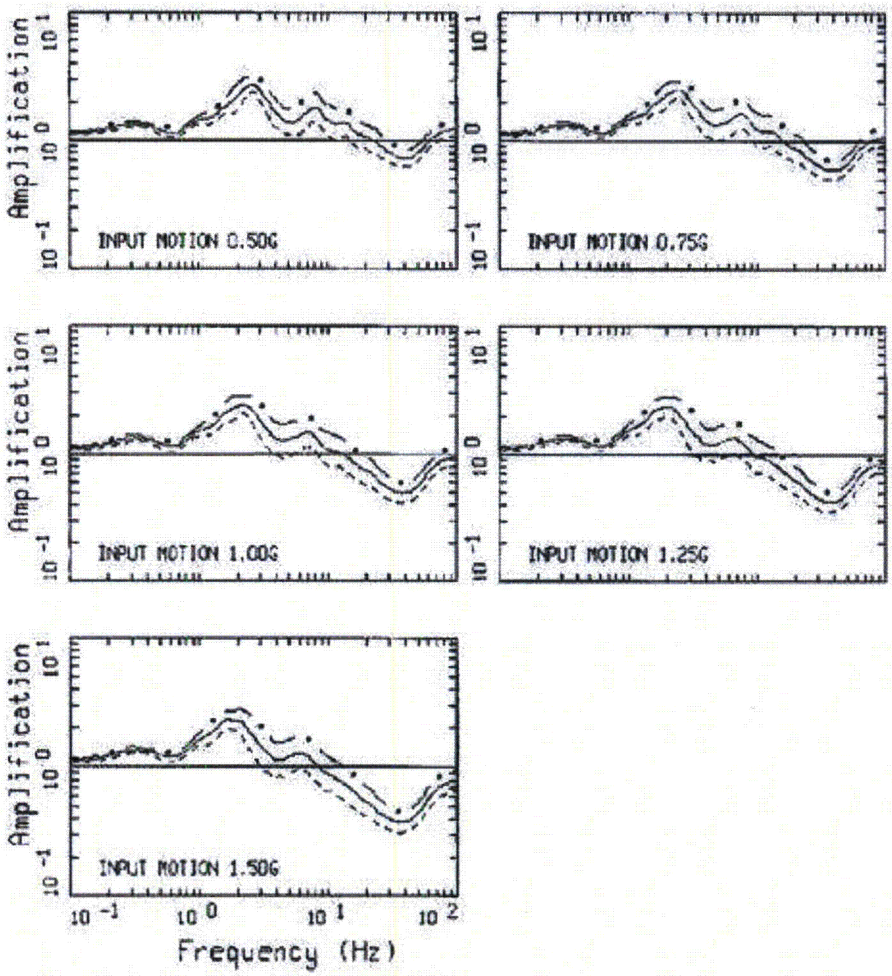


Figure 2.3.6-1. Example suite of amplification factors (5% damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), EPRI soil modulus reduction and hysteretic damping curves (model M1), and base-case kappa at eleven loading levels of hard rock median peak acceleration values from 0.01g to 1.50g. **M** 6.5 and single-corner source model [Ref. 2].



AMPLIFICATION, CNP, M1P1K1
M 6.5, 1 CORNER: PAGE 2 OF 2

Figure 2.3.6-1.(cont.)

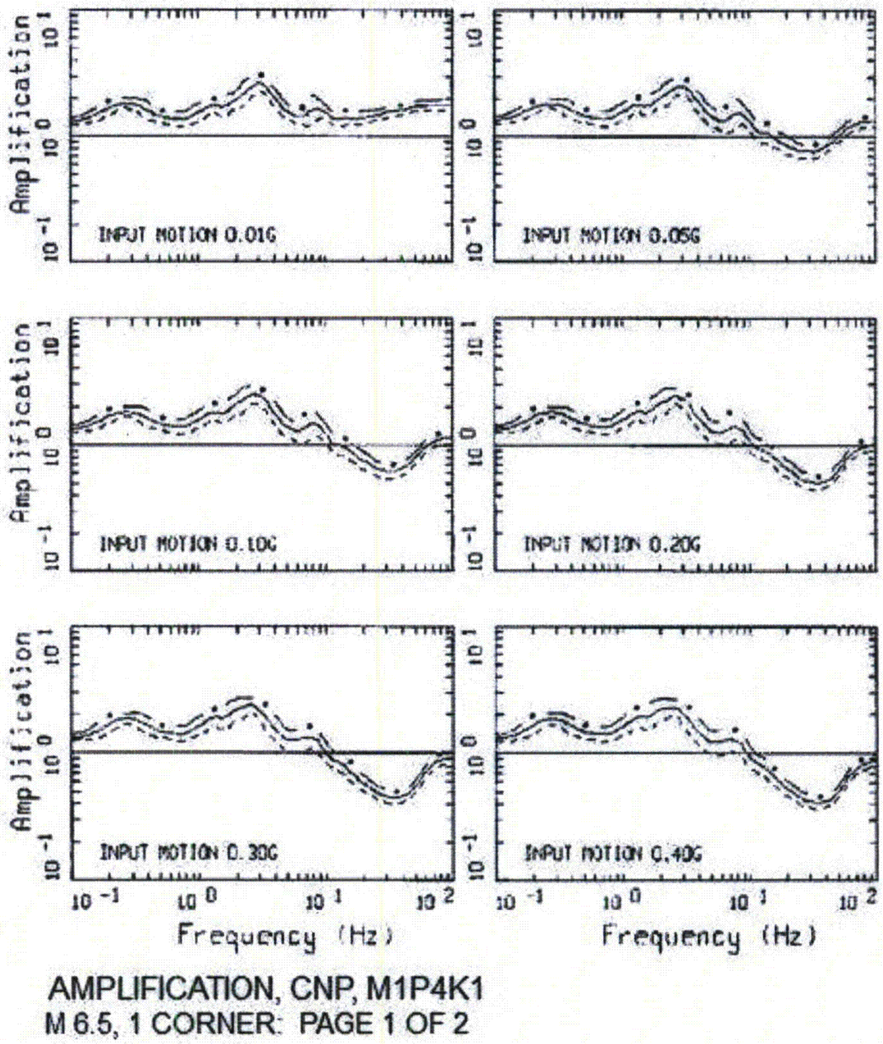


Figure 2.3.6-2. Example suite of amplification factors (5% damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), EPRI soil and firm rock modulus reduction and hysteretic damping curves (model M1), and base-case kappa at eleven loading levels of hard rock median peak acceleration values from 0.01g to 1.50g. **M** 6.5 and single-corner source model [Ref. 2].

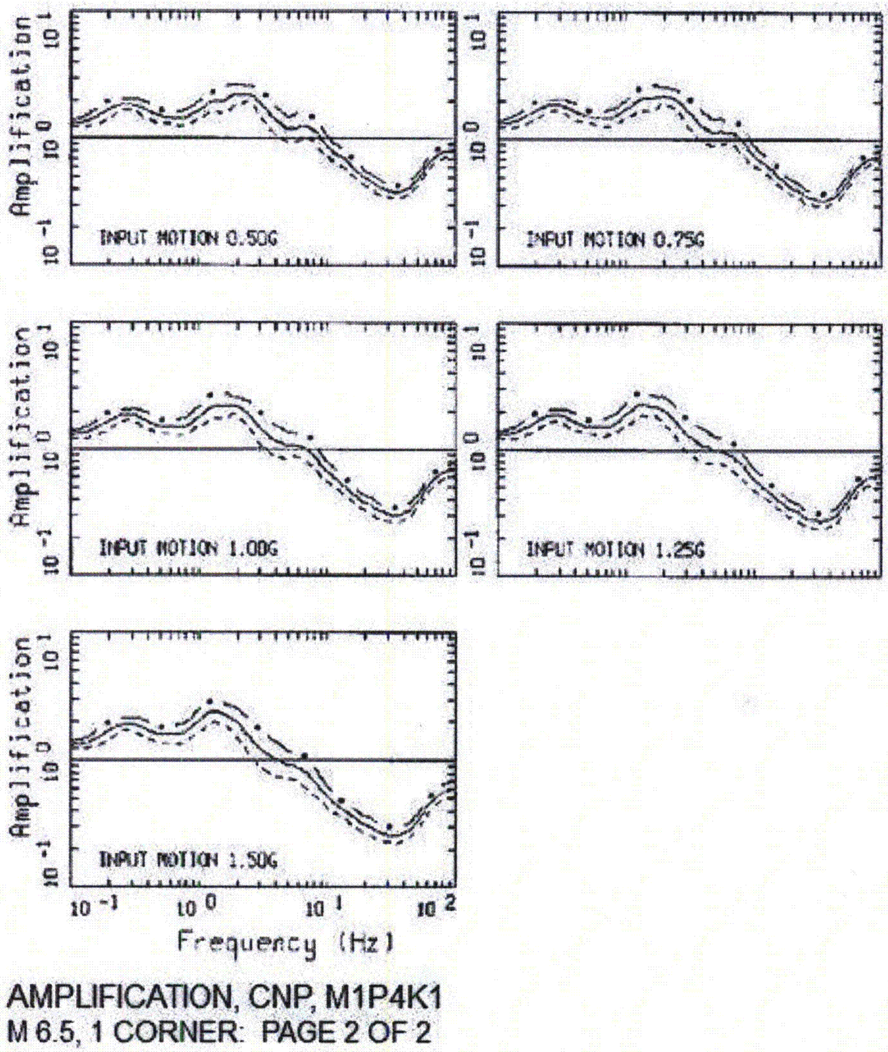


Figure 2.3.6-2.(cont.)

2.3.7 Control Point Seismic Hazard Curves

As documented in Reference 14, the procedure to develop probabilistic site-specific control polnt hazard curves used in the present analysis follows the methodology described in Section B-6.0 of the SPID [Ref. 2]. 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 CNP 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.

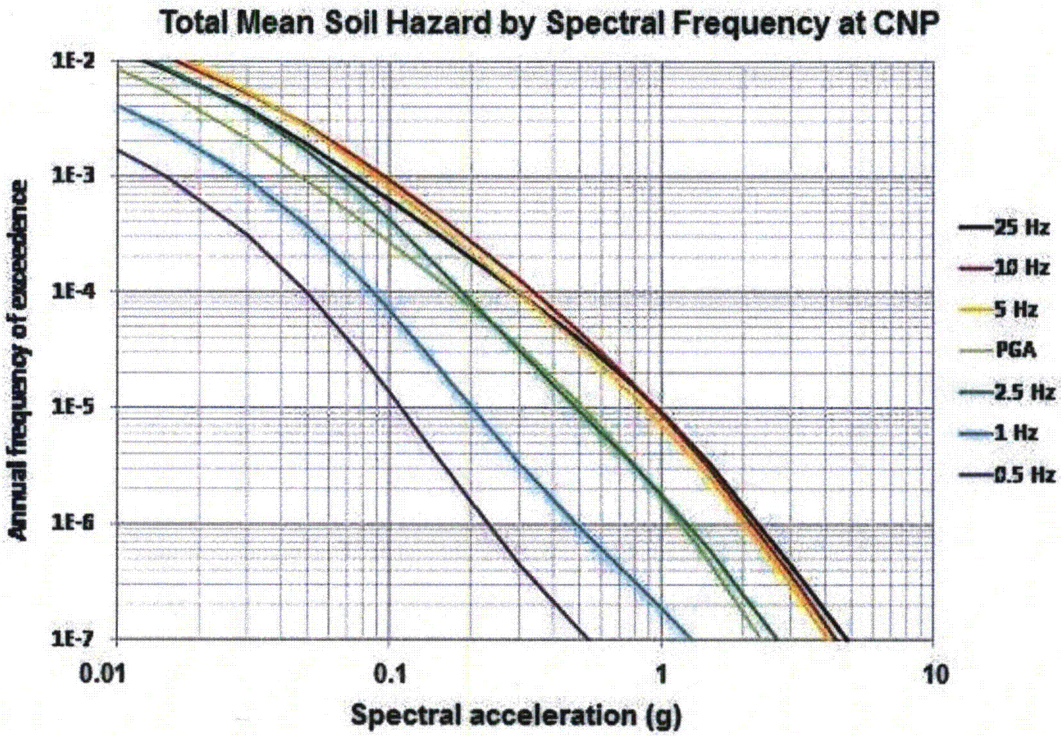


Figure 2.3.7-1. Control point mean hazard curves for spectral frequencies of 0.5, 1, 2.5, 5, 10, 25 and 100 (PGA) Hz at CNP

2.4 Control Point Response Spectrum

The control point hazard curves described in Section 2.3 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 spectral frequency for the 1E-4 and 1E-5 per year hazard levels. Table 2.4-1 shows the UHRS and GMRS accelerations for a range of frequencies.

Table 2.4-1. UHRS for 10-4 and 10-5 and GMRS at Control Point for CNP			
Freq. (Hz)	10^{-4} UHRS (g)	10^{-5} UHRS (g)	GMRS (g)
100	1.71E-01	5.16E-01	2.48E-01
90	1.72E-01	5.22E-01	2.51E-01
80	1.73E-01	5.30E-01	2.54E-01
70	1.77E-01	5.44E-01	2.61E-01
60	1.84E-01	5.72E-01	2.73E-01
50	2.01E-01	6.33E-01	3.02E-01
40	2.30E-01	7.32E-01	3.48E-01
35	2.49E-01	7.89E-01	3.76E-01
30	2.66E-01	8.51E-01	4.05E-01
25	2.95E-01	9.58E-01	4.54E-01
20	3.02E-01	9.70E-01	4.61E-01
15	3.57E-01	1.09E+00	5.25E-01
12.5	3.24E-01	1.05E+00	4.96E-01
10	3.37E-01	9.52E-01	4.64E-01
9	3.35E-01	9.59E-01	4.66E-01
8	3.06E-01	9.49E-01	4.54E-01
7	2.86E-01	8.90E-01	4.26E-01
6	2.97E-01	8.54E-01	4.15E-01
5	2.97E-01	8.69E-01	4.21E-01
4	2.54E-01	7.47E-01	3.61E-01
3.5	2.40E-01	6.54E-01	3.21E-01
3	2.27E-01	5.79E-01	2.88E-01
2.5	1.85E-01	4.87E-01	2.40E-01
2	1.75E-01	4.16E-01	2.10E-01
1.5	1.37E-01	3.32E-01	1.67E-01
1.25	1.08E-01	2.66E-01	1.33E-01
1	8.66E-02	2.02E-01	1.02E-01
0.9	7.94E-02	1.84E-01	9.32E-02
0.8	7.02E-02	1.62E-01	8.22E-02
0.7	6.22E-02	1.42E-01	7.22E-02
0.6	5.54E-02	1.25E-01	6.39E-02
0.5	4.93E-02	1.10E-01	5.63E-02
0.4	3.94E-02	8.82E-02	4.51E-02
0.35	3.45E-02	7.72E-02	3.94E-02
0.3	2.96E-02	6.62E-02	3.38E-02
0.25	2.46E-02	5.52E-02	2.82E-02
0.2	1.97E-02	4.41E-02	2.25E-02
0.15	1.48E-02	3.31E-02	1.69E-02

Table 2.4-1. UHRS for 10-4 and 10-5 and GMRS at Control Point for CNP			
Freq. (Hz)	10^{-4} UHRS (g)	10^{-5} UHRS (g)	GMRS (g)
0.125	1.23E-02	2.76E-02	1.41E-02
0.1	9.86E-03	2.21E-02	1.13E-02

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

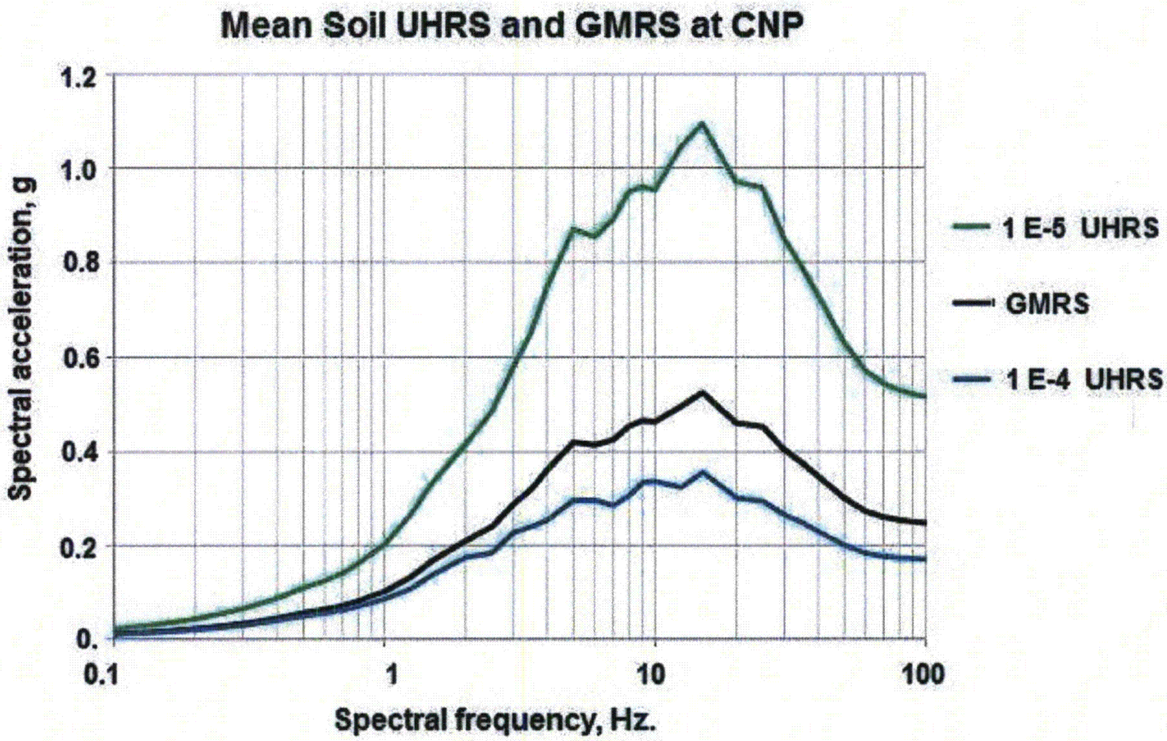


Figure 2.4-1 UHRS for 1E-4 and 1E-5 and GMRS at Control Point for CNP

3.0 Plant Design Basis and Beyond Design Basis Ground Motion

The design basis for CNP is identified in Section 2.5.2 of the CNP UFSAR [Ref. 13].

3.1 SSE Description of Spectral Shape

Section 2.5.2 of the UFSAR [Ref. 13] indicates that the shape and the magnitudes of the CNP DBE and OBE are based on the average (El-Centro) response spectra as presented in TID 7024 [Ref. 21] normalized to the recommended ground accelerations.

On a historical basis as discussed in Section 2.5.2 of the CNP UFSAR [Ref. 13], it did not appear necessary to incorporate a seismic factor in the elastic design of CNP. However, due to the nature of the facility, the major structures were conservatively designed for an Operational Basis Earthquake (OBE) with a maximum horizontal ground acceleration of 10 percent of gravity and a maximum vertical acceleration of 6.66 percent of gravity. The original selection of the maximum potential earthquake assumed that it could be as large as Magnitude 5 and might occur relative to some yet unknown geologic structure in the bedrock near the site, perhaps triggered by glacial rebound. Assuming such a shock might have a focal depth as shallow as 10 kilometers, it was estimated that the maximum ground acceleration at foundation level (within the lake or beach sand deposits) at the site would be about 15 percent of gravity. However, additional margin was provided for by designing the engineered safety features to be operative under a SSE, maximum horizontal ground acceleration of 20 percent of gravity and maximum vertical acceleration of 13.33 percent of gravity.

The SSE is defined in terms of a PGA and a design response spectrum. Considering a site earthquake with an earthquake Magnitude of 5, a Peak Ground Acceleration (PGA) of 0.15g was estimated. For additional conservatism this peak ground acceleration was increased to 0.20g as the anchor point for the SSE. The 5% damped horizontal SSE for the CNP is shown in Table 3.1-1.

Table 3.1-1. SSE for CNP [Ref. 6]

Freq. (Hz)	SA (g)	Freq. (Hz)	SA (g)
100	0.2	2	0.27
50	0.2	1.82	0.25
25	0.2	1.43	0.215
12.5	0.21	1.11	0.18
6.67	0.28	0.77	0.14
5.88	0.31	0.5	0.093
4.17	0.32		
3.45	0.32		

3.2 Control Point Elevation

The SSE control point elevation is defined at elevation 587.4 ft, as shown in Table 2.3.1-1 [Ref. 6]. The SSE control point is not defined in the CNP UFSAR [Ref. 13]. The Control Point is defined in internal documents for structural models and provided in DIT-B-03558-0 [Ref. 6].

3.3 IPEEE Description and Capacity Response Spectrum

The Individual Plant Examinations of External Events (IPEEE) for CNP was performed using a Seismic Probabilistic Risk Assessment (SPRA). The CNP units were binned in the (IPEEE) evaluations as focused scope plants in NUREG-1407 [Ref. 12]. The CNP IPEEE SPRA did not include a relay evaluation because this was not required per NUREG-1407.

NUREG 1742, Volume 2, Table 2.2 [Ref. 11] documents IPEEE HCLPF Spectrum (IHS) for CNP as a 0.25g PGA 1989 Lawrence Livermore National Laboratory (LLNL) – Uniform Hazard Spectrum (UHS) [Ref. 24]. The IHS is not used for screening.

The 5% damped horizontal IHS spectral accelerations are provided in Table 3.3-2. The CNP SSE and IHS for 5% damping are shown in Figure 3.3-1.

Table 3.3-2. IHS for CNP(1)

Frequency (Hz)	Acceleration (g)
1	0.06938
2.5	0.23313
5	0.37005
10	0.42787
25	0.42695
50	0.25
80	0.25

Notes: (1) Scaled from Reference 24.

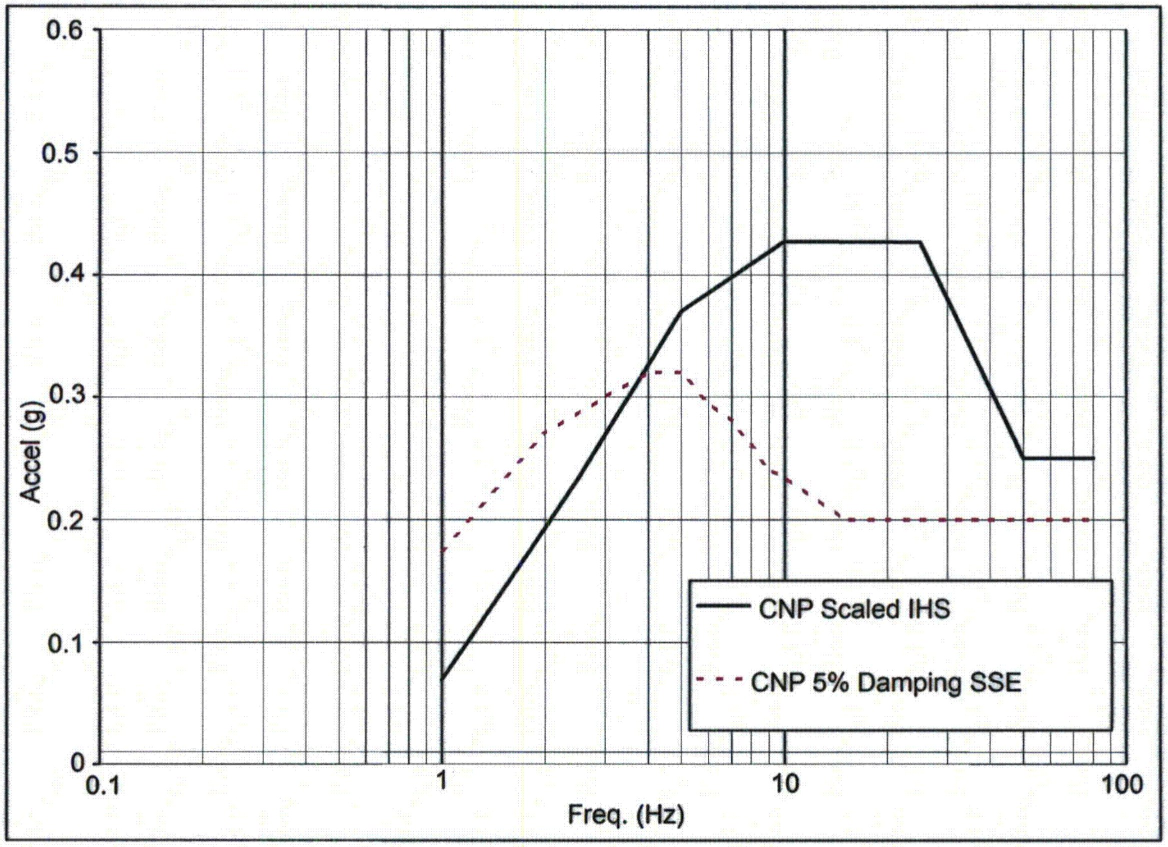


Figure 3.3-1. SSE and IHS Response Spectra for CNP

4.0 Screening Evaluation

In accordance with the SPID Section 3 [Ref. 2], 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 CNP GMRS exceeds the SSE. Therefore, the CNP screens in for risk evaluation.

4.2 High Frequency Screening (>10 Hz)

For the entire frequency range above 10 Hz, the GMRS exceeds the SSE. The high frequency exceedances can be addressed in the risk evaluation discussed in 4.1 above.

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

In the 1 to 10 Hz part of the response spectrum, the CNP GMRS exceeds the SSE. Therefore, the CNP screens in for a Spent Fuel Pool evaluation.

5.0 Interim Actions

Based on the screening evaluation, the expedited seismic evaluation described in EPRI 3002000704 [Ref. 3] will be performed as proposed in a letter to NRC dated April 9, 2013 (ML131 01A379) [Ref. 5] and agreed to by NRC in a letter dated May 7, 2013 (ML13106A331) [Ref. 15].

Consistent with NRC letter dated February 20, 2014, (ML14030A046) [Ref. 22] the seismic hazard reevaluations presented herein are distinct from the current design and licensing bases of the CNP. Therefore, the results do not call into question the operability or functionality of SSCs and are not reportable pursuant to10 CFR 50.72, "Immediate notification requirements for operating nuclear power reactors," [Ref. 16] and10 CFR 50.73, "Licensee event report system" [Ref. 17].

The NRC letter [Ref. 22] 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 [Ref. 18] provides seismic core damage risk estimates using the updated seismic hazards for the operating nuclear plants in the Central and Eastern United States. It was validated in DIT-B-03585-00 [Ref. 23] that the CNP was included in these seismic core damage risk estimates. These risk estimates continue to support the following conclusions of the NRC GI-199 [Ref. 19] 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.

The CNP is included in the March 12, 2014 risk estimates [Ref. 23]. Using the methodology described in the NEI letter, all plants were shown to be below 10^{-4}/year; thus, the above conclusions apply.

The CNP recently completed the Near-Term Task Force (NTTF) Recommendation 2.3 seismic walkdowns and documented the results of that effort in the Reference 20 report. The anomalies or issues identified during that effort were minor and would not prevent the equipment from performing their safety-related functions. Anomalies or issues included minor surface rust, housekeeping issues, anchorage documentation anomalies and potential seismic interaction issues. These anomalies or issues were entered into the CNP Corrective Action Program

(CAP) process and were reconciled using that process. There were no issues or conditions identified that could potentially challenge the seismic licensing basis of the plant.

Section 7 of the Reference 20 report documents that vulnerabilities identified in the CNP1 and CNP2 Individual Plant Evaluation of External Events (IPEEE) Reports have been addressed by either implementing minor enhancements or by corrective maintenance. Furthermore, as described in the discussion of seismic licensing basis evaluations, these conditions and other non-seismic issues were entered into the station's CAP to be addressed. No planned or newly identified protection or mitigation features have resulted from the efforts to address the Recommendation 2.3 Seismic Walkdowns 50.54(f) letter.

6.0 Conclusions

In accordance with the 50.54(f) request for information letter [Ref. 1] a seismic hazard and screening evaluation was performed for CNP. 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 CNP screens in for risk evaluation and a Spent Fuel Pool evaluation.

7.0 References

1) NRC (E Leeds and M Johnson) Letter to All Power Reactor Licensees et al., "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", (ML 12053A340) March 12, 2012.
2) Electric Power Research Institute, (EPRI), Seismic Evaluation Guidance, "*Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic*", Report No. 1025287, November 2012.
3) Electric Power Research Institute, (EPRI), Seismic Evaluation Guidance, "*Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1 – Seismic*", EPRI Final Report 3002000704, May 2013.
4) Atomic Energy Commission, Proposed General Design Criteria, Federal Register, July 11, 1967.
5) NEI (A. R. Pietrangelo) Letter to USNRC (D. L. Skeen), "Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations", (ML13101A379) April 9, 2013.
6) American Electric Power (2013). DIT-B-03558-00, *Site Geologic Conditions for D. C. Cook Nuclear Power Plant,* Design Information Transmittal from AEP to EPRI dated 10/22/13 15 pp.
7) *Central and Eastern United States Seismic Source Characterization for Nuclear Facilities*, U.S. Nuclear Regulatory Commission Report, NUREG-2115; EPRI Report 1021097, 6 Volumes; DOE Report# DOE/NE-0140.
8) *EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project*, Elec. Power Res. Inst, Palo Alto, CA, Rept. 3002000717, June, 2 volumes.
9) Silva, W.J., Abrahamson, N., Toro, G., and Costantino, C. (1997). Appendix of "Description and validation of the stochastic ground motion model", Report Submitted to Brookhaven National Laboratory, Associated Universities, Inc., Upton, New York 11973, Contract No. 770573.
10) U.S. Nuclear Regulatory Commission Reg. Guide 1.208, "A performance-based approach to define the site-specific earthquake ground motion". Rev. 0, 03/2007.
11) NUREG-1742, Volume 2, "Perspectives Gained from the Individual Plant Examination of External Events (IPEEE) Program", Tables, April 2002.
12) USNRC NUREG-1407, Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities, June 1991.
13) D.C. Cook Updated Final Safety Analysis Report (UFSAR), Rev. 25.0, 09/09/13.
14) American Electric Power Report, SD-140218-001, "EPRI Seismic Hazard, GMRS and Screening Report for D. C. Cook Nuclear Plant, Calculation of Seismic Hazards for CEUS Sites", Rev. 0, March 3, 2014.
15) NRC (E. Lees) Letter All Power Reactor Licensees et al., "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," (ML13106A331) May 7, 2013.

16) Code of Federal Regulations 10 CFR 50.72, "Immediate Notification requirements for Operating Nuclear Power Reactors".
17) Code of Federal Regulations 10 CFR 50.73, "Licensee Event Report System".
18) NEI (A. R. Pietrangelo) Letter to USNRC (E. J. Leeds), "Subject: Seismic Risk Evaluations for Plants in the Central and Eastern United States", Including Attachment 1: EPRI Evaluation, "Fleet Seismic Core Damage Frequency Estimates for Central and Eastern U. S. Nuclear Plants Using New Site-Specific Hazard Estimates", and Attachment 2: "Perspectives on the Seismic Capacity of operating Plants", March 12, 2014
19) NRC Information Notice 2010-18: Generic Issue 199, "Implications Of Updated Probabilistic Seismic Hazard Estimates In Central And Eastern United States On Existing Plants, Safety Risk Assessment, August, 2010.
20) American Electric Power Report SD-121023-001, "Seismic Walkdown Report, In Response to the 50.54(f) Information Request Regarding Fukushima Near-Term Task Force Recommendation 2.3: Seismic for the D. C. Cook Unit 1 & Unit 2," Rev. 2, January 13, 2014.
21) TID-7024, "Nuclear Reactors in Earthquakes", United States Atomic Energy Commission, August 1963.
22) NRC (E Leeds) Letter to All Power Reactor Licensees et al., "Supplemental Information Related to Request for information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Seismic Hazard Reevaluations for Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident", (ML14030A046) Feb. 20, 2014.
23) American Electric Power Design Information Transmittal (DIT), DIT-B-03585-00, "Subject: D. C. Cook Nuclear Power Plant site core damage risk estimate using the updated seismic hazard", March 13, 2014.
24) NRC report NUREG/CR-5250, "Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains," Vol. 4, D.L. Bernreuter, J.B. Savy, R.W. Mensing, J.C. Chen, January, 1989.

Appendix A – CNP Seismic Hazard Tables (Ref. 14)

Table A-1a. Mean and Fractile Seismic Hazard Curves for PGA at CNP						
AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	6.26E-02	3.28E-02	4.50E-02	6.26E-02	8.12E-02	9.11E-02
0.001	4.93E-02	2.16E-02	3.28E-02	4.83E-02	6.64E-02	7.77E-02
0.005	1.64E-02	5.66E-03	9.24E-03	1.51E-02	2.32E-02	3.19E-02
0.01	8.55E-03	2.53E-03	4.25E-03	7.55E-03	1.23E-02	1.84E-02
0.015	5.47E-03	1.46E-03	2.39E-03	4.63E-03	8.12E-03	1.29E-02
0.03	2.10E-03	4.43E-04	7.23E-04	1.55E-03	3.19E-03	6.00E-03
0.05	9.06E-04	1.51E-04	2.60E-04	5.91E-04	1.36E-03	2.80E-03
0.075	4.46E-04	6.26E-05	1.13E-04	2.72E-04	6.83E-04	1.42E-03
0.1	2.67E-04	3.47E-05	6.36E-05	1.57E-04	4.13E-04	8.60E-04
0.15	1.29E-04	1.53E-05	2.88E-05	7.45E-05	2.01E-04	4.19E-04
0.3	3.37E-05	3.01E-06	6.45E-06	1.92E-05	5.42E-05	1.10E-04
0.5	1.08E-05	6.09E-07	1.55E-06	5.91E-06	1.79E-05	3.63E-05
0.75	3.85E-06	1.32E-07	4.13E-07	1.92E-06	6.64E-06	1.36E-05
1.	1.70E-06	3.84E-08	1.42E-07	7.66E-07	2.96E-06	6.26E-06
1.5	4.76E-07	5.50E-09	2.60E-08	1.69E-07	8.23E-07	1.90E-06
3.	4.12E-08	1.77E-10	6.83E-10	7.77E-09	6.26E-08	1.82E-07
5.	5.60E-09	1.04E-10	1.21E-10	5.91E-10	6.64E-09	2.49E-08
7.5	9.89E-10	9.11E-11	1.21E-10	1.40E-10	9.51E-10	4.31E-09
10.	2.62E-10	8.12E-11	9.11E-11	1.21E-10	2.68E-10	1.15E-09

Table A-1b. Mean and Fractile Seismic Hazard Curves for 25 Hz at CNP						
AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	6.57E-02	3.95E-02	4.83E-02	6.64E-02	8.35E-02	9.37E-02
0.001	5.43E-02	2.80E-02	3.79E-02	5.35E-02	7.03E-02	8.23E-02
0.005	2.16E-02	8.60E-03	1.27E-02	2.01E-02	3.01E-02	4.07E-02
0.01	1.24E-02	4.31E-03	6.54E-03	1.11E-02	1.74E-02	2.53E-02
0.015	8.48E-03	2.64E-03	4.07E-03	7.45E-03	1.23E-02	1.84E-02
0.03	3.83E-03	8.72E-04	1.40E-03	3.01E-03	6.00E-03	9.51E-03
0.05	1.87E-03	2.88E-04	5.20E-04	1.36E-03	3.01E-03	5.27E-03
0.075	9.98E-04	1.16E-04	2.29E-04	6.83E-04	1.60E-03	2.96E-03
0.1	6.26E-04	6.54E-05	1.32E-04	4.07E-04	1.01E-03	1.90E-03
0.15	3.18E-04	3.19E-05	6.45E-05	1.98E-04	5.20E-04	9.93E-04
0.3	9.69E-05	1.05E-05	2.07E-05	5.91E-05	1.60E-04	3.09E-04
0.5	3.84E-05	4.43E-06	8.60E-06	2.35E-05	6.36E-05	1.21E-04
0.75	1.71E-05	2.01E-06	3.90E-06	1.04E-05	2.88E-05	5.42E-05
1.	9.09E-06	1.05E-06	2.04E-06	5.35E-06	1.55E-05	2.92E-05
1.5	3.33E-06	3.14E-07	6.54E-07	1.90E-06	5.83E-06	1.13E-05
3.	4.41E-07	1.51E-08	4.77E-08	2.39E-07	8.00E-07	1.55E-06
5.	8.94E-08	7.66E-10	3.79E-09	3.52E-08	1.67E-07	3.63E-07
7.5	2.69E-08	1.36E-10	4.50E-10	5.58E-09	4.98E-08	1.23E-07
10.	1.19E-08	1.21E-10	1.53E-10	1.38E-09	2.10E-08	5.83E-08

Table A-1c. Mean and Fractile Seismic Hazard Curves for 10 Hz at CNP						
AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	6.99E-02	4.56E-02	5.27E-02	7.03E-02	8.72E-02	9.65E-02
0.001	6.11E-02	3.52E-02	4.43E-02	6.09E-02	7.89E-02	8.85E-02
0.005	2.78E-02	1.13E-02	1.60E-02	2.60E-02	3.95E-02	4.98E-02
0.01	1.61E-02	5.50E-03	8.23E-03	1.46E-02	2.39E-02	3.09E-02
0.015	1.11E-02	3.37E-03	5.20E-03	9.93E-03	1.67E-02	2.25E-02
0.03	5.25E-03	1.23E-03	2.01E-03	4.43E-03	8.47E-03	1.20E-02
0.05	2.71E-03	5.12E-04	8.72E-04	2.13E-03	4.50E-03	6.93E-03
0.075	1.49E-03	2.39E-04	4.25E-04	1.10E-03	2.46E-03	4.07E-03
0.1	9.34E-04	1.36E-04	2.49E-04	6.64E-04	1.53E-03	2.60E-03
0.15	4.64E-04	6.09E-05	1.16E-04	3.14E-04	7.55E-04	1.34E-03
0.3	1.27E-04	1.49E-05	2.92E-05	8.23E-05	2.13E-04	3.84E-04
0.5	4.47E-05	4.77E-06	9.79E-06	2.84E-05	7.55E-05	1.40E-04
0.75	1.79E-05	1.69E-06	3.63E-06	1.13E-05	3.09E-05	5.66E-05
1.	8.86E-06	7.45E-07	1.64E-06	5.42E-06	1.55E-05	2.84E-05
1.5	2.99E-06	1.98E-07	4.70E-07	1.72E-06	5.35E-06	1.01E-05
3.	3.67E-07	1.23E-08	3.68E-08	1.64E-07	6.54E-07	1.40E-06
5.	6.49E-08	1.10E-09	3.73E-09	2.13E-08	1.11E-07	2.68E-07
7.5	1.48E-08	1.95E-10	5.12E-10	3.63E-09	2.35E-08	6.45E-08
10.	4.87E-09	1.21E-10	1.79E-10	9.79E-10	7.23E-09	2.16E-08

Table A-1d. Mean and Fractile Seismic Hazard Curves for 5 Hz at CNP						
AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	7.23E-02	4.90E-02	5.42E-02	7.23E-02	8.98E-02	9.79E-02
0.001	6.53E-02	4.07E-02	4.83E-02	6.54E-02	8.23E-02	9.24E-02
0.005	3.17E-02	1.36E-02	1.90E-02	3.01E-02	4.50E-02	5.50E-02
0.01	1.80E-02	6.83E-03	9.93E-03	1.67E-02	2.64E-02	3.37E-02
0.015	1.21E-02	4.19E-03	6.36E-03	1.11E-02	1.79E-02	2.35E-02
0.03	5.41E-03	1.53E-03	2.46E-03	4.77E-03	8.35E-03	1.15E-02
0.05	2.62E-03	6.36E-04	1.01E-03	2.16E-03	4.25E-03	6.17E-03
0.075	1.35E-03	2.88E-04	4.63E-04	1.05E-03	2.22E-03	3.47E-03
0.1	8.14E-04	1.55E-04	2.60E-04	6.09E-04	1.32E-03	2.16E-03
0.15	3.82E-04	6.17E-05	1.10E-04	2.72E-04	6.17E-04	1.05E-03
0.3	9.78E-05	1.21E-05	2.39E-05	6.64E-05	1.64E-04	2.88E-04
0.5	3.43E-05	3.23E-06	6.93E-06	2.22E-05	5.91E-05	1.07E-04
0.75	1.41E-05	9.65E-07	2.25E-06	8.60E-06	2.53E-05	4.56E-05
1.	7.19E-06	3.52E-07	8.85E-07	4.13E-06	1.31E-05	2.42E-05
1.5	2.52E-06	6.73E-08	2.01E-07	1.27E-06	4.70E-06	9.24E-06
3.	3.06E-07	1.95E-09	9.24E-09	1.07E-07	5.66E-07	1.27E-06
5.	4.97E-08	1.69E-10	7.13E-10	1.10E-08	8.47E-08	2.22E-07
7.5	1.04E-08	1.21E-10	1.53E-10	1.44E-09	1.49E-08	4.83E-08
10.	3.25E-09	9.11E-11	1.21E-10	3.63E-10	3.90E-09	1.51E-08

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

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	6.99E-02	4.63E-02	5.27E-02	7.03E-02	8.72E-02	9.65E-02
0.001	6.06E-02	3.47E-02	4.37E-02	5.91E-02	7.77E-02	8.98E-02
0.005	2.54E-02	9.93E-03	1.40E-02	2.35E-02	3.73E-02	4.77E-02
0.01	1.35E-02	4.63E-03	6.83E-03	1.21E-02	2.04E-02	2.72E-02
0.015	8.75E-03	2.68E-03	4.13E-03	7.77E-03	1.34E-02	1.82E-02
0.03	3.67E-03	8.12E-04	1.38E-03	3.14E-03	6.00E-03	8.35E-03
0.05	1.66E-03	2.80E-04	5.05E-04	1.27E-03	2.84E-03	4.37E-03
0.075	7.75E-04	1.11E-04	2.04E-04	5.50E-04	1.32E-03	2.22E-03
0.1	4.21E-04	5.50E-05	1.02E-04	2.84E-04	7.13E-04	1.25E-03
0.15	1.65E-04	1.92E-05	3.68E-05	1.07E-04	2.80E-04	4.98E-04
0.3	3.10E-05	2.76E-06	6.00E-06	1.92E-05	5.42E-05	9.93E-05
0.5	9.38E-06	5.83E-07	1.44E-06	5.42E-06	1.67E-05	3.19E-05
0.75	3.63E-06	1.46E-07	4.25E-07	1.90E-06	6.45E-06	1.29E-05
1.	1.79E-06	4.90E-08	1.64E-07	8.47E-07	3.19E-06	6.64E-06
1.5	6.10E-07	9.24E-09	3.79E-08	2.46E-07	1.07E-06	2.39E-06
3.	7.07E-08	4.19E-10	2.01E-09	1.90E-08	1.15E-07	3.09E-07
5.	1.11E-08	1.21E-10	2.32E-10	1.87E-09	1.51E-08	5.05E-08
7.5	2.25E-09	1.01E-10	1.21E-10	2.96E-10	2.46E-09	1.01E-08
10.	6.96E-10	9.11E-11	1.20E-10	1.34E-10	6.36E-10	2.96E-09

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

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	4.71E-02	2.16E-02	3.01E-02	4.56E-02	6.45E-02	7.66E-02
0.001	3.19E-02	1.25E-02	1.84E-02	3.01E-02	4.56E-02	5.66E-02
0.005	8.22E-03	2.57E-03	4.13E-03	7.45E-03	1.23E-02	1.64E-02
0.01	4.05E-03	9.11E-04	1.67E-03	3.57E-03	6.45E-03	8.72E-03
0.015	2.55E-03	4.25E-04	8.47E-04	2.13E-03	4.31E-03	6.17E-03
0.03	9.54E-04	8.98E-05	1.92E-04	6.17E-04	1.74E-03	2.92E-03
0.05	3.65E-04	2.32E-05	5.27E-05	1.90E-04	6.54E-04	1.29E-03
0.075	1.45E-04	7.13E-06	1.72E-05	6.45E-05	2.46E-04	5.50E-04
0.1	6.92E-05	2.96E-06	7.34E-06	2.88E-05	1.11E-04	2.60E-04
0.15	2.27E-05	8.23E-07	2.16E-06	9.11E-06	3.57E-05	8.60E-05
0.3	3.33E-06	7.55E-08	2.49E-07	1.27E-06	5.35E-06	1.34E-05
0.5	9.40E-07	1.08E-08	4.70E-08	3.14E-07	1.53E-06	3.95E-06
0.75	3.69E-07	2.07E-09	1.13E-08	9.93E-08	5.66E-07	1.60E-06
1.	1.89E-07	6.54E-10	3.84E-09	4.31E-08	2.80E-07	8.35E-07
1.5	7.02E-08	1.79E-10	8.23E-10	1.18E-08	9.65E-08	3.19E-07
3.	1.05E-08	1.21E-10	1.32E-10	9.79E-10	1.13E-08	4.63E-08
5.	2.09E-09	9.11E-11	1.21E-10	1.90E-10	1.74E-09	8.60E-09
7.5	5.07E-10	8.47E-11	9.51E-11	1.21E-10	3.84E-10	1.84E-09
10.	1.73E-10	8.12E-11	9.11E-11	1.21E-10	1.69E-10	6.09E-10

Table A-1g. Mean and Fractile Seismic Hazard Curves for 0.5 Hz at CNP						
AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	2.22E-02	1.01E-02	1.42E-02	2.13E-02	3.01E-02	3.73E-02
0.001	1.30E-02	5.50E-03	7.89E-03	1.21E-02	1.79E-02	2.32E-02
0.005	3.35E-03	7.45E-04	1.36E-03	3.01E-03	5.35E-03	7.23E-03
0.01	1.68E-03	1.87E-04	4.13E-04	1.27E-03	3.01E-03	4.50E-03
0.015	1.01E-03	7.03E-05	1.72E-04	6.26E-04	1.90E-03	3.19E-03
0.03	3.09E-04	1.04E-05	2.80E-05	1.31E-04	5.66E-04	1.23E-03
0.05	9.68E-05	2.13E-06	5.91E-06	3.09E-05	1.55E-04	4.13E-04
0.075	3.22E-05	5.42E-07	1.57E-06	8.72E-06	4.70E-05	1.40E-04
0.1	1.36E-05	1.92E-07	6.00E-07	3.33E-06	1.92E-05	5.91E-05
0.15	3.79E-06	4.01E-08	1.44E-07	8.47E-07	5.12E-06	1.69E-05
0.3	4.54E-07	1.90E-09	9.79E-09	8.00E-08	5.91E-07	2.10E-06
0.5	1.21E-07	2.29E-10	1.08E-09	1.31E-08	1.29E-07	5.83E-07
0.75	4.70E-08	1.21E-10	2.25E-10	2.92E-09	3.90E-08	2.19E-07
1.	2.42E-08	1.21E-10	1.31E-10	9.79E-10	1.67E-08	1.07E-07
1.5	9.14E-09	9.11E-11	1.21E-10	2.42E-10	4.56E-09	3.68E-08
3.	1.45E-09	8.12E-11	9.11E-11	1.21E-10	4.56E-10	4.50E-09
5.	3.03E-10	8.12E-11	9.11E-11	1.21E-10	1.38E-10	8.00E-10
7.5	7.56E-11	8.12E-11	9.11E-11	1.21E-10	1.21E-10	2.29E-10
10.	2.60E-11	8.12E-11	9.11E-11	1.21E-10	1.21E-10	1.34E-10

Table A-2a. Amplification Functions for CNP

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	1.99E+00	8.76E-02	1.30E-02	1.75E+00	1.03E-01	1.90E-02	1.82E+00	2.09E-01	2.09E-02	2.12E+00	2.00E-01
4.95E-02	1.60E+00	1.04E-01	1.02E-01	1.22E+00	1.91E-01	9.99E-02	1.59E+00	2.29E-01	8.24E-02	2.04E+00	2.09E-01
9.64E-02	1.42E+00	1.10E-01	2.13E-01	1.07E+00	2.11E-01	1.85E-01	1.47E+00	2.34E-01	1.44E-01	1.99E+00	1.94E-01
1.94E-01	1.25E+00	1.17E-01	4.43E-01	9.28E-01	2.21E-01	3.56E-01	1.31E+00	2.35E-01	2.65E-01	1.89E+00	1.81E-01
2.92E-01	1.14E+00	1.21E-01	6.76E-01	8.43E-01	2.23E-01	5.23E-01	1.20E+00	2.39E-01	3.84E-01	1.80E+00	1.78E-01
3.91E-01	1.07E+00	1.24E-01	9.09E-01	7.79E-01	2.21E-01	6.90E-01	1.13E+00	2.45E-01	5.02E-01	1.72E+00	1.82E-01
4.93E-01	1.01E+00	1.27E-01	1.15E+00	7.25E-01	2.22E-01	8.61E-01	1.07E+00	2.49E-01	6.22E-01	1.65E+00	1.90E-01
7.41E-01	9.02E-01	1.35E-01	1.73E+00	6.23E-01	2.27E-01	1.27E+00	9.65E-01	2.63E-01	9.13E-01	1.51E+00	2.09E-01
1.01E+00	8.21E-01	1.44E-01	2.36E+00	5.47E-01	2.38E-01	1.72E+00	8.85E-01	2.75E-01	1.22E+00	1.39E+00	2.33E-01
1.28E+00	7.57E-01	1.52E-01	3.01E+00	5.00E-01	2.51E-01	2.17E+00	8.22E-01	2.83E-01	1.54E+00	1.29E+00	2.50E-01
1.55E+00	7.08E-01	1.59E-01	3.63E+00	5.00E-01	2.61E-01	2.61E+00	7.73E-01	2.85E-01	1.85E+00	1.21E+00	2.63E-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	2.10E+00	1.97E-01	1.27E-02	1.56E+00	1.59E-01	8.25E-03	1.30E+00	1.25E-01			
7.05E-02	2.02E+00	2.00E-01	3.43E-02	1.60E+00	1.64E-01	1.96E-02	1.32E+00	1.23E-01			
1.18E-01	1.98E+00	2.02E-01	5.51E-02	1.63E+00	1.70E-01	3.02E-02	1.33E+00	1.23E-01			
2.12E-01	1.93E+00	1.95E-01	9.63E-02	1.67E+00	1.79E-01	5.11E-02	1.34E+00	1.25E-01			
3.04E-01	1.88E+00	1.85E-01	1.36E-01	1.70E+00	1.83E-01	7.10E-02	1.35E+00	1.27E-01			
3.94E-01	1.84E+00	1.78E-01	1.75E-01	1.73E+00	1.83E-01	9.06E-02	1.36E+00	1.29E-01			
4.86E-01	1.79E+00	1.77E-01	2.14E-01	1.76E+00	1.78E-01	1.10E-01	1.36E+00	1.31E-01			
7.09E-01	1.68E+00	1.90E-01	3.10E-01	1.81E+00	1.67E-01	1.58E-01	1.37E+00	1.37E-01			
9.47E-01	1.58E+00	2.21E-01	4.12E-01	1.81E+00	1.74E-01	2.09E-01	1.39E+00	1.64E-01			
1.19E+00	1.49E+00	2.47E-01	5.18E-01	1.80E+00	1.92E-01	2.62E-01	1.42E+00	1.93E-01			
1.43E+00	1.45E+00	2.57E-01	6.19E-01	1.79E+00	2.09E-01	3.12E-01	1.44E+00	2.04E-01			

Tables A2-b1 and A2-b2 are tabular versions of the 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. These factors are unverified and are provided for information only. Figures 2.3.6-1 and 2.3.6-2 in the report 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=0.391		
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
100.0	0.174	1.809	0.094	100.0	0.520	1.330	0.119
87.1	0.176	1.789	0.094	87.1	0.525	1.302	0.119
75.9	0.179	1.754	0.094	75.9	0.532	1.252	0.120
66.1	0.184	1.687	0.095	66.1	0.545	1.160	0.123
57.5	0.194	1.563	0.098	57.5	0.570	1.017	0.129
50.1	0.211	1.443	0.103	50.1	0.612	0.900	0.133
43.7	0.232	1.350	0.107	43.7	0.665	0.827	0.140
38.0	0.253	1.327	0.117	38.0	0.723	0.824	0.147
33.1	0.280	1.367	0.139	33.1	0.785	0.854	0.163
28.8	0.306	1.470	0.144	28.8	0.851	0.934	0.175
25.1	0.316	1.487	0.193	25.1	0.936	1.029	0.205
21.9	0.340	1.651	0.175	21.9	0.957	1.116	0.213
19.1	0.335	1.626	0.196	19.1	0.995	1.187	0.205
16.6	0.366	1.823	0.203	16.6	0.998	1.250	0.234
14.5	0.372	1.913	0.264	14.5	1.113	1.469	0.231
12.6	0.339	1.775	0.276	12.6	1.045	1.428	0.271
11.0	0.360	1.913	0.243	11.0	1.032	1.455	0.288
9.5	0.419	2.308	0.245	9.5	1.105	1.640	0.262
8.3	0.364	2.153	0.317	8.3	1.174	1.900	0.256
7.2	0.274	1.714	0.277	7.2	1.003	1.742	0.280
6.3	0.231	1.526	0.184	6.3	0.813	1.510	0.261
5.5	0.229	1.572	0.159	5.5	0.729	1.423	0.214
4.8	0.248	1.728	0.169	4.8	0.726	1.455	0.211
4.2	0.292	2.086	0.195	4.2	0.786	1.631	0.225
3.6	0.363	2.654	0.181	3.6	0.920	1.968	0.249
3.2	0.431	3.327	0.118	3.2	1.090	2.483	0.205
2.8	0.390	3.156	0.171	2.8	1.196	2.881	0.130
2.4	0.276	2.405	0.214	2.4	1.009	2.642	0.188
2.1	0.204	1.953	0.179	2.1	0.776	2.240	0.228
1.8	0.160	1.706	0.140	1.8	0.594	1.924	0.205
1.6	0.131	1.605	0.086	1.6	0.470	1.761	0.125
1.4	0.103	1.459	0.072	1.4	0.358	1.564	0.097
1.2	0.087	1.390	0.083	1.2	0.294	1.462	0.102
1.0	0.079	1.385	0.065	1.0	0.260	1.438	0.078
0.91	0.068	1.318	0.053	0.91	0.222	1.357	0.056
0.79	0.057	1.197	0.058	0.79	0.181	1.227	0.058
0.69	0.048	1.121	0.074	0.69	0.150	1.145	0.074
0.60	0.041	1.114	0.087	0.60	0.128	1.133	0.087
0.52	0.037	1.156	0.081	0.52	0.113	1.173	0.081
0.46	0.033	1.223	0.060	0.46	0.099	1.236	0.060
0.10	0.001	1.165	0.022	0.10	0.004	1.161	0.024

Table A2-b2. Median AFs and sigmas for Model 1, Profile 4, for 2 PGA levels.

M1P4K1	PGA=0.0964			M1P4K1	PGA=0.391		
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
100.0	0.112	1.160	0.107	100.0	0.344	0.880	0.104
87.1	0.112	1.138	0.108	87.1	0.345	0.855	0.104
75.9	0.112	1.102	0.108	75.9	0.346	0.814	0.104
66.1	0.113	1.034	0.109	66.1	0.347	0.738	0.105
57.5	0.114	0.916	0.110	57.5	0.348	0.622	0.106
50.1	0.115	0.786	0.114	50.1	0.352	0.517	0.108
43.7	0.117	0.684	0.119	43.7	0.357	0.444	0.111
38.0	0.121	0.632	0.123	38.0	0.365	0.416	0.115
33.1	0.125	0.611	0.130	33.1	0.376	0.409	0.119
28.8	0.131	0.628	0.137	28.8	0.389	0.428	0.120
25.1	0.138	0.646	0.131	25.1	0.409	0.450	0.130
21.9	0.147	0.714	0.155	21.9	0.427	0.498	0.128
19.1	0.159	0.772	0.182	19.1	0.460	0.549	0.145
16.6	0.171	0.852	0.162	16.6	0.495	0.620	0.162
14.5	0.186	0.955	0.175	14.5	0.539	0.711	0.165
12.6	0.193	1.008	0.195	12.6	0.575	0.786	0.165
11.0	0.204	1.082	0.168	11.0	0.604	0.851	0.168
9.5	0.239	1.315	0.190	9.5	0.670	0.995	0.204
8.3	0.247	1.458	0.213	8.3	0.734	1.187	0.217
7.2	0.226	1.418	0.285	7.2	0.732	1.272	0.200
6.3	0.197	1.303	0.211	6.3	0.679	1.261	0.243
5.5	0.192	1.319	0.169	5.5	0.626	1.223	0.219
4.8	0.205	1.431	0.190	4.8	0.618	1.239	0.214
4.2	0.233	1.669	0.206	4.2	0.666	1.382	0.238
3.6	0.272	1.990	0.202	3.6	0.747	1.598	0.250
3.2	0.308	2.374	0.162	3.2	0.837	1.907	0.227
2.8	0.307	2.485	0.162	2.8	0.906	2.184	0.173
2.4	0.267	2.327	0.191	2.4	0.873	2.285	0.146
2.1	0.224	2.136	0.216	2.1	0.773	2.233	0.189
1.8	0.182	1.932	0.192	1.8	0.654	2.119	0.216
1.6	0.145	1.771	0.179	1.6	0.518	1.939	0.217
1.4	0.127	1.800	0.156	1.4	0.443	1.934	0.194
1.2	0.109	1.739	0.152	1.2	0.371	1.847	0.168
1.0	0.092	1.615	0.168	1.0	0.306	1.694	0.168
0.91	0.078	1.496	0.155	0.91	0.255	1.554	0.154
0.79	0.066	1.399	0.136	0.79	0.213	1.442	0.140
0.69	0.059	1.382	0.132	0.69	0.185	1.417	0.137
0.60	0.052	1.411	0.123	0.60	0.163	1.438	0.126
0.52	0.046	1.444	0.114	0.52	0.141	1.467	0.114
0.46	0.041	1.509	0.136	0.46	0.122	1.527	0.133
0.10	0.002	1.342	0.060	0.10	0.004	1.340	0.060

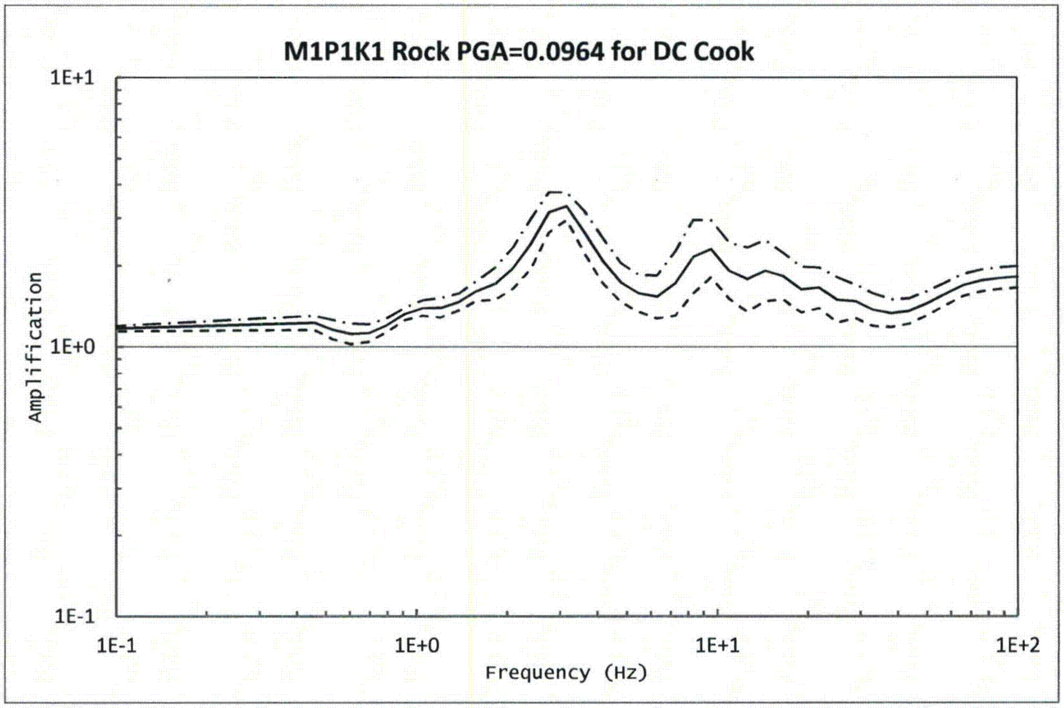


Figure A2-1 Amplification factors (median and median ± sigma) plotted from Table A2-b1 for PGA 0.0964 g

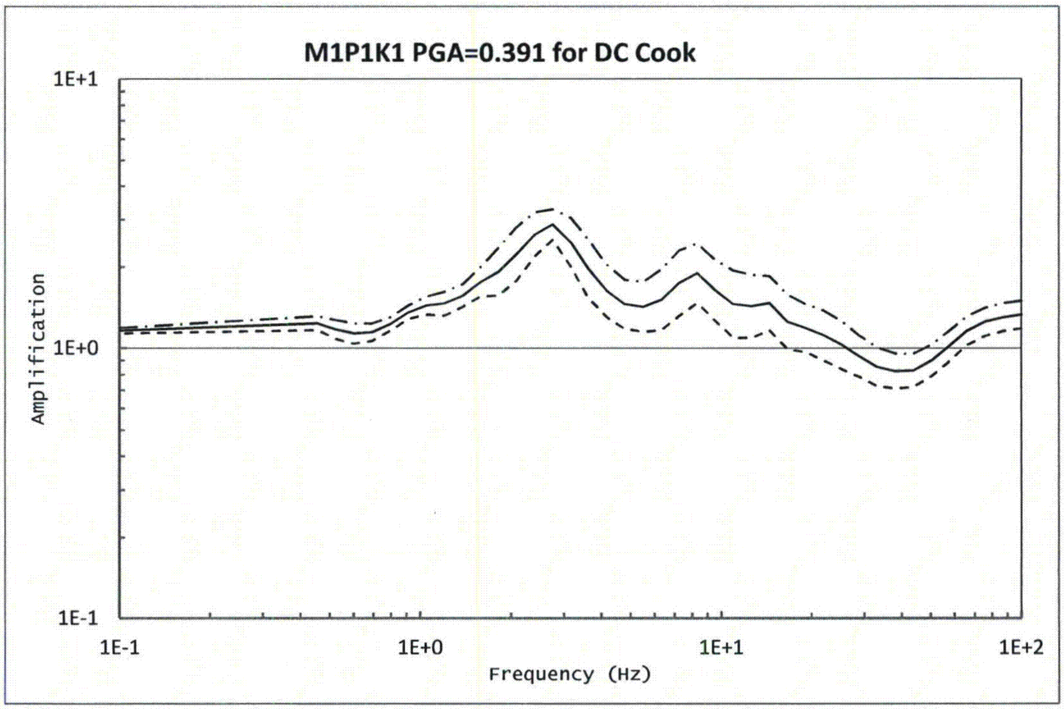


Figure A2-2 Amplification factors (median and median ± sigma) plotted from Table A2-b1for PGA 0.391 g

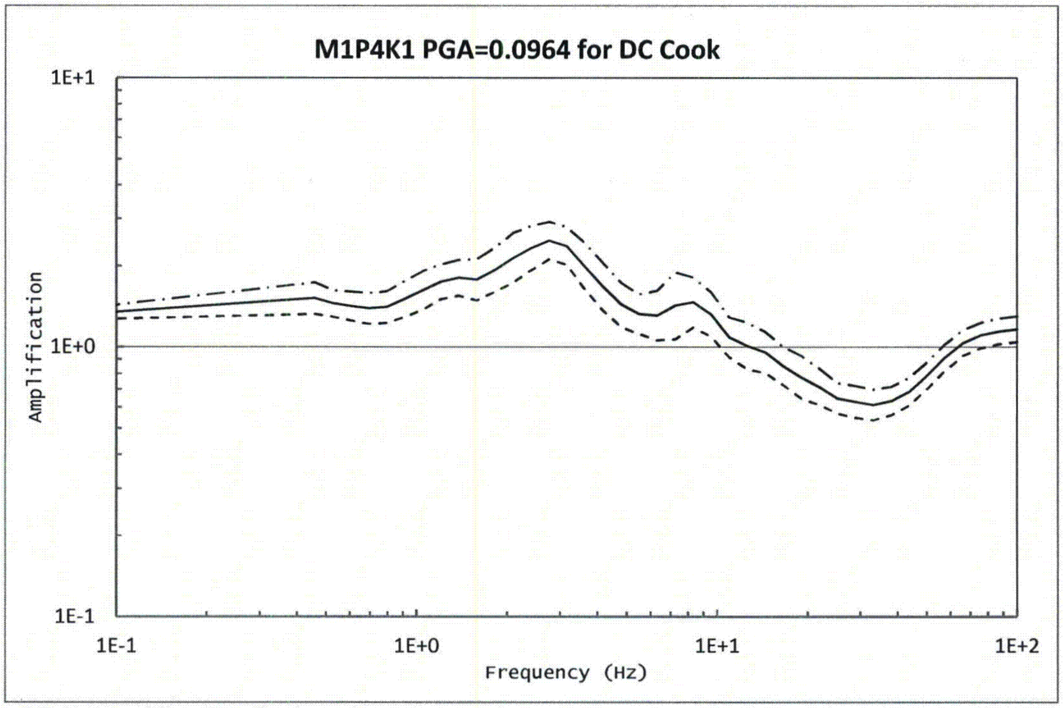


Figure A2-3 Amplification factors (median and median ± sigma) plotted from Table A2-b2 for PGA 0.0964 g.

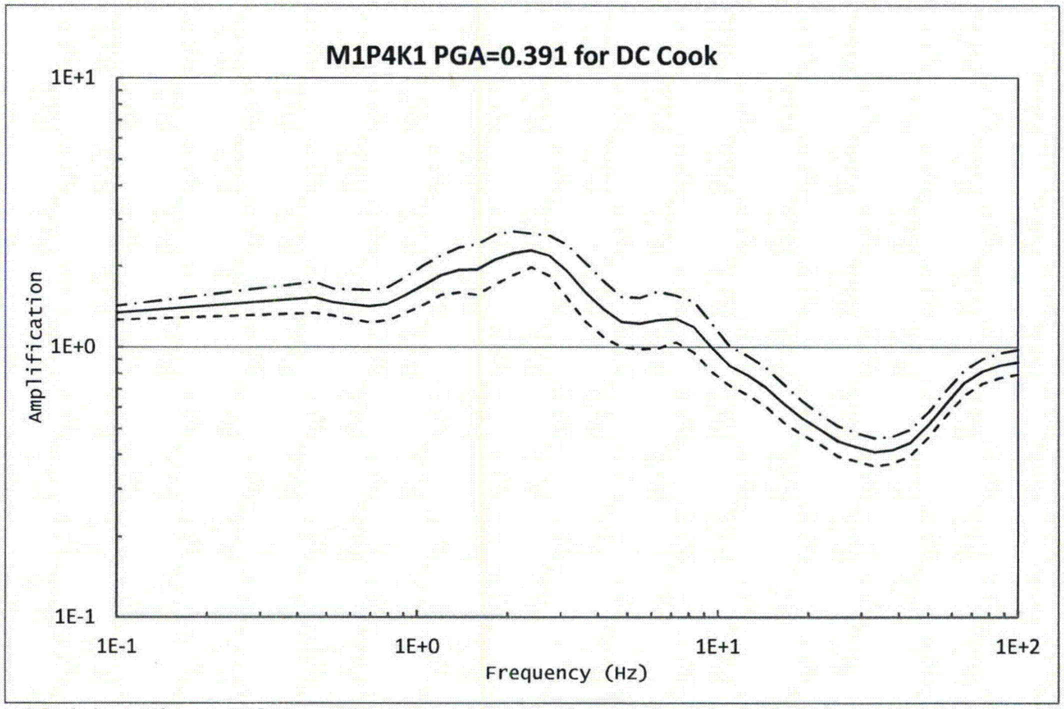


Figure A2-4 Amplification factors (median and median ± sigma) plotted from Table A2-b2 for PGA 0.391 g