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Omaha, NE 68102-2247

LIC-14-0047
March 31, 2014

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

Fort Calhoun Station, Unit No. 1
Renewed Facility Operating License No. DPR-40
NRC Docket No. 50-285

Subject: Omaha Public Power District (OPPD) 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

References:

1. NRC Letter, *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*, dated March 12, 2012
2. NEI Letter, *Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations*, dated April 9, 2013, ADAMS Accession No. ML13101A379
3. NRC Letter, *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*, dated May 7, 2013, ADAMS Accession No. ML13106A331
4. 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*, ADAMS Accession No. ML12333A170
5. NRC Letter, *Endorsement of EPRI Final Draft Report 1025287, "Seismic Evaluation Guidance,"* dated February 15, 2013, ADAMS Accession No. ML12319A074

On March 12, 2012, the Nuclear Regulatory Commission (NRC) issued Reference 1 to all power reactor licensees and holders of construction permits in active or deferred status. Enclosure 1 of Reference 1 requested each addressee located in the Central and Eastern United States (CEUS) 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 2, the Nuclear Energy Institute (NEI) requested NRC agreement to delay submittal of the final 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 3.

Reference 4 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 5.

The attached Seismic Hazard Evaluation and Screening Report for Fort Calhoun Station, provides the information described in Section 4 of Reference 4 in accordance with the schedule identified in Reference 2.

This letter contains no new regulatory commitments.

If you should have any questions regarding this submittal or require additional information, please contact Mr. Bill R. Hansher, Supervisor-Nuclear Licensing, at 402-533-6894.

I declare under penalty of perjury that the foregoing is true and correct. Executed on March 31, 2014.

Respectfully,

Louis P. Cortopassi
Site Vice President and CNO

LPC/JKG/mle

Attachment: Seismic Hazard Evaluation and Screening Report for Fort Calhoun Station

c: M. L. Dapas, NRC Regional Administrator, Region IV)
J. W. Sebrosky, NRC Senior Project Manager
J. C. Kirkland, NRC Senior Resident Inspector

LIC-14-0047
Attachment

Seismic Hazard Evaluation and Screening Report

For Fort Calhoun Station

March 2014

Seismic Hazard and Screening Report for Fort Calhoun

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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 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) (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 Fort Calhoun Station (FCS), located in Washington County, Nebraska. In providing this information, OPPD 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, 2013a). The Augmented Approach, Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic (EPRI 3002000704, 2013c), has been developed as the process for evaluating critical plant equipment prior to performing the complete plant seismic risk evaluations.

FCS was licensed in accordance with the draft criteria set forth in the 70 General Design Criteria for Nuclear Power Plant Construction, published for comment in the Federal Register (32 FR 10213) on July 11,1967.

In response to the 50.54(f) letter and following the guidance provided in the SPID (EPRI 1025287, 2013a), a seismic hazard reevaluation for FCS was performed to develop a Ground Motion Response Spectrum (GMRS).

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

2. Seismic Hazard Re-evaluation

As noted in Section 2 of the FCS Updated Safety Analysis Report (OPPD, 2011), FCS is located approximately 19.4 miles north of Omaha, Nebraska. The site is underlain by 65 to 75 feet of unconsolidated alluvial and glacial deposits, largely loose to moderately compact silty sand and deeper sands and gravels resting on sedimentary bedrock. The bedrock is generally flat with a westward dip.

A study of the possible existence of faults was made during the geologic investigation of the area. No faulting is apparent in the unconsolidated Pleistocene and recent sediments of the Missouri River lowlands.

The closest known regional structures in the vicinity of the site are the Nehawka-Richfield Arch and the La Platte Fault. The Nehawka-Richfield Arch extends from near Omaha-Council Bluffs south and southwest for about 20 to 30 miles. There is no record of movement of the fault in historic times, or any indication of activity in recent geologic time.

One of the major structural features of the Nebraska-Iowa region is the Thurman-Wilson Fault that extends from south of Lincoln, Nebraska, northeast for about 150 miles, almost to Des Moines, Iowa. There is no record of movement of this fault in historic times.

The epicenters of several shocks in the region with a Modified Mercalli Intensity greater than V are located in a zone south of Omaha parallel to the Nemaha Uplift and the Abilene Arch. The epicenters fall between the Salina Basin on the west and the Forest City Basin on the east. Other activity is centered south and west of the Sioux Uplift, northwest of the site. Epicentral locations of all known earthquakes in the vicinity of the site with Modified Mercalli Intensity V were tabulated in the Dames and Moore study referenced in Appendix B of the FCS USAR.

A number of smaller earthquakes have been experienced in the Nebraska-Iowa region. The epicenters of some of these shocks were along the Missouri, Platte, and Solomon Rivers. Studies in Illinois indicate a possible relationship between river load and earthquake occurrence, but no similar studies have been performed for this area. In general, because of poor records and lack of damage associated with these smaller shocks, they are of little significance.

The significant shocks i.e., those within 200 miles of the site, were tabulated. On the basis of this history, it is evident that the site lies in a region of infrequent seismic activity. Since the middle of the 19th century, from the first historical record of earthquake occurrence in the area, only 12 shocks with epicentral Modified Mercalli Intensities of V or greater have occurred within 200 miles of the plant site. These shocks were all of light to moderate intensity, with few of sufficient intensity to cause structural damage.

The largest earthquakes reported in the area had epicentral intensities of Modified Mercalli VII. Three shocks of this intensity originated within 200 miles of the site. Of these, the closest occurred in November 1877 near Lincoln, Nebraska, about 60 miles from the site. It is estimated that this shock had a magnitude of about 5 or slightly higher on the Richter Scale.

A shock of Modified Mercalli Intensity VII occurred in April 1867, near Manhattan, Kansas, about 170 miles from the site, and was felt over an area of 300,000 square miles. It is estimated that this shock had an intensity of about 5-1/2 on the Richter Scale. Another shock of Modified Mercalli Intensity VII occurred in the same area in January 1906, and was perceptible over an area of 10,000 square miles. The magnitude of this shock was probably not more than 5 on the Richter Scale.

Only one earthquake of Modified Mercalli Intensity VI has been reported within 200 miles of the site. It occurred in March 1935, near Tecumseh, Nebraska, and was felt in an area over 50,000 square miles.
Eight earthquakes of Modified Mercalli Intensity V have been reported within 200 miles of the site. The earthquake with its epicenter nearest the site occurred in February 1910, near Columbus, Nebraska, about 65 miles from the site. No significant structural damage occurred.

No damaging earthquakes have been reported within 50 miles of the site. While some of the regional shocks were undoubtedly felt in the locality of the site, no significant damage would be expected in even moderately well-built structures from a recurrence of these disturbances. It is probable that the earthquake of November 1877 was felt at the site with an intensity of about Modified Mercalli V.

No major earthquake has occurred near the site. The closest major shock was about 500 miles to the southeast. In 1811 and 1812 a series of large shocks were experienced near New Madrid, Missouri, but these shocks bore no relation to the structural geology surrounding the site.

Therefore, on a historical basis, it would appear that the site will not experience damaging earthquake motion.

An update of the seismic evaluation was performed with updated method and relying on updated information in the framework of the industry response to NRC 50.54(f) letter pertaining to NTTF Recommendation 2.1. The seismic evaluation was performed by Lettis Consulting International (LCI) as subcontractor of EPRI and provided to FCS in their letter addressed to Fort Calhoun: Fort Calhoun Seismic Hazard and Screening Report (RSM-112013-041, EPRI 2013d).

2.1 Regional and Local Geology

The OPPD Fort Calhoun Station (FCS) is located in eastern Nebraska within the Central Lowlands physiographic province. The FCS site is situated on an old river terrace called the Fort Calhoun Terrace that has formed from several overbank events occurring along the right (east) bank of the Missouri River (OPPD, 2012).

The topography of the project area is characterized as mostly low lying and flat, with portions of rolling land within a deep mantle of wind-deposited loess in upland bluffs and material laid down by glaciers (till and outwash) deposited during the pre-Illinoian glacial advances. Throughout much of this region, rivers have carved relatively deep, broad valleys into the loess bluffs, glacial deposits, and lower alluvium. The river alluvium within the relatively broad river valley and floodplain has formed through a complex sequence of deposition and erosional events during overbank flooding and from colluvial (slopewash) material that has washed down from the upland bluffs.

The ground surface prior to site development was sloping gently from the series of terrace deposits toward the Missouri River and ranged from about Elevation 992 to 1003 feet. Re-grading of the site for the construction of the FCS generally leveled the site to about Elevation 1005 feet.

The subsurface profile at the FCS site generally consists of a relatively thin layer of man-placed fill, Quaternary (Recent) deposits of recent fine and coarse alluvium, Pleistocene deposits of glacio-fluvial sand, overlying a thick sequence of Tertiary and Cretaceous rock strata (sedimentary formations of Pennsylvanian, Mississippian, Devonian, Ordovician, and Cambrian). These sedimentary rock strata are generally flat lying or show very gentle dips in areas of broad regional depressions or structural arches. Significant faulting in the sedimentary rock is rare in this vicinity. The entire region is underlain by Precambrian crystalline basement bedrock comprised of granitic bedrock. The depths and thicknesses of the various rock strata are provided in Table 2.3.1.1 below.

The generalized subsurface soil profile at the FCS site consists of the following strata in descending order:

- A 5 to 10-foot thick layer of existing earth fill, most of which was placed at the time of the original FCS construction. The compacted fill is comprised of stiff lean clay with silt.
- An intermittent layer of soft to firm, fine alluvium (silts and clays) that varies in thickness from 5 to 20 feet.

- A 50- to 60-foot thick layer of loose to medium dense, coarse granular alluvium (primarily silty to poorly graded sands with some clay seams).
- Limestone/shale bedrock at depth of about 75 feet below present grades, or at about elevation 930 feet.

Groundwater levels at the times of the pre-flood and current investigations varied in elevation from about 986 to 1001 feet. River levels during the 2011 Flood reached a high water elevation of about 1007 feet.

A listing of the references that were used in the development of the site characterization and site geotechnical profile is provided in Section 7.0 of (OPPD 2012).

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 Fort Calhoun 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. Illinois Basin Extended Basement (IBEB)
2. Mesozoic and younger extended prior – wide (MESE-W)
3. Midcontinent-Craton alternative A (MIDC_A)
4. Midcontinent-Craton alternative B (MIDC_B)
5. Midcontinent-Craton alternative C (MIDC_C)
6. Midcontinent-Craton alternative D (MIDC_D)
7. Non-Mesozoic and younger extended prior – narrow (NMESE-N)
8. Non-Mesozoic and younger extended prior – wide (NMESE-W)
9. 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 (Safe Shutdown Earthquake) control point elevation.

2.3 Site Response Evaluation

Following the guidance contained in Seismic Enclosure 1 of the 3/12/2012 50.54(f) Request for Information 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 Fort Calhoun.

2.3.1 Description of Subsurface Material

FCS is located in eastern Nebraska within the Central Lowlands physiographic province. The general site conditions consist of about 75 ft (23 m) of alluvial terraces overlying limestone and shales with Precambrian basement at a depth of about 2,200 ft (671 m). The site is located on the Fort Calhoun river terrace along the west bank of the Missouri River. The location of the SSE was taken at the surface of the profile (Table 2.3.1-1; OPPD, 2012).

Table 2.3.1-1. Summary of Geotechnical Profile for FCS

Depth Range (feet)	Soil / Rock Description	Density (pcf)	Shear Wave (Vs) Velocity (feet/sec)	Compression Wave (P) Velocity (feet/sec)	Average Poisson's Ratio
0-10	Man-Placed Fill: clays, silts, sands	120	1000	1500 +/- 500	0.40
10-20	Quaternary System: Recent alluvial clay, silt	115	500 +/- 250	1500 +/- 500	0.28
20-40	Quaternary System: Recent alluvial sand, some silt	120	1000 +/- 500	2000 +/- 500	0.30
40-75	Pleistocene System: Older sands	125	1500 +/-500	3000 +/- 500	0.32
75-700	Pennsylvanian System: Limestone and Shale	140	5000 +/- 1000	10000 +/- 1000	0.28
700-970	Mississippian System: Limestone, Shale, Dolomite, and Sandstone	155	9000 +/- 1000	14,000 +/- 1000	0.18
970-1310	Devonian System: Shale and Dolomite	145	6000 +/- 1000	9500 +/- 1000	0.21
1310-2130	Ordovician System: Dolomite, Shale, Sandstone, and Limestone	150	7000 +/- 1000	11,000 +/- 1000	0.18
2130-2200	Cambrian System: Dolomite and Sandstone	155	8500 +/- 1000	14,000 +/- 1000	0.17
2200+	Precambrian System: Granite	165	10,000+	17,000 +/- 1000	0.25

Notes:

1. The ground surface elevation of 1005 feet was assumed to correspond to a depth of 0 feet.
2. The dynamic properties (density, shear wave and P-wave velocities and Poisson's ratio) for the man placed fills and the overburden soils were developed based on Standard Penetration Test data (ASTM D 1586), cone penetration test soundings (ASTM D 5778) and seismic refraction and ReMi profiles taken at the site (HDR, 2012 and Geotechnology, 2011).
3. The dynamic parameters for the rock of the Pennsylvania System were estimated from seismic refraction (P-wave) and ReMi (shear wave) methods taken at the site by Geotechnology (2011) and D&M (1967).
4. The dynamic parameters for the deeper rock strata were estimated based upon an estimated percentage of rock type within each geologic unit, its age, and the stratigraphy noted in the logs of oil and gas wells (NGS, 1961 and 1967).
5. The uncertainties in the dynamic parameters are expressed in a range of values (that is, 18,000 +/- 1000).

The subsurface profile at the FCS site generally consists of a relatively thin layer of man-placed fill, Quaternary (Recent) deposits of recent fine and coarse alluvium, Pleistocene deposits of glaciofluvial sand, overlying a thick sequence of Tertiary and Cretaceous rock strata (sedimentary formations of Pennsylvanian, Mississippian, Devonian, Ordovician, and Cambrian). These sedimentary rock strata are generally flat lying or show very gentle dips in areas of broad regional depressions or structural arches. Significant faulting in the sedimentary rock is rare in this vicinity. The entire region is underlain by Precambrian crystalline basement bedrock comprised of granitic bedrock. The depths and thicknesses of the various rock strata are provided in Table 2.3.1-1.

2.3.2 Development of Base Case Profiles and Nonlinear Material Properties

Table 2.3.1-1 shows the recommended shear-wave velocities and unit weights versus depth for the best estimate single profile. From Table 2.3.1-1 hard reference rock shear-wave velocities (at or exceeding 9,285 ft/s, 2,830 m/s) were reached at Precambrian basement at a depth of 2,200 ft (671 m). Shear-wave velocities were measured directly to a depth of 700 ft (213m), which included the firm rock of the Pennsylvanian Limestone and Shale. Below that depth shear-wave velocities were estimated based on material type identified in water, oil, and gas wells. Recommended shear-wave velocities listed in Table 2.3.1-1 were taken as the mean base-case profile (P1). Lower- and upper-range profiles (P2 and P3 respectively) were developed with scale factors 1.25 over the top 700 ft (213 m), reflecting measured velocities, and 1.57 below a depth of 700 ft (213m), reflecting increased epistemic uncertainty for inferred shear-wave velocities. The two scale factors, 1.25 and 1.57, reflect $\sigma_{\mu \ln}$ of about 0.2 and 0.35 respectively accounting for a 1.28 factor on $\sigma_{\ln}$ for 10% and 90% fractiles (EPRI, 2013a). Profile P3, the stiffest profile, was taken to encounter hard reference rock at a depth of 700 ft (213 m). Profiles P1 and P2 have a mean depth of 2,200 ft (671 m) randomized ± 660 ft (201 m). The three base-case profiles (P1, P2, and P3) are shown in Figure 2.3.2-1 and listed in Table 2.3.2-1.

Table 2.3.2-1. Layer thicknesses, depths, and shear-wave velocities (Vs) for 3 profiles for FCS

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	1000		0	800		0	1250
5.0	5.0	1000	5.0	5.0	800	5.0	5.0	1250
5.0	10.0	1000	5.0	10.0	800	5.0	10.0	1250
5.0	15.0	500	5.0	15.0	400	5.0	15.0	625
5.0	20.0	500	5.0	20.0	400	5.0	20.0	625
5.0	25.0	1000	5.0	25.0	800	5.0	25.0	1250
5.0	30.0	1000	5.0	30.0	800	5.0	30.0	1250
5.0	35.0	1000	5.0	35.0	800	5.0	35.0	1250
5.0	40.0	1000	5.0	40.0	800	5.0	40.0	1250
5.0	45.0	1500	5.0	45.0	1200	5.0	45.0	1875
5.0	50.0	1500	5.0	50.0	1200	5.0	50.0	1875
5.0	55.0	1500	5.0	55.0	1200	5.0	55.0	1875
5.0	60.0	1500	5.0	60.0	1200	5.0	60.0	1875
5.0	65.0	1500	5.0	65.0	1200	5.0	65.0	1875
5.0	70.0	1500	5.0	70.0	1200	5.0	70.0	1875
5.0	75.0	1500	5.0	75.0	1200	5.0	75.0	1875
5.0	80.0	5000	5.0	80.0	4000	5.0	80.0	6250
10.0	90.0	5000	10.0	90.0	4000	10.0	90.0	6250
10.0	100.0	5000	10.0	100.0	4000	10.0	100.0	6250
10.0	110.0	5000	10.0	110.0	4000	10.0	110.0	6250
10.0	120.0	5000	10.0	120.0	4000	10.0	120.0	6250
10.0	130.0	5000	10.0	130.0	4000	10.0	130.0	6250
10.0	140.0	5000	10.0	140.0	4000	10.0	140.0	6250
10.0	150.0	5000	10.0	150.0	4000	10.0	150.0	6250
10.0	160.0	5000	10.0	160.0	4000	10.0	160.0	6250

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)
10.0	170.0	5000	10.0	170.0	4000	10.0	170.0	6250
10.0	180.0	5000	10.0	180.0	4000	10.0	180.0	6250
10.0	190.0	5000	10.0	190.0	4000	10.0	190.0	6250
10.0	200.0	5000	10.0	200.0	4000	10.0	200.0	6250
10.0	210.0	5000	10.0	210.0	4000	10.0	210.0	6250
10.0	220.0	5000	10.0	220.0	4000	10.0	220.0	6250
10.0	230.0	5000	10.0	230.0	4000	10.0	230.0	6250
10.0	240.0	5000	10.0	240.0	4000	10.0	240.0	6250
10.0	250.0	5000	10.0	250.0	4000	10.0	250.0	6250
10.0	260.0	5000	10.0	260.0	4000	10.0	260.0	6250
10.0	270.0	5000	10.0	270.0	4000	10.0	270.0	6250
10.0	280.0	5000	10.0	280.0	4000	10.0	280.0	6250
10.0	290.0	5000	10.0	290.0	4000	10.0	290.0	6250
10.0	300.0	5000	10.0	300.0	4000	10.0	300.0	6250
10.0	310.0	5000	10.0	310.0	4000	10.0	310.0	6250
10.0	320.0	5000	10.0	320.0	4000	10.0	320.0	6250
10.0	330.0	5000	10.0	330.0	4000	10.0	330.0	6250
10.0	340.0	5000	10.0	340.0	4000	10.0	340.0	6250
10.0	350.0	5000	10.0	350.0	4000	10.0	350.0	6250
10.0	360.0	5000	10.0	360.0	4000	10.0	360.0	6250
10.0	370.0	5000	10.0	370.0	4000	10.0	370.0	6250
10.0	380.0	5000	10.0	380.0	4000	10.0	380.0	6250
10.0	390.0	5000	10.0	390.0	4000	10.0	390.0	6250
10.0	400.0	5000	10.0	400.0	4000	10.0	400.0	6250
10.0	410.0	5000	10.0	410.0	4000	10.0	410.0	6250
10.0	420.0	5000	10.0	420.0	4000	10.0	420.0	6250
10.0	430.0	5000	10.0	430.0	4000	10.0	430.0	6250
10.0	440.0	5000	10.0	440.0	4000	10.0	440.0	6250
10.0	450.0	5000	10.0	450.0	4000	10.0	450.0	6250
10.0	460.0	5000	10.0	460.0	4000	10.0	460.0	6250
10.0	470.0	5000	10.0	470.0	4000	10.0	470.0	6250
10.0	480.0	5000	10.0	480.0	4000	10.0	480.0	6250
10.0	490.0	5000	10.0	490.0	4000	10.0	490.0	6250
10.0	500.0	5000	10.0	500.0	4000	10.0	500.0	6250
25.0	525.0	5000	25.0	525.0	4000	25.0	525.0	6250
25.0	550.0	5000	25.0	550.0	4000	25.0	550.0	6250
25.0	575.0	5000	25.0	575.0	4000	25.0	575.0	6250
25.0	600.0	5000	25.0	600.0	4000	25.0	600.0	6250
25.0	625.0	5000	25.0	625.0	4000	25.0	625.0	6250
25.0	650.0	5000	25.0	650.0	4000	25.0	650.0	6250

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)**
25.0	675.0	5000	25.0	675.0	4000	25.0	675.0	6250
25.0	700.0	5000	25.0	700.0	4000	25.0	700.0	6250
90.0	790.0	9000	90.0	790.0	5732	90.0	790.0	9285
90.0	880.0	9000	90.0	880.0	5732	90.0	880.0	9285
90.0	970.0	9000	90.0	970.0	5732	90.0	970.0	9285
85.0	1055.0	6000	85.0	1055.0	3821	85.0	1055.0	9285
85.0	1140.0	6000	85.0	1140.0	3821	85.0	1140.0	9285
85.0	1225.0	6000	85.0	1225.0	3821	85.0	1225.0	9285
85.0	1310.0	6000	85.0	1310.0	3821	85.0	1310.0	9285
164.0	1474.0	7000	164.0	1474.0	4458	164.0	1474.0	9285
164.0	1638.0	7000	164.0	1638.0	4458	164.0	1638.0	9285
164.0	1802.0	7000	164.0	1802.0	4458	164.0	1802.0	9285
164.0	1965.9	7000	164.0	1965.9	4458	164.0	1965.9	9285
164.0	2129.9	7000	164.0	2129.9	4458	164.0	2129.9	9285
35.0	2164.9	8500	35.0	2164.9	5414	35.0	2164.9	9285
35.0	2199.9	8500	35.0	2199.9	5414	35.0	2199.9	9285
3280.8	5480.8	9285	3280.8	5480.8	9285	3280.8	5480.8	9285

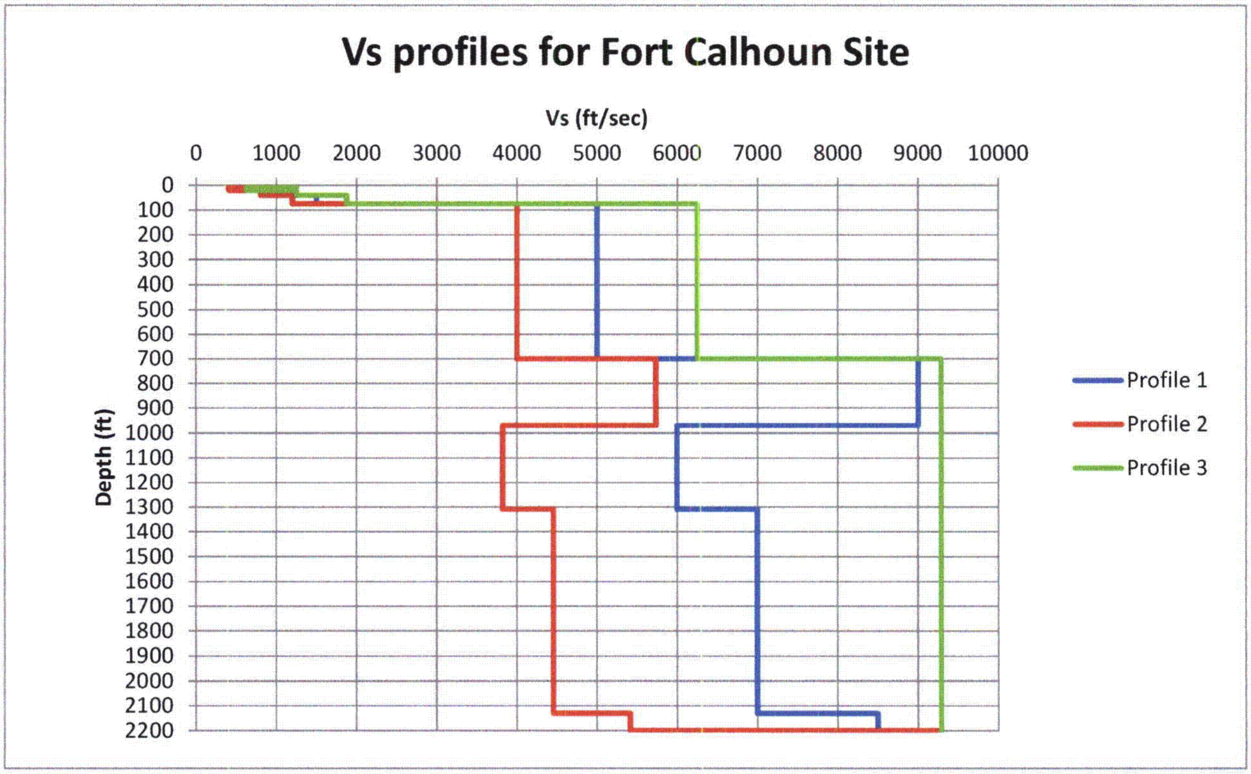

Figure 2.3.2-1. Shear-wave velocity profiles for the Fort Calhoun site

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 FCS. 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 (152 m) of the profile.

2.3.2.2 Kappa

For the Fort Calhoun profile of about 2,200 ft (671 m) 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, 0.019s, and 0.007s respectively[1]. The total kappa values, after adding the hard reference rock value of 0.006s, were 0.020s, 0.025s, and 0.013s respectively (Table 2.3.2-2). The total range in kappa is about a factor of two with increased epistemic

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[1] Kappa values listed in EPRI 2013d were amended by LCI, as documented in (WEC, 2014)

uncertainty in overall profile damping (kappa) at design loading levels through multiple sets of modulus reduction and hysteretic damping curves for the soil.

Table 2.3.2-2. Kappa Values and Weights Used for Site Response Analyses

Velocity Profile	**Kappa(s)**
P1	0.020
P2	0.025
P3	0.013
	Weights
P1	0.4
P2	0.3
P3	0.3
G/G_{max} and Hysteretic Damping Curves	
M1, EPRI Soil, EPRI Rock	0.5
M2, PR Soil, Linear Rock	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 FCS 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 FCS site were the same as those identified in Tables B-4, B-5, B-6 and B-7of the SPID (EPRI, 2013a) as appropriate for typical CEUS sites.

2.3.5 Methodology

To perform the site response analyses for the Fort Calhoun 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 FCS 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 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 (0.01 g to 1.50 g) 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 FCS firm rock 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 at high-frequency ($\geq$ 10 Hz) at high loading levels ($\geq$ 0.2g). Tabulated values of the amplification factors are provided in Appendix A.

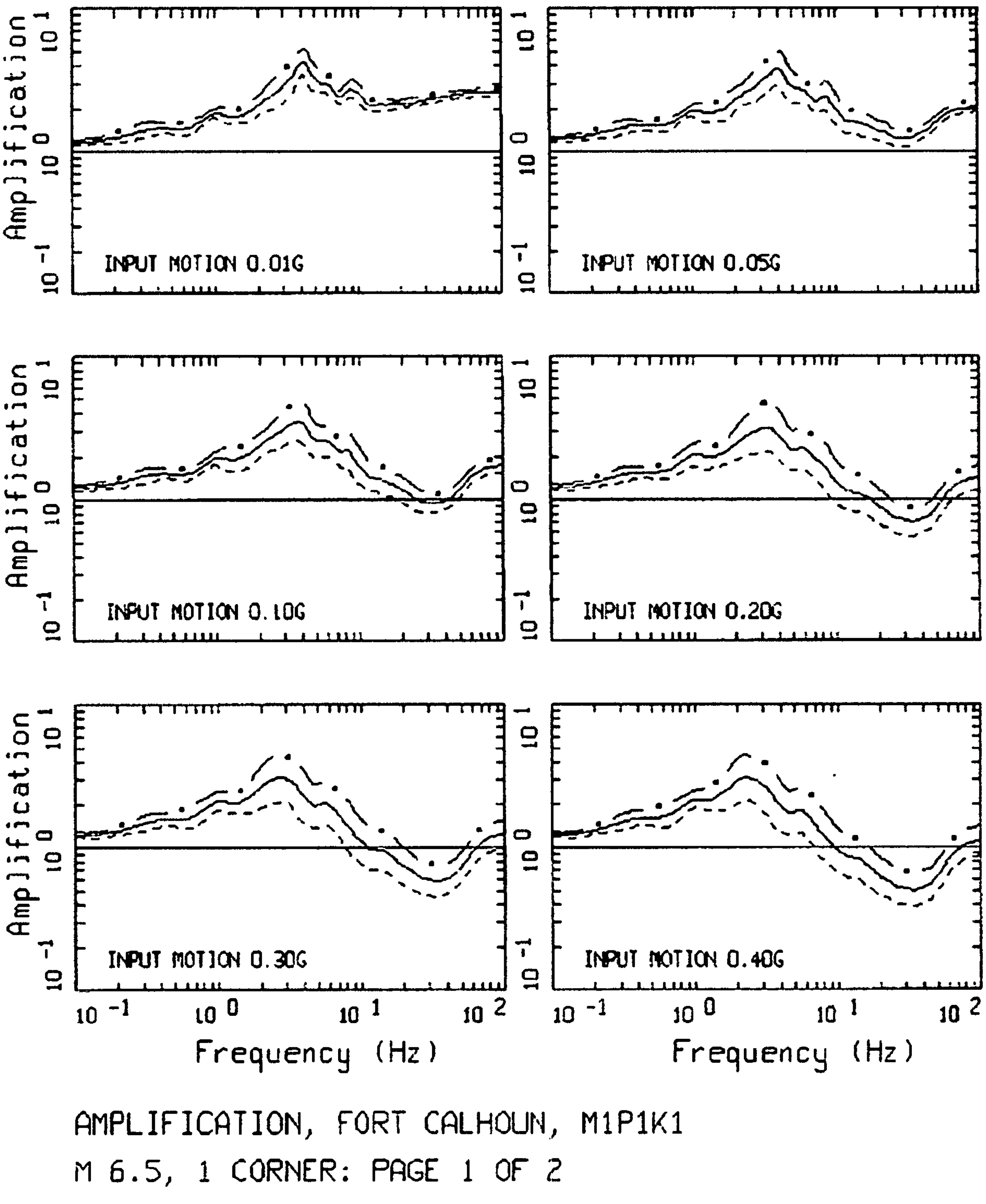
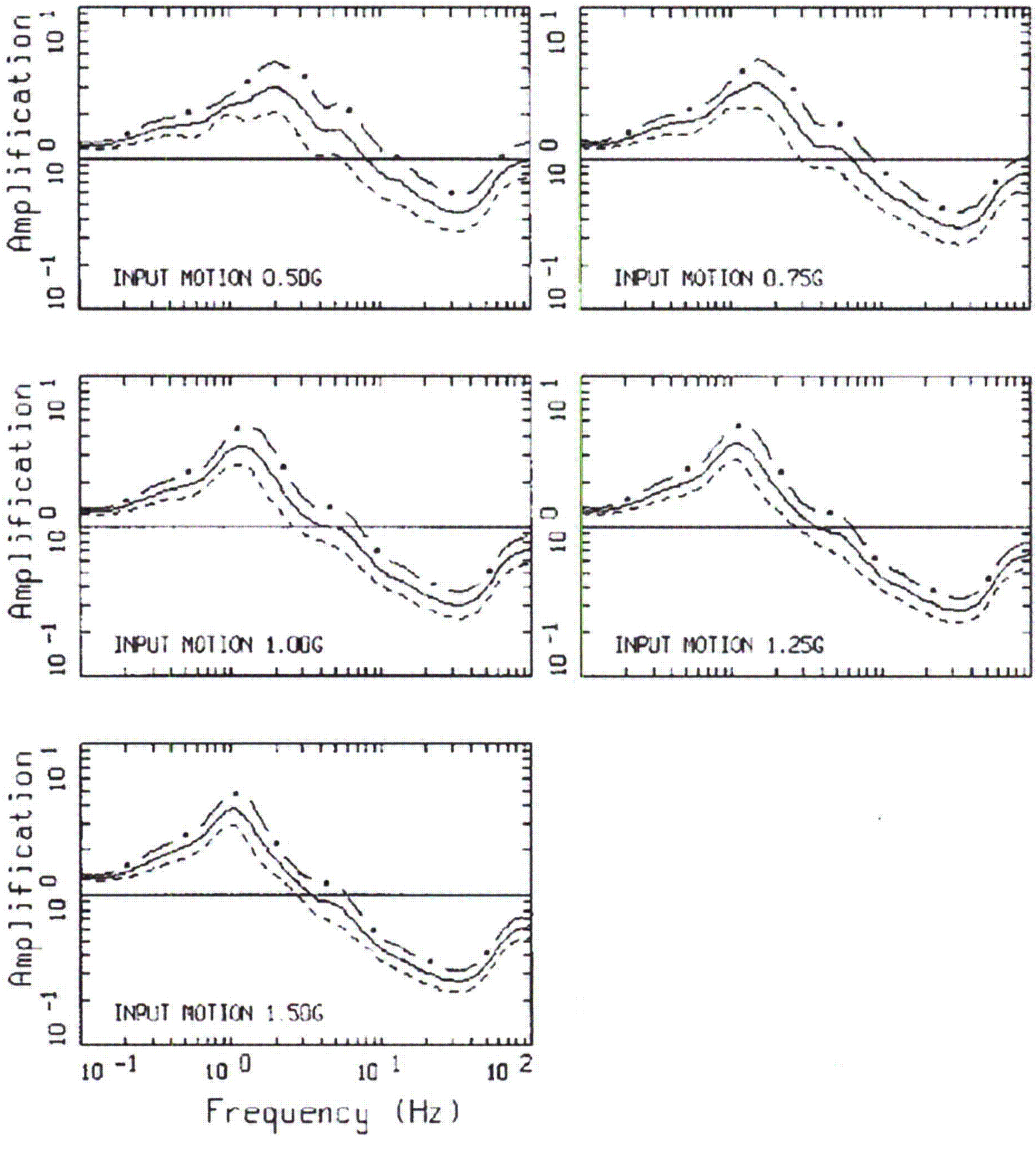


Figure 2.3.6-1. Example suite of amplification factors (5% damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), EPRI soil and rock modulus reduction and hysteretic damping curves (model M1), and base-case kappa at eleven loading levels of hard rock median peak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



AMPLIFICATION, FORT CALHOUN, M1P1K1

M 6.5, 1 CORNER: PAGE 2 OF 2

Figure 2.3.6-1. (cont.)

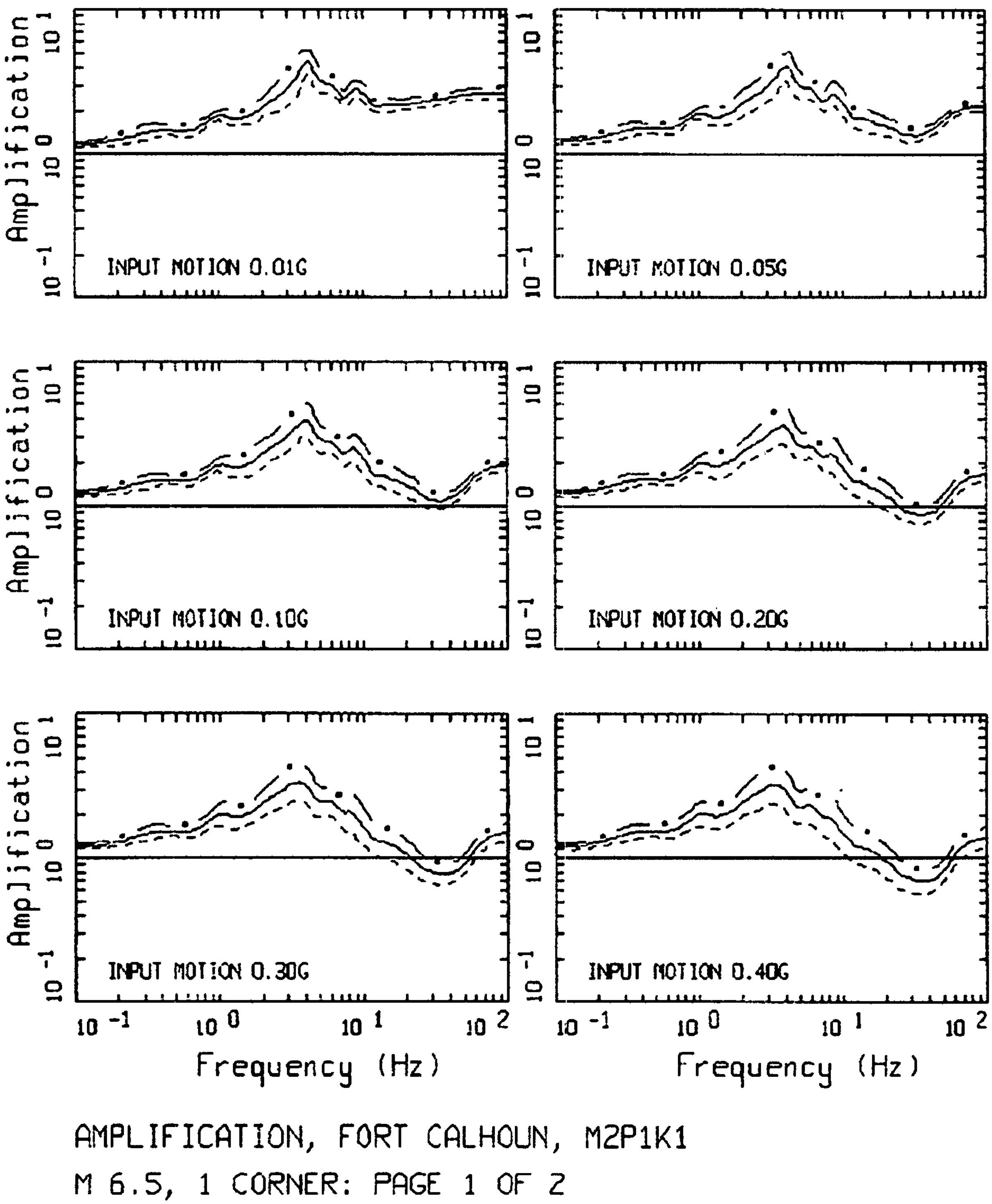
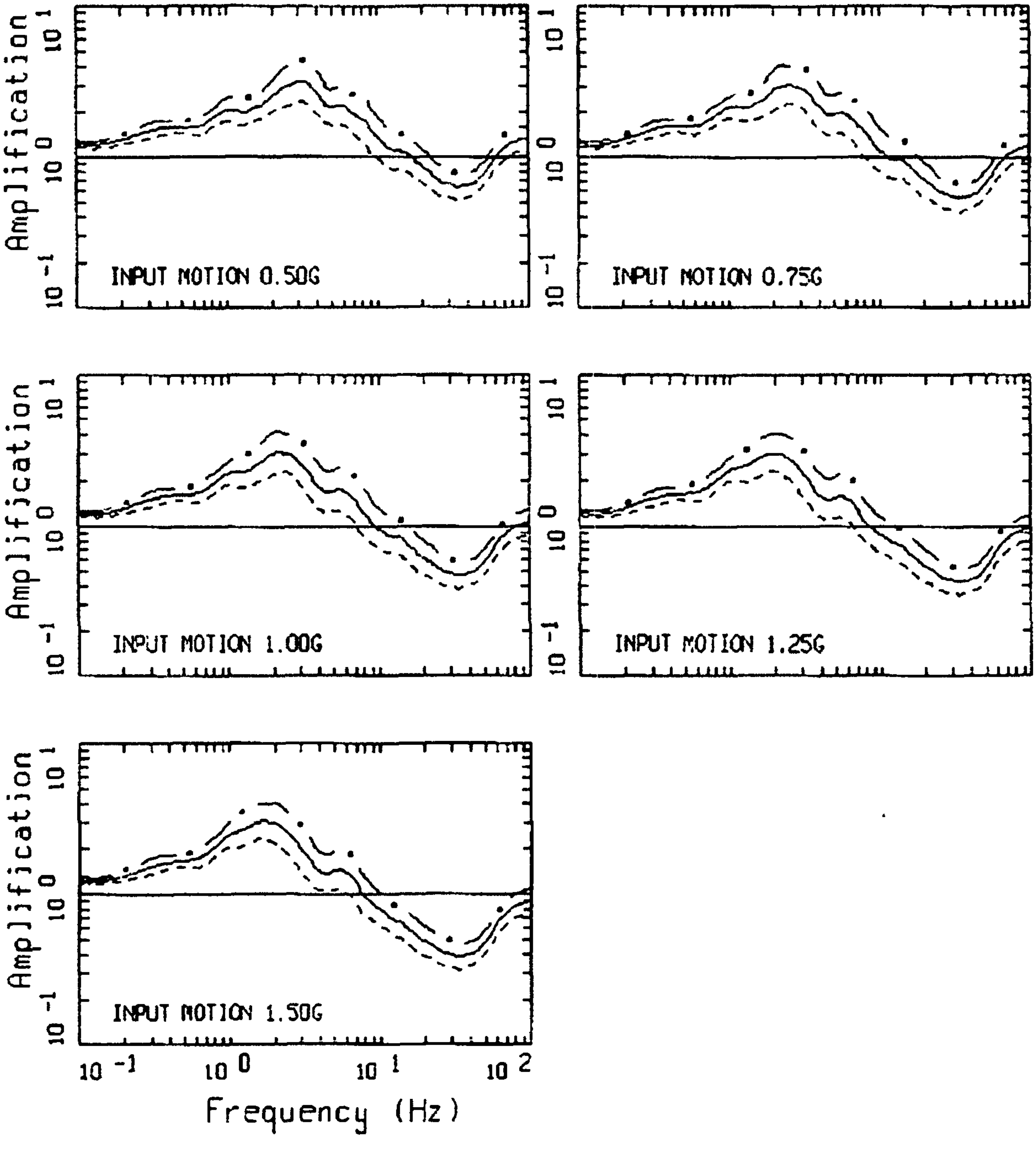


Figure 2.3.6-2. Example suite of amplification factors (5% damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), Peninsular Range curves for soil and linear site response for firm rock (model M2), and base-case kappa at eleven loading levels of hard rock median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



AMPLIFICATION, FORT CALHOUN, M2P1K1

M 6.5, 1 CORNER: PAGE 2 OF 2

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 FCS 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.

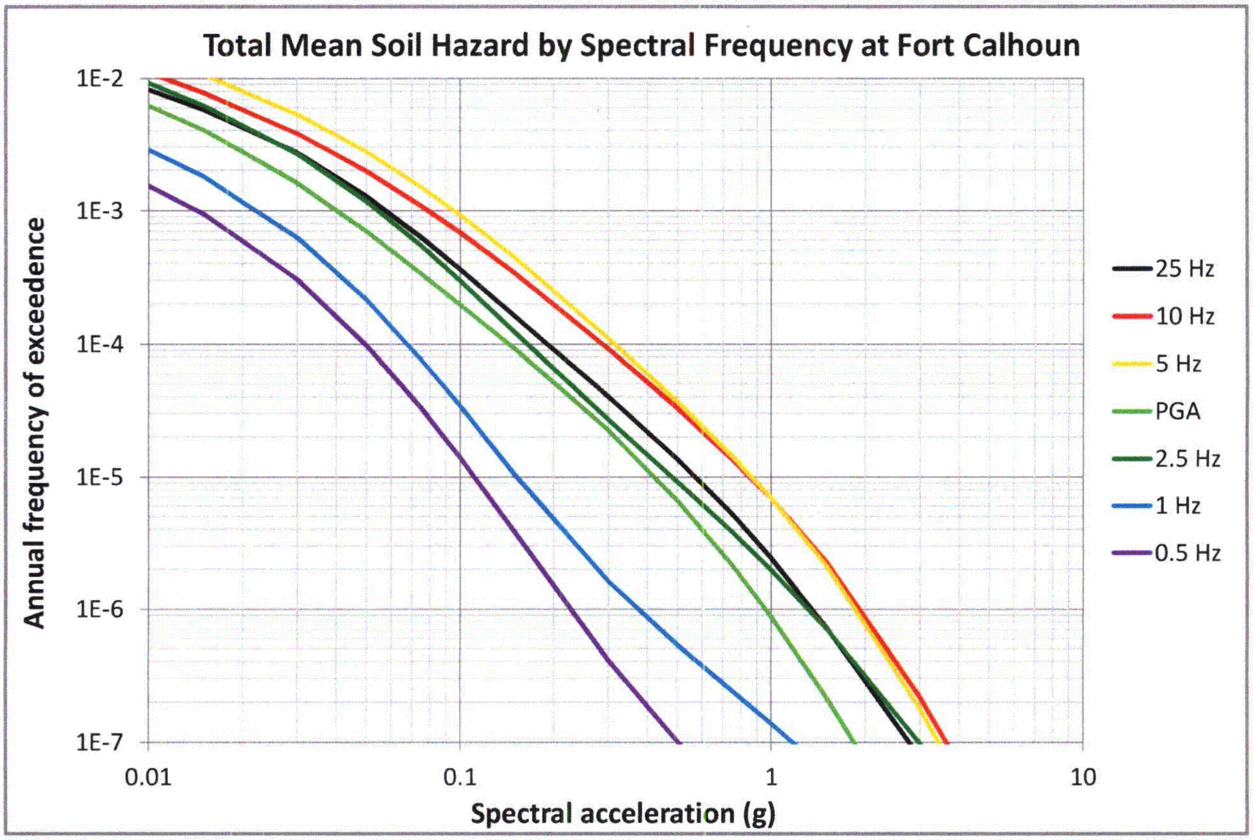


Figure 2.3.7-1. Control point mean hazard curves for spectral frequencies of 0.5, 1, 2.5, 5, 10, 25, and 100 Hz at FCS

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 spectral 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 FCS.

Table 2.4-1. UHRS and GMRS for Fort Calhoun

Freq. (Hz)	10^{-4} UHRS (g)	10^{-5} UHRS (g)	GMRS (g)
100	1.44E-01	4.21E-01	2.04E-01
90	1.44E-01	4.22E-01	2.04E-01
80	1.44E-01	4.24E-01	2.05E-01
70	1.45E-01	4.27E-01	2.06E-01
60	1.46E-01	4.34E-01	2.09E-01
50	1.50E-01	4.48E-01	2.16E-01
40	1.60E-01	4.78E-01	2.30E-01
35	1.67E-01	5.00E-01	2.41E-01
30	1.76E-01	5.28E-01	2.54E-01
25	1.90E-01	5.70E-01	2.74E-01
20	2.13E-01	6.35E-01	3.06E-01
15	2.23E-01	6.96E-01	3.32E-01
12.5	2.53E-01	7.48E-01	3.61E-01
10	2.86E-01	8.53E-01	4.11E-01
9	2.85E-01	8.58E-01	4.13E-01
8	2.82E-01	8.65E-01	4.15E-01
7	2.81E-01	8.50E-01	4.09E-01
6	2.91E-01	8.61E-01	4.16E-01
5	3.14E-01	8.65E-01	4.24E-01
4	2.94E-01	8.02E-01	3.94E-01
3.5	2.53E-01	7.04E-01	3.44E-01
3	2.22E-01	6.01E-01	2.95E-01
2.5	1.64E-01	4.80E-01	2.33E-01
2	1.36E-01	4.05E-01	1.95E-01
1.5	9.45E-02	2.63E-01	1.29E-01
1.25	8.04E-02	2.04E-01	1.02E-01
1	6.75E-02	1.53E-01	7.77E-02
0.9	6.34E-02	1.43E-01	7.29E-02
0.8	5.98E-02	1.35E-01	6.87E-02
0.7	5.65E-02	1.27E-01	6.48E-02
0.6	5.31E-02	1.19E-01	6.09E-02
0.5	4.94E-02	1.11E-01	5.67E-02
0.4	3.95E-02	8.90E-02	4.54E-02
0.35	3.46E-02	7.78E-02	3.97E-02
0.3	2.97E-02	6.67E-02	3.40E-02
0.25	2.47E-02	5.56E-02	2.84E-02

Freq. (Hz)	10^{-4} UHRS (g)	10^{-5} UHRS (g)	GMRS (g)
0.2	1.98E-02	4.45E-02	2.27E-02
0.15	1.48E-02	3.34E-02	1.70E-02
0.125	1.24E-02	2.78E-02	1.42E-02
0.1	9.89E-03	2.22E-02	1.13E-02

The 1E-4 and 1E-5 UHRS are used to compute the GMRS at the control point and are shown in Figure 2.4-1.

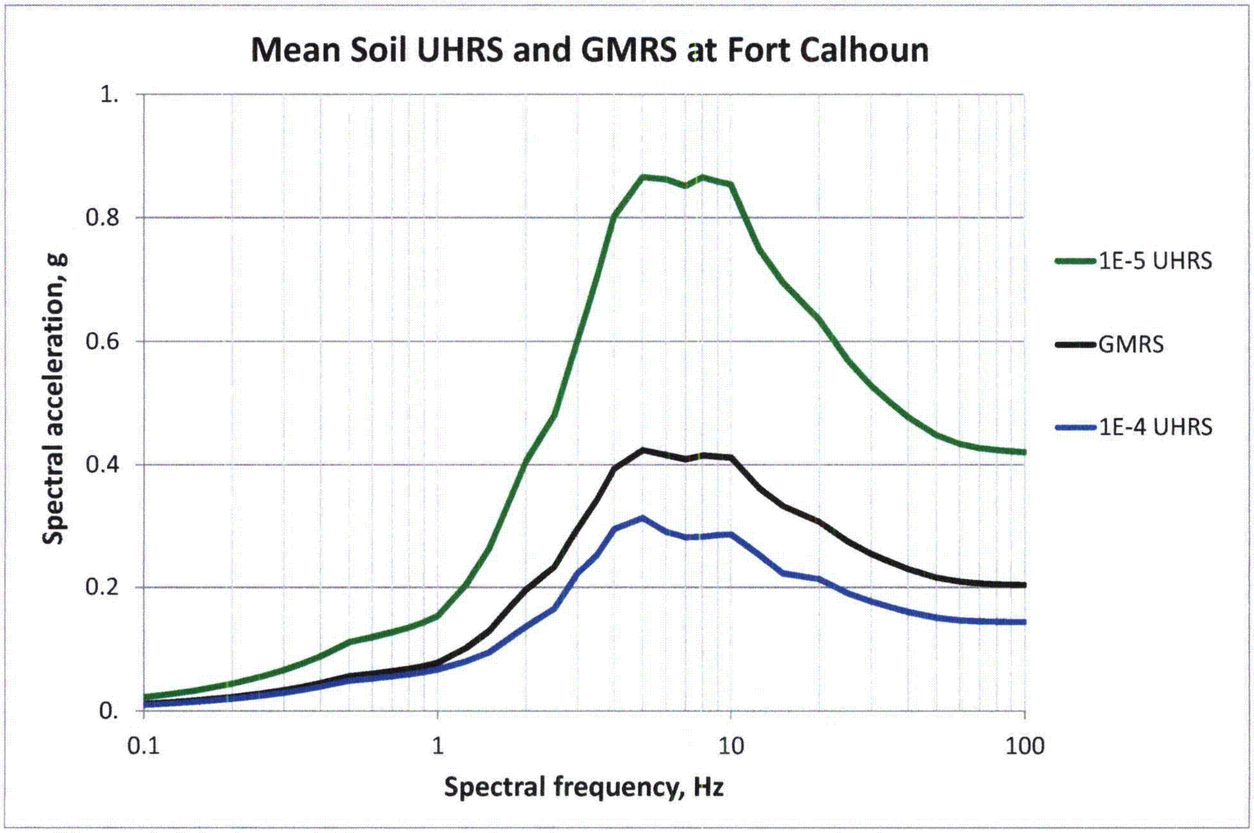


Figure 2.4-1. Plots of 1E-4 and 1E-5 uniform hazard spectra and GMRS at control point for Fort Calhoun (5%-damped response spectra)

3. Plant Design Basis

The design basis for FCS is identified in the Updated Safely Evaluation Report (USAR).

An evaluation for beyond design basis (BDB) ground motions was performed in the Individual Plant Examination of External Events (IPEEE). The IPEEE plant level HCLPF response spectrum is included below for screening purposes.

3.1 SSE Description of Spectral Shape

The definition of the SSE for FCS is discussed in Appendix F of the FCS USAR.

According to Section 2.4 of the FCS USAR, the SSE was developed through an evaluation of the maximum earthquake potential for the region surrounding the site. Although on the basis of the history of the region no significant earthquake ground motion is expected at the site, occasional shocks along the Missouri River and a continuation of shocks in the belt extending northward from the Abilene Arch to the Sioux Uplift could be postulated. For conservation in the determination of appropriate seismic criteria, the proximity of a fault to the site is considered.

The SSE is defined in terms of a PGA and a design response spectrum. The response spectra for the FCS maximum hypothetical earthquake is provided in Figure F-2 of the USAR and was used for the design of Class I components and structures at FCS.

The FCS spectra conform to the average spectra developed by Housner for frequencies higher than about 0.33 cycles per second. The FCS spectra for frequencies lower than about 0.33 cycles per second were prepared utilizing data presented by Newmark.

The spectra have been normalized to a horizontal ground acceleration of seventeen percent of gravity for the maximum hypothetical earthquake (i.e., 0.17 g).

Figure 3.1-1 shows the response spectra for the maximum hypothetical earthquake. The spectra was digitized (OPPD, 2012) and the Table 3.1-1 shows the spectral acceleration values as a function of frequency for the 5% damped horizontal SSE. The SSE is shown in Figure 3.3-1.

Table 3.1-1. SSE for Fort Calhoun (OPPD, 2012)

Freq. (Hz)	0.5	1	2.5	5	9	25	33
SA (g)	0.09	0.14	0.25	0.25	0.18	0.17	0.17

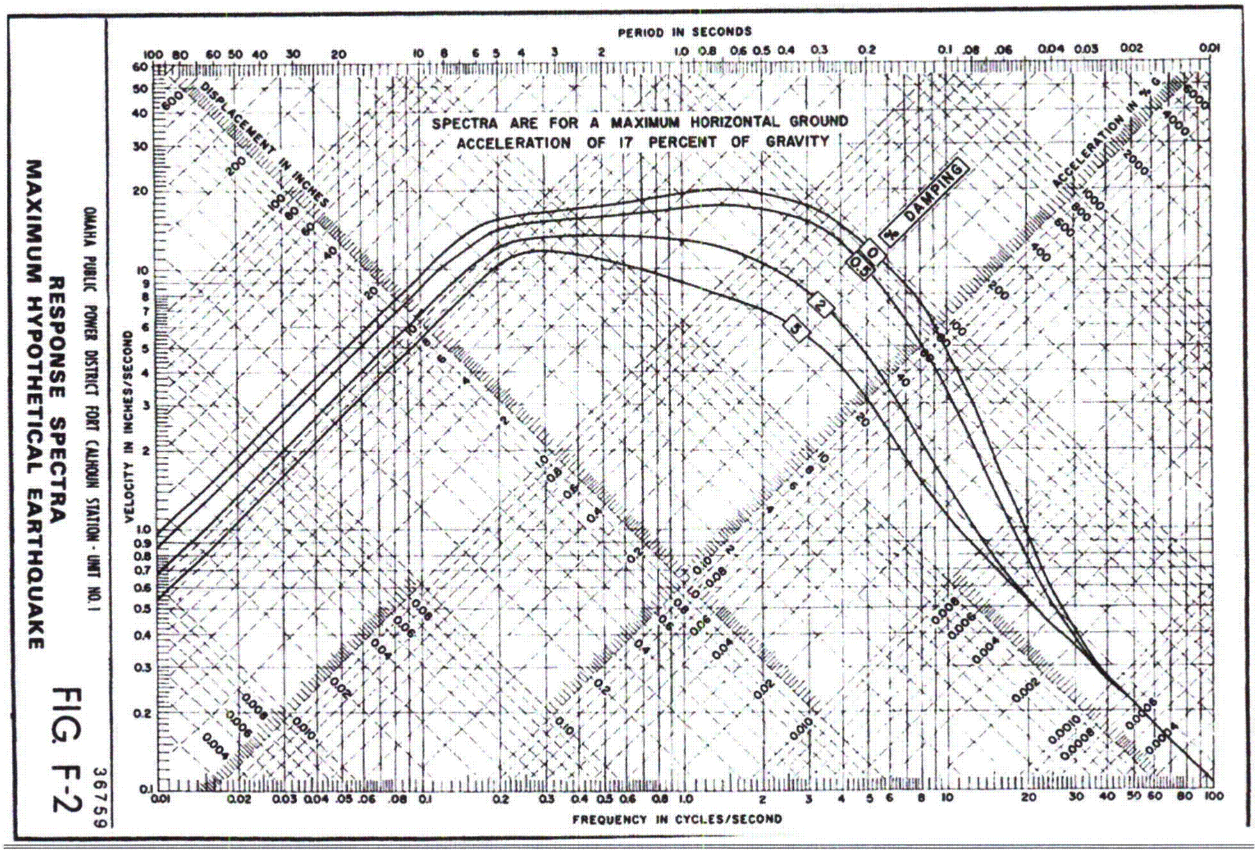


Figure 3.1-1. SSE Ground Response Spectrum for Maximum Hypothetical Earthquake

3.2 Control Point Elevation

The FCS SSE control point is defined at the ground surface elevation 1004'-6" ft (OPPD, 2012).

3.3 IPEEE Description and Capacity Response Spectrum

A seismic margin assessment (SMA) was performed for the seismic portion of the FCS IPEEE using the fault based SMA methodology (NUREG/CR-4334). FCS adopted as Review Level Earthquake (RLE) anchored at 0.3g, utilizing a 7% damping NUREG-CR/0098 spectral shape for a soil site. The calculated plant-level high confidence of low probability of failure (HCLPF) for FCS resulting from performance of the IPEEE was 0.25g (OPPD, 1995).

The IPEEE Adequacy Determination according to SPID Section 3.3.1 is included as Appendix B. The results of the review have shown, in accordance with the criteria established in SPID Section 3.3, that the IPEEE is adequate to support screening of the updated seismic hazard for FCS. The review also concluded that the risk insights obtained from the IPEEE are still valid under the current plant configuration.

The IPEEE RLE and IHS spectral accelerations are provided in Table 3.3-1 and are shown in Figure 3.3-1.

Table 3.3-1. IPEEE RLE and IHS for Fort Calhoun

Freq. (Hz)	0.1	0.25	1.5	8	33	100
IPEEE RLE SA (g)	0.024	0.12	0.567	0.567	0.3	0.3
IHS SA (g)	0.02	0.1	0.4725	0.4725	0.25	0.25

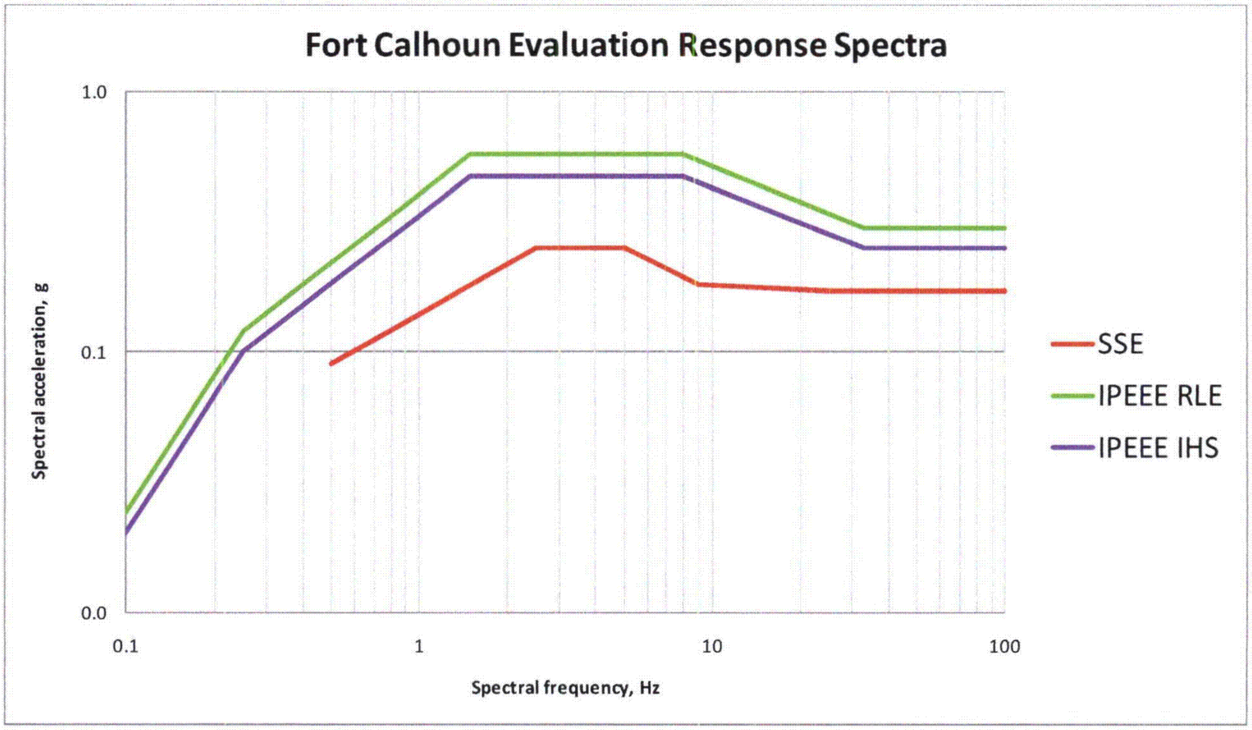


Figure 3.3-1. SSE, IPEEE RLE, and IHS Response Spectra for FCS

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 IHS exceeds the GMRS. Based on this comparison, a risk evaluation will not be performed.

4.2 High Frequency Screening (> 10 Hz)

Above 10 Hz, the IHS exceeds the GMRS. Therefore, the high frequency confirmation will not be performed.

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

In the 1 to 10 Hz part of the response spectrum, the GMRS exceeds the 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 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 FCS. 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," 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.

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

OPPD letter LIC-13-0070 (Attachment to OPPD, 2013), dated June 28, 2013 documented the fully completed 2.3 Seismic Walkdown Program performed for FCS. 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 FCS CAP. Current status and resolutions (where applicable and available) for CRs related to potentially adverse seismic conditions were noted in Attachment 11.4 of the letter referenced above.

6. Conclusions

In accordance with the 50.54(f) request for information, a seismic hazard and screening evaluation was performed for FCS. 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, FCS screens in for a Spent Fuel Pool evaluation.

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Appendix A – Hazard Information in Tabular Format

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

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	3.46E-02	1.95E-02	2.84E-02	3.47E-02	4.19E-02	4.56E-02
0.001	2.89E-02	1.34E-02	2.22E-02	2.92E-02	3.63E-02	4.07E-02
0.005	1.14E-02	3.57E-03	7.45E-03	1.08E-02	1.55E-02	2.01E-02
0.01	6.21E-03	1.84E-03	3.57E-03	5.58E-03	8.85E-03	1.27E-02
0.015	4.03E-03	1.20E-03	2.10E-03	3.47E-03	5.75E-03	9.24E-03
0.03	1.61E-03	4.63E-04	7.13E-04	1.27E-03	2.19E-03	4.56E-03
0.05	6.95E-04	1.77E-04	2.68E-04	5.05E-04	9.51E-04	2.22E-03
0.075	3.35E-04	6.93E-05	1.11E-04	2.25E-04	4.83E-04	1.13E-03
0.1	1.97E-04	3.33E-05	5.83E-05	1.25E-04	2.96E-04	6.73E-04
0.15	9.23E-05	1.21E-05	2.39E-05	5.58E-05	1.42E-04	3.19E-04
0.3	2.24E-05	2.07E-06	5.20E-06	1.36E-05	3.52E-05	7.34E-05
0.5	6.61E-06	4.07E-07	1.18E-06	3.84E-06	1.07E-05	2.16E-05
0.75	2.14E-06	7.45E-08	2.68E-07	1.15E-06	3.63E-06	7.34E-06
1.	8.72E-07	1.77E-08	8.00E-08	4.19E-07	1.53E-06	3.14E-06
1.5	2.16E-07	1.84E-09	1.21E-08	8.35E-08	3.84E-07	8.47E-07
3.	1.59E-08	1.34E-10	3.14E-10	3.37E-09	2.46E-08	7.03E-08
5.	2.10E-09	1.21E-10	1.32E-10	3.19E-10	2.57E-09	1.01E-08
7.5	3.76E-10	1.21E-10	1.32E-10	1.34E-10	4.37E-10	1.92E-09
10.	1.01E-10	1.21E-10	1.21E-10	1.32E-10	1.84E-10	5.83E-10

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

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	3.57E-02	2.32E-02	2.96E-02	3.57E-02	4.19E-02	4.63E-02
0.001	3.07E-02	1.67E-02	2.46E-02	3.09E-02	3.73E-02	4.19E-02
0.005	1.37E-02	5.42E-03	9.51E-03	1.32E-02	1.79E-02	2.35E-02
0.01	8.21E-03	2.96E-03	5.05E-03	7.55E-03	1.11E-02	1.62E-02
0.015	5.77E-03	2.04E-03	3.33E-03	5.12E-03	7.89E-03	1.23E-02
0.03	2.71E-03	9.11E-04	1.38E-03	2.25E-03	3.68E-03	6.83E-03
0.05	1.28E-03	3.95E-04	5.91E-04	1.02E-03	1.74E-03	3.52E-03
0.075	6.26E-04	1.62E-04	2.53E-04	4.77E-04	8.98E-04	1.74E-03
0.1	3.60E-04	7.66E-05	1.29E-04	2.64E-04	5.35E-04	1.01E-03
0.15	1.61E-04	2.46E-05	4.70E-05	1.11E-04	2.57E-04	4.70E-04
0.3	4.01E-05	4.07E-06	9.24E-06	2.60E-05	6.64E-05	1.23E-04
0.5	1.36E-05	1.20E-06	3.09E-06	8.72E-06	2.29E-05	4.13E-05
0.75	5.22E-06	4.43E-07	1.21E-06	3.37E-06	8.85E-06	1.60E-05
1.	2.43E-06	2.01E-07	5.66E-07	1.57E-06	4.13E-06	7.34E-06
1.5	7.24E-07	5.12E-08	1.60E-07	4.98E-07	1.25E-06	2.16E-06
3.	7.67E-08	2.35E-09	9.79E-09	4.31E-08	1.38E-07	2.64E-07
5.	1.55E-08	2.10E-10	6.26E-10	5.42E-09	2.92E-08	6.45E-08
7.5	4.27E-09	1.32E-10	1.49E-10	1.05E-09	8.00E-09	1.90E-08
10.	1.62E-09	1.21E-10	1.32E-10	3.68E-10	2.96E-09	7.55E-09

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

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	3.80E-02	2.92E-02	3.19E-02	3.79E-02	4.37E-02	4.77E-02
0.001	3.47E-02	2.49E-02	2.88E-02	3.47E-02	4.07E-02	4.50E-02
0.005	1.81E-02	9.79E-03	1.31E-02	1.77E-02	2.32E-02	2.76E-02
0.01	1.10E-02	5.12E-03	7.23E-03	1.07E-02	1.49E-02	1.84E-02
0.015	7.79E-03	3.23E-03	4.77E-03	7.34E-03	1.07E-02	1.40E-02
0.03	3.79E-03	1.34E-03	2.01E-03	3.37E-03	5.42E-03	7.89E-03
0.05	1.97E-03	6.54E-04	9.65E-04	1.67E-03	2.84E-03	4.50E-03
0.075	1.08E-03	3.33E-04	4.98E-04	8.85E-04	1.55E-03	2.60E-03
0.1	6.81E-04	1.92E-04	2.92E-04	5.42E-04	9.93E-04	1.69E-03
0.15	3.37E-04	8.00E-05	1.31E-04	2.60E-04	5.05E-04	8.60E-04
0.3	9.16E-05	1.42E-05	2.76E-05	6.54E-05	1.49E-04	2.57E-04
0.5	3.28E-05	3.52E-06	7.66E-06	2.22E-05	5.58E-05	9.79E-05
0.75	1.36E-05	1.05E-06	2.53E-06	8.60E-06	2.39E-05	4.25E-05
1.	6.84E-06	4.31E-07	1.13E-06	4.07E-06	1.23E-05	2.22E-05
1.5	2.28E-06	1.16E-07	3.37E-07	1.23E-06	4.13E-06	7.89E-06
3.	2.18E-07	8.60E-09	2.68E-08	1.02E-07	3.90E-07	8.12E-07
5.	2.84E-08	6.45E-10	2.25E-09	1.29E-08	5.05E-08	1.08E-07
7.5	5.97E-09	1.49E-10	2.92E-10	1.92E-09	1.04E-08	2.64E-08
10.	2.18E-09	1.32E-10	1.42E-10	4.98E-10	3.73E-09	1.07E-08

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

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	3.88E-02	3.01E-02	3.28E-02	3.84E-02	4.43E-02	4.83E-02
0.001	3.68E-02	2.76E-02	3.09E-02	3.68E-02	4.31E-02	4.70E-02
0.005	2.28E-02	1.21E-02	1.57E-02	2.25E-02	3.01E-02	3.47E-02
0.01	1.48E-02	6.54E-03	9.24E-03	1.42E-02	2.04E-02	2.46E-02
0.015	1.07E-02	4.19E-03	6.17E-03	1.02E-02	1.53E-02	1.87E-02
0.03	5.33E-03	1.67E-03	2.57E-03	4.83E-03	8.12E-03	1.07E-02
0.05	2.77E-03	7.34E-04	1.16E-03	2.39E-03	4.37E-03	6.26E-03
0.075	1.50E-03	3.57E-04	5.75E-04	1.21E-03	2.39E-03	3.68E-03
0.1	9.25E-04	2.04E-04	3.37E-04	7.23E-04	1.46E-03	2.32E-03
0.15	4.41E-04	8.60E-05	1.49E-04	3.33E-04	6.93E-04	1.15E-03
0.3	1.10E-04	1.72E-05	3.19E-05	8.00E-05	1.79E-04	3.01E-04
0.5	3.67E-05	4.56E-06	9.51E-06	2.57E-05	6.26E-05	1.05E-04
0.75	1.44E-05	1.44E-06	3.33E-06	9.65E-06	2.49E-05	4.31E-05
1.	6.91E-06	5.75E-07	1.42E-06	4.50E-06	1.21E-05	2.13E-05
1.5	2.14E-06	1.31E-07	3.57E-07	1.29E-06	3.84E-06	7.03E-06
3.	1.78E-07	5.05E-09	1.67E-08	8.12E-08	3.23E-07	6.73E-07
5.	2.04E-08	3.42E-10	1.01E-09	6.26E-09	3.47E-08	8.72E-08
7.5	3.48E-09	1.32E-10	1.74E-10	7.23E-10	5.12E-09	1.60E-08
10.	1.03E-09	1.23E-10	1.32E-10	2.19E-10	1.31E-09	4.83E-09

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

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	3.73E-02	2.84E-02	3.14E-02	3.73E-02	4.31E-02	4.70E-02
0.001	3.34E-02	2.29E-02	2.68E-02	3.33E-02	4.01E-02	4.43E-02
0.005	1.61E-02	7.55E-03	1.02E-02	1.55E-02	2.22E-02	2.68E-02
0.01	9.23E-03	3.63E-03	5.27E-03	8.72E-03	1.32E-02	1.67E-02
0.015	6.20E-03	2.07E-03	3.23E-03	5.75E-03	9.24E-03	1.18E-02
0.03	2.65E-03	6.26E-04	1.05E-03	2.22E-03	4.31E-03	6.09E-03
0.05	1.17E-03	2.19E-04	3.84E-04	8.85E-04	1.95E-03	3.14E-03
0.075	5.41E-04	8.72E-05	1.60E-04	3.79E-04	8.85E-04	1.55E-03
0.1	2.97E-04	4.50E-05	8.35E-05	2.01E-04	4.77E-04	8.60E-04
0.15	1.22E-04	1.69E-05	3.28E-05	8.23E-05	1.95E-04	3.57E-04
0.3	2.70E-05	3.23E-06	6.93E-06	1.87E-05	4.50E-05	7.89E-05
0.5	9.19E-06	9.51E-07	2.19E-06	6.26E-06	1.55E-05	2.76E-05
0.75	3.82E-06	3.19E-07	8.23E-07	2.49E-06	6.54E-06	1.18E-05
1.	1.97E-06	1.38E-07	3.84E-07	1.25E-06	3.37E-06	6.17E-06
1.5	7.13E-07	3.63E-08	1.13E-07	4.13E-07	1.23E-06	2.39E-06
3.	9.83E-08	2.53E-09	8.60E-09	4.07E-08	1.69E-07	3.84E-07
5.	1.90E-08	3.28E-10	8.85E-10	5.05E-09	3.01E-08	8.35E-08
7.5	4.68E-09	1.42E-10	2.04E-10	8.00E-10	6.36E-09	2.16E-08
10.	1.64E-09	1.32E-10	1.34E-10	2.60E-10	1.98E-09	7.66E-09

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

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	2.59E-02	1.38E-02	1.84E-02	2.60E-02	3.33E-02	3.79E-02
0.001	1.82E-02	8.23E-03	1.20E-02	1.79E-02	2.42E-02	2.88E-02
0.005	5.43E-03	1.64E-03	2.80E-03	5.12E-03	8.12E-03	1.02E-02
0.01	2.84E-03	5.05E-04	1.04E-03	2.49E-03	4.70E-03	6.45E-03
0.015	1.80E-03	2.19E-04	4.83E-04	1.40E-03	3.19E-03	4.70E-03
0.03	6.26E-04	4.13E-05	1.01E-04	3.63E-04	1.16E-03	2.07E-03
0.05	2.14E-04	1.04E-05	2.64E-05	9.93E-05	3.73E-04	8.12E-04
0.075	7.65E-05	3.33E-06	8.47E-06	3.23E-05	1.20E-04	3.01E-04
0.1	3.42E-05	1.44E-06	3.68E-06	1.42E-05	5.20E-05	1.36E-04
0.15	1.04E-05	4.31E-07	1.16E-06	4.43E-06	1.60E-05	4.07E-05
0.3	1.62E-06	4.70E-08	1.60E-07	7.03E-07	2.72E-06	6.45E-06
0.5	5.37E-07	7.66E-09	3.52E-08	2.07E-07	8.72E-07	2.19E-06
0.75	2.42E-07	1.72E-09	1.02E-08	7.89E-08	3.84E-07	1.04E-06
1.	1.38E-07	6.17E-10	4.07E-09	3.84E-08	2.16E-07	6.00E-07
1.5	6.06E-08	2.13E-10	1.07E-09	1.34E-08	8.98E-08	2.72E-07
3.	1.26E-08	1.32E-10	1.82E-10	1.82E-09	1.64E-08	5.75E-08
5.	3.26E-09	1.32E-10	1.32E-10	4.07E-10	3.79E-09	1.49E-08
7.5	9.72E-10	1.21E-10	1.32E-10	1.79E-10	1.05E-09	4.31E-09
10.	3.78E-10	1.21E-10	1.32E-10	1.36E-10	4.37E-10	1.67E-09

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

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	1.41E-02	6.83E-03	9.65E-03	1.38E-02	1.87E-02	2.22E-02
0.001	8.99E-03	3.79E-03	5.58E-03	8.72E-03	1.23E-02	1.53E-02
0.005	2.87E-03	4.31E-04	9.65E-04	2.53E-03	4.77E-03	6.54E-03
0.01	1.53E-03	9.37E-05	2.72E-04	1.11E-03	2.84E-03	4.31E-03
0.015	9.42E-04	3.28E-05	1.08E-04	5.50E-04	1.87E-03	3.09E-03
0.03	3.03E-04	4.50E-06	1.64E-05	1.08E-04	5.75E-04	1.23E-03
0.05	9.75E-05	9.37E-07	3.42E-06	2.49E-05	1.60E-04	4.43E-04
0.075	3.31E-05	2.53E-07	9.24E-07	6.83E-06	4.70E-05	1.51E-04
0.1	1.40E-05	9.37E-08	3.57E-07	2.60E-06	1.84E-05	6.26E-05
0.15	3.83E-06	2.13E-08	9.37E-08	6.73E-07	4.70E-06	1.67E-05
0.3	4.10E-07	1.29E-09	7.89E-09	7.03E-08	5.12E-07	1.92E-06
0.5	1.02E-07	2.16E-10	1.07E-09	1.31E-08	1.18E-07	4.83E-07
0.75	3.95E-08	1.32E-10	2.72E-10	3.33E-09	3.79E-08	1.84E-07
1.	2.08E-08	1.32E-10	1.55E-10	1.25E-09	1.69E-08	9.37E-08
1.5	8.26E-09	1.32E-10	1.32E-10	3.42E-10	5.27E-09	3.42E-08
3.	1.48E-09	1.21E-10	1.32E-10	1.32E-10	6.26E-10	5.05E-09
5.	3.49E-10	1.21E-10	1.21E-10	1.32E-10	1.87E-10	1.01E-09
7.5	9.68E-11	1.21E-10	1.21E-10	1.32E-10	1.32E-10	3.14E-10
10.	3.60E-11	1.21E-10	1.21E-10	1.32E-10	1.32E-10	1.77E-10

Table A-2a. Amplification Functions for Fort Calhoun

PGA	Median AF	Sigma ln(AF)
1.00E-02	2.80E+00	6.80E-02
4.95E-02	2.17E+00	8.46E-02
9.64E-02	1.87E+00	1.07E-01
1.94E-01	1.57E+00	1.43E-01
2.92E-01	1.39E+00	1.66E-01
3.91E-01	1.26E+00	1.89E-01
4.93E-01	1.16E+00	2.04E-01
7.41E-01	9.82E-01	2.28E-01
1.01E+00	8.59E-01	2.32E-01
1.28E+00	7.75E-01	2.30E-01
1.55E+00	7.16E-01	2.26E-01

25 Hz	Median AF	Sigma ln(AF)
1.30E-02	2.33E+00	7.47E-02
1.02E-01	1.38E+00	1.59E-01
2.13E-01	1.15E+00	1.97E-01
4.43E-01	9.21E-01	2.36E-01
6.76E-01	7.91E-01	2.55E-01
9.09E-01	6.96E-01	2.72E-01
1.15E+00	6.24E-01	2.83E-01
1.73E+00	5.03E-01	3.05E-01
2.36E+00	5.00E-01	3.08E-01
3.01E+00	5.00E-01	2.99E-01
3.63E+00	5.00E-01	2.89E-01

10 Hz	Median AF	Sigma ln(AF)
1.90E-02	2.55E+00	1.64E-01
9.99E-02	2.20E+00	2.23E-01
1.85E-01	2.00E+00	2.53E-01
3.56E-01	1.72E+00	3.03E-01
5.23E-01	1.51E+00	3.29E-01
6.90E-01	1.35E+00	3.45E-01
8.61E-01	1.22E+00	3.55E-01
1.27E+00	9.83E-01	3.82E-01
1.72E+00	8.22E-01	3.94E-01
2.17E+00	7.16E-01	3.92E-01
2.61E+00	6.44E-01	3.82E-01

5 Hz	Median AF	Sigma ln(AF)
2.09E-02	3.70E+00	1.91E-01
8.24E-02	3.36E+00	2.20E-01
1.44E-01	3.11E+00	2.43E-01
2.65E-01	2.73E+00	2.76E-01
3.84E-01	2.45E+00	2.93E-01
5.02E-01	2.23E+00	3.04E-01
6.22E-01	2.03E+00	3.12E-01
9.13E-01	1.69E+00	3.26E-01
1.22E+00	1.45E+00	3.24E-01
1.54E+00	1.30E+00	3.22E-01
1.85E+00	1.20E+00	3.19E-01

2.5 Hz	Median AF	Sigma ln(AF)
2.18E-02	2.64E+00	2.22E-01
7.05E-02	2.85E+00	2.11E-01
1.18E-01	2.92E+00	1.97E-01
2.12E-01	2.94E+00	2.35E-01
3.04E-01	2.89E+00	2.75E-01
3.94E-01	2.79E+00	3.04E-01
4.86E-01	2.65E+00	3.26E-01
7.09E-01	2.40E+00	3.59E-01
9.47E-01	2.18E+00	3.55E-01
1.19E+00	2.02E+00	3.53E-01
1.43E+00	1.95E+00	3.51E-01

1 Hz	Median AF	Sigma ln(AF)
1.27E-02	1.70E+00	9.17E-02
3.43E-02	1.77E+00	1.03E-01
5.51E-02	1.82E+00	1.18E-01
9.63E-02	1.92E+00	1.45E-01
1.36E-01	2.02E+00	1.54E-01
1.75E-01	2.13E+00	1.60E-01
2.14E-01	2.25E+00	1.70E-01
3.10E-01	2.44E+00	1.92E-01
4.12E-01	2.53E+00	2.04E-01
5.18E-01	2.60E+00	2.10E-01
6.19E-01	2.66E+00	2.08E-01

Table A-2a. Amplification Functions for Fort Calhoun (cont.)

0.5 Hz	**Median AF**	**Sigma ln(AF)**
8.25E-03	1.61E+00	1.20E-01
1.96E-02	1.65E+00	1.17E-01
3.02E-02	1.67E+00	1.16E-01
5.11E-02	1.71E+00	1.19E-01
7.10E-02	1.74E+00	1.22E-01
9.06E-02	1.78E+00	1.28E-01
1.10E-01	1.80E+00	1.33E-01
1.58E-01	1.84E+00	1.42E-01
2.09E-01	1.89E+00	1.48E-01
2.62E-01	1.94E+00	1.60E-01
3.12E-01	1.99E+00	1.69E-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. These factors are unverified and are provided for information only (EPRI, 2014). 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=0.391**		
Freq. (Hz)	**Soil_SA**	**med. AF**	**sigma ln(AF)**	**Freq. (Hz)**	**Soil_SA**	**med. AF**	**sigma ln(AF)**
100.0	0.168	1.748	0.120	100.0	0.436	1.115	0.245
87.1	0.169	1.717	0.120	87.1	0.437	1.083	0.245
75.9	0.169	1.663	0.121	75.9	0.437	1.030	0.246
66.1	0.170	1.561	0.122	66.1	0.438	0.933	0.246
57.5	0.172	1.387	0.125	57.5	0.440	0.785	0.247
50.1	0.175	1.197	0.131	50.1	0.442	0.651	0.249
43.7	0.180	1.046	0.139	43.7	0.447	0.556	0.253
38.0	0.186	0.976	0.150	38.0	0.454	0.518	0.259
33.1	0.194	0.944	0.160	33.1	0.464	0.505	0.265
28.8	0.200	0.962	0.167	28.8	0.475	0.522	0.271
25.1	0.212	0.994	0.181	25.1	0.489	0.538	0.277
21.9	0.229	1.111	0.199	21.9	0.507	0.592	0.283
19.1	0.247	1.198	0.211	19.1	0.538	0.642	0.305
16.6	0.260	1.294	0.217	16.6	0.575	0.720	0.326
14.5	0.265	1.362	0.222	14.5	0.613	0.810	0.336
12.6	0.271	1.419	0.223	12.6	0.618	0.845	0.327
11.0	0.288	1.529	0.265	11.0	0.624	0.879	0.342
9.5	0.332	1.826	0.310	9.5	0.664	0.986	0.366
8.3	0.369	2.183	0.293	8.3	0.702	1.136	0.396
7.2	0.347	2.173	0.242	7.2	0.773	1.341	0.411
6.3	0.370	2.445	0.220	6.3	0.866	1.609	0.387
5.5	0.372	2.559	0.241	5.5	0.923	1.803	0.368
4.8	0.383	2.673	0.289	4.8	0.878	1.760	0.343
4.2	0.453	3.241	0.341	4.2	0.871	1.808	0.374
3.6	0.474	3.465	0.303	3.6	0.979	2.095	0.459
3.2	0.424	3.268	0.275	3.2	1.118	2.549	0.446
2.8	0.363	2.934	0.259	2.8	1.193	2.874	0.397
2.4	0.308	2.690	0.203	2.4	1.170	3.065	0.376
2.1	0.260	2.488	0.179	2.1	1.048	3.028	0.387
1.8	0.208	2.208	0.203	1.8	0.839	2.716	0.350
1.6	0.167	2.039	0.212	1.6	0.650	2.434	0.298
1.4	0.136	1.924	0.188	1.4	0.509	2.222	0.223
1.2	0.120	1.921	0.184	1.2	0.433	2.156	0.179
1.0	0.111	1.964	0.141	1.0	0.393	2.176	0.146
0.91	0.098	1.887	0.091	0.91	0.343	2.092	0.138
0.79	0.081	1.709	0.086	0.79	0.280	1.896	0.154
0.69	0.067	1.578	0.106	0.69	0.228	1.743	0.182
0.60	0.057	1.523	0.105	0.60	0.189	1.665	0.185
0.52	0.048	1.516	0.086	0.52	0.157	1.631	0.149

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)**
0.46	0.041	1.525	0.075	0.46	0.129	1.619	0.119
0.10	0.001	1.225	0.038	0.10	0.004	1.256	0.041

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

M2P1K1		PGA=0.0964		M2P1K1		PGA=0.391	
Freq. (Hz)	**Soil_SA**	**med. AF**	**sigma ln(AF)**	**Freq. (Hz)**	**Soil_SA**	**med. AF**	**sigma ln(AF)**
100.0	0.186	1.927	0.085	100.0	0.549	1.404	0.167
87.1	0.186	1.894	0.085	87.1	0.551	1.367	0.168
75.9	0.187	1.837	0.086	75.9	0.553	1.302	0.168
66.1	0.189	1.729	0.087	66.1	0.556	1.183	0.170
57.5	0.191	1.542	0.090	57.5	0.562	1.003	0.173
50.1	0.196	1.340	0.096	50.1	0.572	0.841	0.178
43.7	0.203	1.181	0.101	43.7	0.588	0.731	0.186
38.0	0.213	1.114	0.111	38.0	0.611	0.697	0.197
33.1	0.222	1.085	0.120	33.1	0.637	0.693	0.208
28.8	0.232	1.116	0.135	28.8	0.667	0.732	0.220
25.1	0.252	1.186	0.145	25.1	0.694	0.763	0.228
21.9	0.272	1.321	0.177	21.9	0.753	0.878	0.244
19.1	0.291	1.413	0.182	19.1	0.822	0.981	0.268
16.6	0.302	1.505	0.196	16.6	0.873	1.092	0.276
14.5	0.311	1.598	0.213	14.5	0.879	1.160	0.278
12.6	0.311	1.629	0.182	12.6	0.879	1.201	0.283
11.0	0.344	1.824	0.226	11.0	0.929	1.310	0.296
9.5	0.412	2.267	0.259	9.5	1.047	1.554	0.332
8.3	0.423	2.502	0.210	8.3	1.151	1.862	0.352
7.2	0.366	2.292	0.182	7.2	1.129	1.960	0.316
6.3	0.403	2.662	0.178	6.3	1.188	2.206	0.291
5.5	0.408	2.801	0.190	5.5	1.187	2.318	0.280
4.8	0.437	3.050	0.256	4.8	1.145	2.296	0.268
4.2	0.530	3.788	0.268	4.2	1.311	2.721	0.333
3.6	0.507	3.703	0.235	3.6	1.482	3.170	0.321
3.2	0.424	3.274	0.274	3.2	1.429	3.257	0.313
2.8	0.352	2.850	0.244	2.8	1.260	3.037	0.306
2.4	0.296	2.585	0.209	2.4	1.070	2.802	0.279
2.1	0.251	2.397	0.204	2.1	0.889	2.568	0.241
1.8	0.199	2.119	0.229	1.8	0.701	2.270	0.205
1.6	0.160	1.955	0.201	1.6	0.558	2.091	0.210
1.4	0.131	1.854	0.155	1.4	0.453	1.979	0.187
1.2	0.117	1.868	0.159	1.2	0.399	1.986	0.201
1.0	0.109	1.924	0.123	1.0	0.368	2.037	0.192
0.91	0.096	1.857	0.080	0.91	0.321	1.962	0.166
0.79	0.080	1.688	0.081	0.79	0.261	1.772	0.140
0.69	0.066	1.563	0.104	0.69	0.213	1.628	0.132
0.60	0.056	1.513	0.104	0.60	0.177	1.564	0.121
0.52	0.048	1.508	0.083	0.52	0.149	1.551	0.098
0.46	0.041	1.519	0.072	0.46	0.124	1.555	0.085
0.10	0.001	1.224	0.038	0.10	0.004	1.234	0.041

Appendix B – IPEEE Adequacy Evaluation

B.1. Introduction

The guidance for developing the seismic hazard, performing the seismic hazard screening, and performing the subsequent seismic risk assessment work in response to Post-Fukushima NTTF Recommendation 2.1 requirements for seismic are contained in 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" (Reference 1). In the SPID guidance, Ground Motion Response Spectra (GMRS) using current seismic hazard data and source characterization are developed for each site. This new GMRS is compared to the site design basis response spectra using the SPID guidance. The first method for seismic screening is based on a comparison of GMRS to the site design basis Safe Shutdown Earthquake (SSE) spectrum. The second method for seismic screening is to compare the GMRS to the site Individual Plant Examination of External Events (IPEEE) High Confidence of a Low Probability of Failure (HCLPF) spectrum (IHS). Plants that do not screen out must perform a seismic risk assessment.

In order to perform the GMRS to IHS screening, the site IPEEE is subject to an adequacy review to ensure that the IPEEE is of sufficient quality. The adequacy review guidance is provided in Section 3.3.1 of the SPID.

The purpose of this Appendix is to perform the IPEEE adequacy review for Fort Calhoun Station (FCS) using the criteria of Section 3.3.1 of the SPID.

B.1.1 SPID Requirements for IPEEE Adequacy

Nuclear power plant licensees were required to perform the Individual Plant Examination of External Events for Severe Accident Vulnerabilities per Generic Letter No. 88-20, Supplement 4 (Reference 2). Seismic hazards were one of the external events evaluated in the IPEEE program. Guidance for performing the IPEEE analysis was provided in NUREG-1407 (Reference 3). The seismic IPEEE was accomplished by performing a Seismic Probabilistic Risk Assessment (SPRA) or Seismic Margins Method (SMM) (also referred to as Seismic Margins Assessment (SMA)).

The SPID (Reference 1) defines four categories that must be addressed in order to use the IHS for seismic hazard screening. The four categories are:

- General Considerations
- Prerequisites
- Adequacy Demonstration
- Documentation

The General Considerations state that reduced scope SMAs cannot be used for screening. Focused-scope SMAs must complete (1) a full-scope review of relay chatter, and (2) a full review of soil failure modes.

Four Prerequisites are defined in the SPID that must be confirmed and documented in the hazard submittal to the NRC. These prerequisites generally relate to closure of any open items from the IPEEE submittal including commitments, plant improvements/modifications, and addressing any weaknesses from the IPEEE submittal. The final prerequisite requires a review of plant modifications since the IPEEE submittal to confirm that the conclusions of the IPEEE are not invalidated.

Adequacy Demonstrations must be performed on nine different items from the IPEEE submittal. Each of the Adequacy Demonstration items must evaluate (1) the methodology used, (2) whether the analysis was conducted in accordance with NUREG-1407, and (3) a statement, if applicable, as to whether the results are adequate for screening purposes.

Licensees are also requested to have documentation of the Prerequisites and Adequacy Demonstration and the information used to assess these items available for review at the site for potential staff audits.

B.1.2 Fort Calhoun IPEEE Seismic Description

A seismic margin assessment (SMA) was performed for the seismic portion of the FCS IPEEE (Reference 9) using the SMA methodology documented in NUREG/CR-4334 (Reference 4). FCS performed a 0.3g focused-scope SMA utilizing a NUREG-CR/0098 (Reference 7) spectral shape for a soil site. FCS is also a USI A-46 plant and the IPEEE seismic walkdowns were performed in conjunction with the USI A-46 walkdown. Note that the SMA methodology described in NUREG/CR-4334 is consistent with the fault based SMA approach documented in the NRC Interim Staff Guidance on Performing a Seismic Margin Assessment in Response to the March 2012 Request for Information Letter (Reference 41).

The calculated plant-level high confidence of low probability of failure (HCLPF) for FCS resulting from performance of the IPEEE was 0.25g. The results of the FCS IPEEE were provided to NRC in a letter dated June 30, 1995 (Reference 9).

NRC contracted Energy Research, Inc. to conduct a completeness and reasonableness review of the FCS IPEEE submittal and associated documentation in March 1995 and sent a Request for Additional Information (RAI) to FCS in June 1996. FCS responded to the RAI in August 1998. On the basis of this review and further review by a senior review board, the NRC staff concluded that the aspects of seismic accidents were adequately addressed.

The NRC issued its staff Safety Evaluation Report (SER) on May 6, 1999, for the FCS IPEEE. The SER (Reference 11) concluded that the FCS IPEEE process was capable of identifying the most likely severe accidents and severe accident vulnerabilities, meeting the intent of GL 88-20.

B.2. General Considerations

Fort Calhoun was a focused-scope plant for the IPEEE seismic evaluation. The SPID (Reference 1) Section 3.3.1 - General Considerations requires that focused-scope plants perform full-scope relay chatter reviews and a soil failures evaluation.

B.2.1 Relay Chatter

Fort Calhoun is a focused-scope review IPEEE plant and therefore must perform full-scope relay chatter reviews. NEI Letter "Relay Chatter Reviews for Seismic Hazard Screening" dated October 3, 2013 (Reference 8) states that full-scope relay chatter reviews will be performed on a schedule consistent with high frequency evaluations. Thus, this report does not address relay chatter, and FCS will perform relay chatter reviews on the schedule discussed in the NEI letter.

B.2.2 Soil Liquefaction Evaluation

Even though Fort Calhoun was a focused-scope IPEEE plant, a soil evaluation failure was part of the IPEEE. FCS calculation FC06334 (Reference 20) documents a soil liquefaction analysis, using two methods in Appendix C to EPRI-NP-6041-SL (Reference 5). For the soil under Category-I structures, Methods A and B yielded HCLPF values of 0.4g and 0.35g, respectively. For soil outside the Category-I structures, both of the methods yielded a HCLPF value of 0.25g, thus the value 0.25g was used in the determination of the plant HCLPF.

B.3. Prerequisites

In accordance with the requirements of the SPID, the following prerequisites must be addressed in order to use the IPEEE analysis for seismic hazard screening purposes and to demonstrate that the IPEEE results can be used for comparison with the GMRS:

1. Confirm that commitments made under the IPEEE have been met. If not, address and close those commitments.
2. Confirm whether all of the modifications and other changes credited in the IPEEE analysis are in place.
3. Confirm that any identified deficiencies or weaknesses to NUREG-1407 in the plant-specific NRC SER are properly justified to ensure that the IPEEE conclusions remain valid.
4. Confirm that major plant modifications since the completion of the IPEEE have not degraded/impacted the conclusion reached in the IPEEE.

Prerequisites 1 and 2

The IPEEE commitments, listed in Table 4.1 of the SER (Reference 11), and modifications have been completed (Reference 12).

The vulnerabilities that were identified under the IPEEE program were also incorporated as outliers under the USI A-46 program. OPPD joined the Seismic Qualification Utility Group (SQUG), which published the Generic Implementation Procedure, Revision 2 (GIP-2) (Reference 6) for evaluating these plants and equipment. OPPD used GIP-2 in its entirety to evaluate the adequacy of selected safe shutdown equipment in the Fort Calhoun Station. NRC issued two SERs to OPPD: the first on July 30, 1998 (Reference 10), which accepted the results of the USI A-46 program for FCS, including the approach used to resolve all outliers and vulnerabilities, and the second on May 6, 1999 (Reference 11), which reviewed the seismic portion of the IPEEE submittal. Within the SER letter (Reference 11), there are no IPEEE vulnerabilities to report because all "outliers" have been resolved and incorporated into the plant design.

Verification of the completion of these commitments and modifications were provided in the FCS Response (Reference 12) to 10CFR 50.54(f) Request for Information Recommendation 2.3 Seismic.

Prerequisite 3

The FCS NRC Safety Evaluation Report (SER) on the seismic portion of the IPEEE submittal (Reference 11) identified the following weaknesses in the IPEEE seismic analysis:

1) The assumptions of loss of offsite power and loss of instrument air for all sequences led to an overestimate of the significance of operator actions to replenish the EFWST, and prevented

insights from being gained with respect to the Power Conversion System (PCS), instrument air system, and the Shutdown Cooling (indicated as Residual Heat Removal by the SER) system.

2) The discussion of seismically induced fires did not include: (1) the effect of the proximity of non-1E cabinets to essential safety equipment; and (2) inadvertent fire protection system actuation.

3) The inference of the turbine building HCLPF capacity from the wind loading specifications may have underestimated the capacity and, thereby, overestimated the significance of the turbine building.

The first and the third items indicated as weaknesses by the NRC SER are in essence over-conservative approaches to the fragility estimate for offsite power (i.e., assumed failed) and for the Turbine Building. In a probabilistic approach, this has the possibility to skew the risk profile of the plant. That said, even though the FCS SMA used the structure of the IPE (i.e. internal events PRA) as a tool to generate potential accident sequences, the SMA itself is a deterministic exercise in the fact that the min-max plant HCLPF evaluation is deterministic. For this reason, the overall conclusions of the IPEEE are not affected from the over-conservative estimate of fragilities.

The second weakness has to do with the seismic-induced fires. While this was apparently not addressed to NRC reviewer satisfaction, it must be considered that FCS used the IPEEE seismic and fire sections as starting point for the development of the FCS fire PRA in support to NFPA 805 transition. The fire PRA elements associated with seismic-induced fires were reviewed during the peer review of the fire PRA and were considered adequate and meeting the requirements of the modern PRA standard.

The weaknesses identified by the NRC SER are therefore considered not to be significant for the overall assessment of seismic capacity of FCS.

Prerequisite 4

Consistent with the requirements of NTTF Recommendation 2.3 on seismic walkdowns, a number of plant modifications have been addressed for their potential to result in changes to the conclusions of the IPEEE as part of the 2.3 program. This IPEEE adequacy assessment has reviewed the balance of the plant changes. The plant modification assessment was based on the review of the plant and system Design Basis Documents (PLDBD and SDBD) documents from the plant, and the associated modifications summaries. Each change was reviewed under two points of view:

- Whether the modification had the possibility to change the success criteria associated to the IPE/PRA that was used as starting point for the IPEEE evaluation. This included consideration of modified mitigation system success criteria or additional initiating events (e.g., seismic-induced flood scenarios)
- Whether the modification had the possibility to change the HCLPF or screening considerations of any equipment in the SSEL.

The review, which is documented in Table B.3-1, did not identify any major modification that invalidates the conclusions of the IPEEE.

Table B.3-1: Review of Plant Modifications Since IPEEE

DBD number	Title	Generic Comments	Success Criteria Impact	Structural/HCLPF Impact
PLDBD-ME-10	PIPE STRESS AND SUPPORTS	No major modifications, pipe stress and support code requirements		
PLDBD-ME-11	INTERNAL MISSILES &HELB	Reviewed as part of 2.3 program		
PLDBD-EE-21	ELECTRICAL EQUIPMENT	Reviewed as part of 2.3 program		
PLDBD-IC-30	INSTRUMENTATION INSTALLATION	Reviewed as part of 2.3 program		
PLDBD-IC-32	INSTRUMENTATION AND CONTROL	Reviewed as part of 2.3 program		
PLDBD-CS-50	EXTERNAL MISSILES	No major modifications listed, design requirement document		
PLDBD-CS-51	SEISMIC CRITERIA	Reviewed as part of 2.3 program		
PLDBD-CS-52	HEAVY LOADS	Reviewed as part of 2.3 program		
PLDBD-CS-54	GEOTECHNICAL	No major modifications since IPEEE submittal		
PLDBD-CS-55	MASONRY WALLS	Reviewed as part of 2.3 program		
PLDBD-NU-61	REGULATIONS, CODES AND STANDARDS	No modifications listed		
PLDBD-NU-63 (Reference 32)	PERSONNEL PROTECTION	EC 38262, EC 40070, EC31967 installed since IPEEE Submittal, see Attachment 6 of DBD.	**EC 38262** addresses the relocation of a radiation monitor to the new fuel receipt room 25a, which has no impact on IPEEE success criteria. **EC 40070** addresses radiological consequences and credit for containment HEPA filters.	Relocated radiation monitor to the new fuel receipt room 25a documented in **EC 38262** does not present a spatial interaction hazard. **EC 40070** and **EC**

Table B.3-1: Review of Plant Modifications Since IPEEE

DBD number	Title	Generic Comments	Success Criteria Impact	Structural/HCLPF Impact
			Containment sprays have minimal impact on LERF and no impact on CDF and they are not credited for averted LERF in the PRA model although they were used for Level 2 PRA mitigation of impact. The change was likely a result of demonstrating that CARCs are capable of supporting post-accident design basis doses so that the sprays do not actuate following a LOCA. Because of this, there is no expected impact on the IPEEE conclusions due to these modifications. **EC 31967** addresses the installation of eye washes and safety shower stations in the Turbine Building and Intake Structure. PRA-SN-19, Volume 1 documents the full internal flooding evaluation done for FCS. This was performed in 2012 and therefore includes the modification discussed in EC 31967. In the internal flooding evaluation every water system is evaluated for the potential for a flood or spray scenario. Table 5.5-1 of PRA-SN-19, Volume 1 (Reference 40) addresses	**31967** do not have any structural effect.

Table B.3-1: Review of Plant Modifications Since IPEEE

DBD number	Title	Generic Comments	Success Criteria Impact	Structural/HCLPF Impact
			potential flood sources in the Intake Structure and in the Turbine Building and does not mention the cye washes or safety showers as a specific spray concern on PRA equipment. Eyewashes are not considered capable of generating a significant flood scenario because of the low capacity (see Section 5.4.1 of PRA-SN-19, Volume 1). The conclusions from the internal flooding evaluation do not change in case of a seismic-induced flood. Therefore, even if the additional piping would result in added potential for seismic-induced flood (i.e., spray), the overall conclusions of the IPEEE are not expected to change as the internal flooding evaluation already concluded that this system is not risk significant.	
PLDBD-EV-70	SITE METEOROLOGY	F-98-003, removal of chlorine and acid toxic monitors are the only modification listed after IPEEE submittal. This is not a major modification.		
SDBD-AC-CCW-100	COMPONENT COOLING WATER	Reviewed as part of 2.3 program		
SDBD-AC-RW-101	RAW WATER	Reviewed as part of 2.3 program		

Table B.3-1: Review of Plant Modifications Since IPEEE

DBD number	Title	Generic Comments	Success Criteria Impact	Structural/HCLPF Impact
SDBD-AC-SFP-102	SPENT FUEL STORAGE AND FUEL POOL COOLING	Reviewed as part of 2.3 program		
SDBD-CA-IA-105	INSTRUMENT AIR	Reviewed as part of 2.3 program		
SDBD-CH-108	CHEMICAL AND VOLUME CONTROL SYSTEM	Reviewed as part of 2.3 program		
SDBD-CN-110 (Reference 33)	PLANT COMMUNICATIONS	EC28141, 30329 installed after IPEEE submittal, Attachment 5 of DBD explains summary of ECs, one EC for installation of SpectraLink Wireless, the other to expand the wireless communications	The two modifications performed since IPEEE have no success criteria implications.	**EC28141** and **30329** do not have any structural effect.
SDBD-DG-112	EMERGENCY DIESEL GENERATORS	Reviewed as part of 2.3 program		
SDBD-DW-113	DEMINERALIZED WATER	EC31160 installation of well for second supply of water to Reverse Osmosis unit. This is not a major modification.		
SDBD-FP-115 (Reference 34)	FIRE PROTECTION	Attachment 14 summarizes modifications for FP system	A number of plant changes following IPEEE are documented in this DBD. **FC-94-018** removes the fire protection system as an emergency fill source for FW-19; this is expected to have no impact on the IPEEE conclusions because the IPE/PRA model has a single event to model failure to refill	Installed Valve RW-262 as documented in **FC-94-018** has negligible structural effect on the Emergency Feedwater Storage Tank. Installed collection pans and drain lines as documented in **FC-97-019** have negligible structural effect on the

Table B.3-1: Review of Plant Modifications Since IPEEE

DBD number	Title	Generic Comments	Success Criteria Impact	Structural/HCLPF Impact
			the tank, independent from the sources, this change does not therefore impact the success criteria or the system modeling. A number of changes (e.g., **FC-98-005/EC 14803** and **EC 31442** address modifications required to prevent spurious actuation due to fire (e.g., additional signals or cable re-routing). These modifications do not normally impact the internal events conclusions due to the very fire-specific failure mode, which is not related to seismic. A number of modifications listed in this DBD (e.g., **EC 41804, EC 33033, EC 32813, EC30842, EC28212,** and **FC-90-072**) address equipment replacement (i.e., no significant modifications) with no potential for success criteria impact.	Reactor Coolant Pump Motors. **DCN 10010** is a seismic improvement to prevent sliding of the cabinets. Installed 8" pipe to tie the 2 fire pump flow test discharge headers together, as documented in EC 14834 has negligible structural effect on the anchorage capacity of the pumps. A number of changes (e.g., **FC-98-005/EC 14803** and **EC 31442**) address modifications required to prevent spurious actuation due to fire. They do not have any structural effect. A number of modifications listed in this DBD (e.g., **EC 41804, EC 33033, EC 32813, EC30842, EC28212,** and **FC-90-072**) address equipment replacement. They do not have any structural

Table B.3-1: Review of Plant Modifications Since IPEEE

DBD number	Title	Generic Comments	Success Criteria Impact	Structural/HCLPF Impact
				effect on the components on the IPEEE equipment list.
SDBD-FW-116	FEEDWATER	Reviewed as part of 2.3 program		
SDBD-FW-AFW-117	AUXILIARY FEEDWATER	Reviewed as part of 2.3 program		
SDBD-HG-122	NITROGEN AND HYDROGEN GAS	Reviewed as part of 2.3 program		
SDBD-MS-125	MAIN STEAM AND TURBINE STEAM EXTRACTION	Reviewed as part of 2.3 program		
SDBD-RC-128	REACTOR COOLANT	Reviewed as part of 2.3 program		
SDBD-SI-130	SHUTDOWN COOLING	Reviewed as part of 2.3 program		
SDBD-SI-CS-131	CONTAINMENT SPRAY	Reviewed as part of 2.3 program		
SDBD-SI-HP-132	HIGH PRESSURE SAFETY INJECTION	Reviewed as part of 2.3 program		
SDBD-SI-LP-133	LOW PRESSURE SAFETY INJECTION	Reviewed as part of 2.3 program		
SDBD-SL-135 (Reference 35)	PRIMARY AND SECONDARY SAMPLING		The sampling system is not normally modeled in internal events PRA and therefore any hardware modifications (such as **DCN 5097**, **EC 14940,** and **EC 31536**) have no functional implications on a PRA system. Therefore, no impact is expected to the IPE success criteria and consequentially to the IPEEE. The sampling system is also indicated in section 5.4.1 of PRA-SN-19 as a system without	Hardware replacement (**ECN96-0438**) has no structural effect. Small Hardware addition (such as **ECN-96-030**) has negligible structural effect. The sampling system (**DCN 5097**, **DCN 5515**, **EC 14940**, and **EC**

Table B.3-1: Review of Plant Modifications Since IPEEE

DBD number	Title	Generic Comments	Success Criteria Impact	Structural/HCLPF Impact
			the potential for inducing any significant flood scenario. Addition of isolation features such as modifications **DCN 5515** are actually beneficial for the isolation of the system from interfacing with any PRA related system. Nevertheless, it is observed that flow diversion induced by sampling systems is not usually significant in IPE.	**14998**) was not credited in IPEEE. Therefore, the changes have no structural effect on the components on the IPEEE equipment list. Installed samplers (**EC 31536**) are not part of IPEEE. Therefore, the changes have no structural effect on the components on the IPEEE equipment list. Supports of the replacement steam generators (**EC 31589**) are at least as strong as those of the old ones. Because of their high HCLPF, they were screened out at 0.5g PGA.
SDBD-VA-AUX-138	AUXILIARY BUILDING HVAC	Reviewed as part of 2.3 program		
SDBD-VA-CON-139	CONTAINMENT HVAC	Reviewed as part of 2.3 program		
SDBD-VA-CR-140	CONTROL ROOM HABITABILITY	Reviewed as part of 2.3 program		
SDBD-WD-144 (Reference 36)	WASTE DISPOSAL SYSTEMS		The waste disposal system is not modeled in internal events	The waste disposal system is not part of

Table B.3-1: Review of Plant Modifications Since IPEEE

DBD number	Title	Generic Comments	Success Criteria Impact	Structural/HCLPF Impact
			IPE/PRA, thus any modification to this system is not expected to impact the success criteria of the IPEEE. A number of modifications listed in this DBD are equipment replacement (e.g., **EC 26944, DCN 10123**, which do not change the functionality of the system). The waste disposal system is also indicated in section 5.4.1 of PRA-SN-19 as a system without the potential for inducing any significant flood scenario, which supports the conclusion that partial re-routing of the system (e.g., modification **EC 33895**) are not inducing additional hazard not previously considered.	IPEEE model. All the changes to the system are minor from the structural point of view. Therefore, they have no structural effect on the components on the IPEEE equipment list.
SDBD-EE-200	120 VAC VITAL DISTRIBUTION	Reviewed as part of 2.3 program		
SDBD-EE-201	AC DISTRIBUTION	Reviewed as part of 2.3 program		
SDBD-EE-202	DC DISTRIBUTION	Reviewed as part of 2.3 program		
SDBD-EE-203	CATHODIC PROTECTION	ECN92-379 cathodic protection upgrade, ECN94-386 fuel oil tank cathodic protection, not a major modification		
SDBD-COMP-300 (Reference 37)	ERF COMPUTER AND QSPDS COMPUTER		Only software related or cyber-security related changes that do not impact the success criteria of systems modeled in IPE/PRA.	Software related or cyber-security related changes have not structural effects.
SDBD-CONT-501	CONTAINMENT	Reviewed as part of 2.3 program		

Table B.3-1: Review of Plant Modifications Since IPEEE

DBD number	Title	Generic Comments	Success Criteria Impact	Structural/HCLPF Impact
SDBD-AUX-502 (Reference 38)	AUXILIARY BUILDING		The structural changes associated with this BDB do not impact the success criteria of systems credited in PRA.	Two 4-ton monorail hoists (**EC 30688**) were installed. This is a rigging improvement and does not have any structural effect on the components on the IPEEE equipment list. This is not a spatial interaction concern either, since monorail anchorage has high capacity. Replacement of trolley/hoist (**EC 33089**) does not have any structural effect. Installed access platform to DG emergency starting air tanks/relief valves (**EC 32743**), which is a maintenance improvement, is not a seismic interaction concern, since it is anchored to the floor and is very unlikely to collapse on the DG.
SDBD-STRUC-503 (Reference 39)	INTAKE STRUCTURE		These changes addressed improving seals for external flooding. No changes are	Installed River Barrier Wall (**EC 43876**) is not on IPEEE equipment

Table B.3-1: Review of Plant Modifications Since IPEEE

DBD number	Title	Generic Comments	Success Criteria Impact	Structural/HCLPF Impact
			expected to impact success criteria for equipment credited in PRA.	list. It is not a seismic interaction concern to the Intake Structure since it is very unlikely the wall completely collapses at 0.25g PGA. Installed penetration seals (**EC 47163**) have not structural effect.
SDBD-STRUC-504	SECURITY BUILDING	No major modifications were performed that would impact IPEEE submittal		

Prerequisites Review Conclusion

Based on the material presented previously, all four IPEEE Adequacy prerequisites from the EPRI SPID have been met for FCS.

B.4. Adequacy Demonstration

This section includes review and evaluation of the existing documentation for the FCS IPEEE project performed in the mid 1990's, in accordance to Section 3.3.1 of the SPID (Reference 1). Per the SPID, seismic risk assessments performed as part of the IPEEE for Severe Accident Vulnerabilities (Generic Letter 88-20, Supplement 4) (Reference 2) that demonstrate plant capacity to levels higher than the new GMRS can be used to "screen out" plants, provided they meet certain criteria, in which case these plants would not need to perform new seismic risk analyses. IPEEE submittals using the NRC Seismic Margins Assessment (SMA) Methodology at FCS can be considered for screening, but the analysis must have certain attributes to be considered for review by the USNRC staff.

In accordance with the guidance of the SPID, each of the nine Adequacy Demonstration items is addressed. Each Adequacy Demonstration item evaluates (1) the methodology used, (2) whether the analysis was conducted in accordance with NUREG-1407, and (3) a statement as to whether the results are adequate for screening purposes.

B.4.1 Structural Models and Structural Response Analysis

B.4.1.1 Structural Models

Dynamic models were developed for the Class I structures (Auxiliary Building/Containment Building/Internal Structure and Intake Structure) at FCS. The following description of the structural models comes directly from LIC-92-016R (Reference 23).

Combined Model for Auxiliary Building/Containment Building/Internal Structure

The Auxiliary Building/Containment Building and Internal Structure are founded on a common basemat, which is supported on 803 steel piles driven to bedrock. The Auxiliary Building includes the control room, spent fuel storage pool, safety injection and refueling water storage tank, and emergency diesel generator rooms. The Containment Building includes the Containment Shield and the Internal Structure. Other than sharing a common basemat, these three structures are structurally separate from each other. For this reason, separate "stick" models are developed for each, connected only at the basemat level.

The combined model for the Auxiliary Building, Containment Shield, and Internal Structure is a three-dimensional stick model consisting of elastic beam elements with lumped masses at major floor elevations. Each beam element represents the stiffness of a section of the structure between two floors and is located at the center of rigidity of that section. The stiffness properties of each beam element are given by the section's axial (Az) and shear areas (Ax, Ay), moments of inertia about the horizontal axes (Ixx, Iyy), and torsional constant about the vertical axis (Jzz). The mass of each floor consists of: the mass of the concrete floor slab itself, heavy equipment, storage tanks and contained liquid, steel platforms, and one-half of the concrete walls above and below a particular floor. In addition, to account for other light equipment, piping, and miscellaneous structural steel, a distributed weight of 20 psf is uniformly distributed over the area of each floor. The calculated total mass is lumped at the center of mass of the particular floor elevation. Rigid links connect the centers of mass with the centers of rigidity at each floor elevation. Thus, the model captures torsional effects due to eccentricities that exist between the center of mass and center of rigidity. The development of the combined model for the Auxiliary Building/Containment/Internal Structure is documented in Reference 25. Figure B.4-1 shows a sketch of the combined model.

Structural damping of 7% of critical was used. Forty modes were used in the actual Soil Structure Interaction (SSI) analyses, with cumulative mass participation of over 90% in each direction.

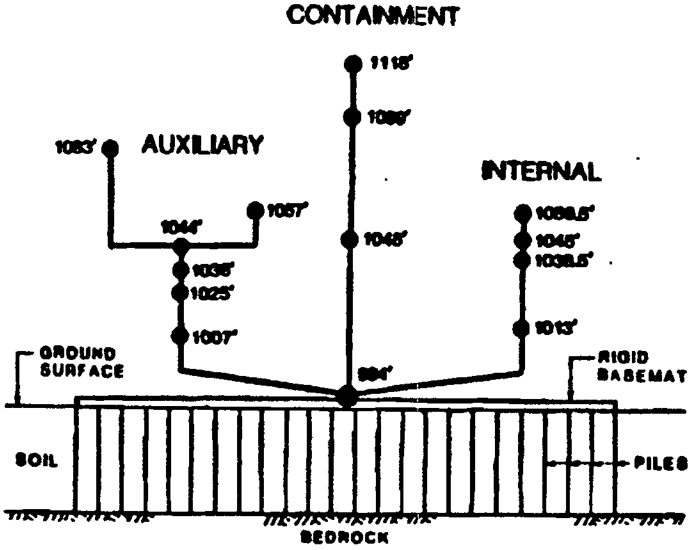

Figure B.4-1. Combined Model for Auxiliary Building/Containment/Internal Structure

Intake Structure Model

The Intake Structure is located east of the Auxiliary and Containment Building, alongside the Missouri River. The lower part of the structure is of concrete shear wall construction and the upper part is of steel frame construction. The foundation mat is supported on 64 piles driven to bedrock. The development of the Intake Structure stick model followed similar procedures as described for the combined model of the Auxiliary Building/Containment/Internal Structure. The development of the Intake Structure model is documented in Reference 27. A sketch of the stick model is shown in Figure B.4-2. Twenty modes were used in the actual SSI analyses, with cumulative mass participation of over 90% in each direction.

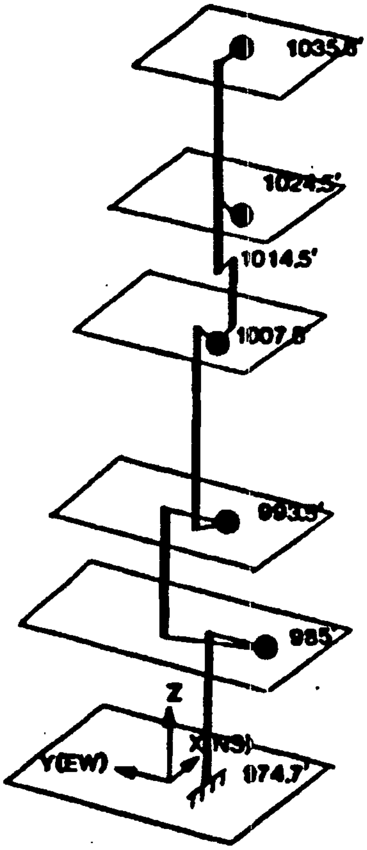

Figure B.4-2. Model for Intake Structure

Per the recommendations for evaluation of existing structural models provided in EPRI NP-6041-SL (Reference 5), each structure model is assessed for its adequacy to represent important dynamic characteristics of the structure. The combined model for the Auxiliary Building, Containment Shield and Internal Structure and the model for the Intake Structure are each a 3-dimensional lumped-mass stick model, which includes the effects of structural rocking and torsion due to eccentricities from the center of mass to the center of rigidity. Each model is found to have adequate number of nodes to represent masses at major floor elevations and inter-floor stiffnesses of the structure, so the important dynamic characteristics of the structure are captured.

B.4.1.2 Structural Response Analysis

In July 1992, OPPD submitted report "Soil Variation Analyses and Generation of In-Structure Response Spectra" to the NRC (Enclosure 3 of Reference 23). These analyses are state-of-the art SSI analyses performed using the SASSI/CLASSI methodologies to generate in-structure response spectra (ISRS) for the Containment Building (Containment and Internal Structure), Auxiliary Building and Intake Structure. The SASSI/CLASSI methodologies are based on the SSI substructure approach. The SASSI program was used to compute complex and frequency-dependent impedance functions for the soil/pile foundation system, with piles modeled as being driven to bedrock and capped to the concrete basemat. The CLASSI program was used to calculate the structural responses in terms of response spectra at each major elevation of the structures. Input to CLASSI was the SASSI-generated impedance functions, the dynamic properties of the lumped-mass stick models described in Section B.4.1.1 and free-field artificial time histories, which were generated from the modified Housner response spectra anchored at 0.17g peak ground acceleration for SSE. For the SSI analyses, the ground motion time histories were applied at the level of the foundation in the free-field.

Uncertainties in soil material properties were addressed by performing upper and lower bound soil variation analyses with shear modulus variation factor of ±30% of the best estimate soil shear modulus. The final broadened floor response spectra were the envelope of the upper bound (+30%), lower bound (-30%) and the ±15% broadened best estimate response spectra (±15% to account for other uncertainties in the analyses).

The ISRS generated from Reference 23 became part of the Alternate Seismic Criteria and Methodology (ASCM), which was approved by the NRC (Reference 24) for use as an alternative to the existing updated safety analysis report (USAR) criteria and methodologies within Appendix F (Reference 29). A detailed description of the ISRS generation performed for FCS is provided in (References 1, 26, and 28).

Structural Model and Structural Response Analysis Review Conclusion

Based on the review results in Sections B.4.1.1 and B.4.1.2, it is concluded that the structure models and structural response analysis used for IPEEE are adequate for screening purposes.

B.4.2 In-Structure Demands and ISRS

For the seismic IPEEE Review, the Review Level Earthquake (RLE) is a 0.3g NUREG/CR-0098 median spectrum for soil site (Reference 7), which has a 0.57g spectral acceleration (7% damped) from about 1.7 Hz to 8.0 Hz. The SSI and floor spectra analysis presented in Reference 23 were for a time-history whose response spectrum conservatively enveloped the modified Housner spectrum anchored to 0.17g. In accordance with EPRI NP-6041-SL (Reference 5), the floor spectra from Reference 23 can be scaled to produce approximate floor spectra for a 0.3g CR/0098 median soil site spectrum. The appropriate scale factor should be the ratio of the 7% damped 0.3g CR/0098 median spectral acceleration (i.e., 0.57g) for soil site to the average 7% damped time-history spectral acceleration within plus/minus 10% of the fundamental structure frequency.

To obtain approximate 0.3g CR/0098 median floor spectra, SSE floor spectra from Reference 23 were amplitude scaled by appropriate scale factors and frequency shifted plus/minus 10%. These scaled and frequency shifted floor spectra, as documented in FCS Calculation FC06323 (Reference 16), were used in the Seismic IPEEE Review.

In-Structure Demand and ISRS Review Conclusion

In conclusion, in-structures demands and ISRS generated for Seismic Margin Assessment (SMA) meet the requirements of NUREG-1407 and EPRI NP-6041-SL and are adequate for screening purposes.

B.4.3 Selection of SSEL

The FCS SMA was conducted to follow the fault based SMA methodology in Reference 4 and to support both the IPEEE and A-46 efforts concurrently. The fault based approach uses PRA techniques for identifying equipment to be included in the seismic analysis, and for screening out unimportant equipment or combinations of equipment failures. The FCS Individual Plant Examination (IPE) model (Reference 30) was used to develop the IPEEE equipment list. This approach goes beyond the identification of two success paths as in the EPRI SMA approach and results in a more comprehensive list of equipment.

Using the earlier PRA insights for limiting the types of accident scenarios of concern (discussed in Section 3.1.2 of the IPEEE report (Reference 9)), the analysts prepared an initial list of plant components and structures that required a plant walkdown. The list initially included all IPE fault tree events relevant to mitigating a loss of offsite power (LOSP), due to the assumption of a LOSP for any seismic event. The internal events fault tree often modeled several failures per component, thus many components were listed more than once. This list was refined to eliminate the duplicates due to the multiple failure modes, and the "rule-of-the-box" was used to group subcomponents within parent components to give a final SSEL of approximately 680 components.

Table 3.2 ("IPEEE Component List") within IPEEE Appendix A provides a listing of IPEEE components. This identifies the parent components (or "boxes") in which the components associated with the event failures listed in Table 3.1 (IPE model) are located using the "rule-of-the-box" concept.

Table 3.3 ("List of Equipment considered for SMA Modeling") within IPEEE Appendix A provides a listing of the parent components for IPEEE and A-46 SSEL components which were considered to be included in the IPEEE fault tree models. Only the A-46 items required for IPEEE analysis were included. Table 3.3 was used as the final walkdown list by the Seismic Review Teams (SRTs).

Section 4.0 of NUREG/CR-4334 provides the basis for an initial function/system screening used in the fault based SMA approach. This is summarized in Table 4-13 of NUREG/CR-4334 (or Table 3.0 of the IPEEE report, Reference 9). The FCS seismic IPEEE was performed using these considerations but went beyond the criteria such that both Group A and Group B functions/systems were included in the analysis and thus in the selection of components for the SSEL. The peer review performed by the OPPD team and by the NRC contractors did not identify any vulnerabilities or shortcomings pertaining to the selection of equipment.

Selection of SSEL Review Conclusion

The methodology used is in compliance with NUREG-1407 and the IPEEE seismic equipment selection results are adequate for screening purposes.

B.4.4 Screening of Components

B.4.4.1 Screening

For seismic IPEEE evaluation, the NRC Seismic Margins Assessment (SMA) Methodology, as documented in NUREG/CR-4334, was used along with additional guidance provided in NUREG-1407. The main features of the evaluation included development of a SMA model, development of an equipment list for plant walkdowns, performance of plant walkdowns by Seismic Capability Engineers (SCE), identification of any vulnerabilities, screening and HCLPF calculation structures and components, soil liquefaction evaluation, relay evaluations, and finally, plant HCLPF capacity evaluation based on a review of the HCLPF capacities for the dominant cutsets present in the SMA model.

The screening of components on the SMA component list, produced by the SMA model, and plant structures which house SMA components was performed using the criteria in Table 2-3 (for structures) and Table 2-4 (for components) of EPRI NP-6041-SL (Reference 5). The supplemental screening guidance in Appendix A of EPRI Report was also followed. The walkdowns of the SMA components were performed concurrently with the USI A-46 walkdowns, since FCS is a USI A-46 plant. Seismic Evaluation Work Sheets (SEWS) were used to document caveats, anchor capacities, and seismic spatial interactions per Appendix F of EPRI NP-6041-SL.

Although FCS is a focused-scope plant with a Review Level Earthquake (RLE) of 0.3g, which puts FCS in screening Lane 1, the screening and evaluations were performed for 0.5g RLE. Details of the screening of the components and the structures are documented in Reference 18.

The components on the SMA component list are housed in four buildings: Containment, Auxiliary, Intake and Turbine buildings. As demonstrated in Reference 18, all structures, except masonry walls, the Intake Structure roof, and the Turbine Building, were screened out at the RLE level of 0.5g PGA, per the screening criteria in Table 2-3 of EPRI NP-6041-SL. For block walls that did not pass screening, their HCLPF capacities were calculated using the conservative deterministic failure margin (CDFM) approach.

All of the components on the SMA component list but 91 were screened out at the 0.5g PGA level. For those 91 components that did not pass the screening, HCLPF capacities were calculated using the CDFM approach.

Screening of Components Review Conclusion

Screening of structures and components on the SMA component list was performed using the criteria in Table 2-3 and Table 2-4 of EPRI NP-6041-SL and following the guidelines of NUREG-1407, thus the methodology is considered adequate for IPEEE screening purposes.

B.4.4.2 HCLPF Evaluations

Structures and components that passed the screening criteria in Lane 2 of Tables 2-3 and 2-4 of EPRI NP-6041-SL (Reference 5) were assigned a HCLPF value of 0.5g, as shown in Reference 18. Reference 17 and Reference 19 document the calculation of HCLPF capacities for the components that did not pass the screening criteria in Lane 2 of Table 2-4 of EPRI NP-6041-SL. Sections 3.1.4.1, 3.1.4.2, and 3.1.4.3 of the IPEEE submittal discuss the HCLPF capacities of civil structures, components, and the plant, respectively.

HCLPF Seismic Capacities of Civil Structures

Table 3.15 of the IPEEE submittal lists the HCLPF values for civil structures potentially important to the risk of core damage from a seismic event. The types of structures listed in Table 2-3 of EPRI NP-6041-SL are applicable for the FCS structures and foundations included in Table 3.15. In addition to HCLPF values, Table 3.15 also contains a column for seismic interactions that specific structural/soil failures may cause.

HCLPF Seismic Capacities of Components

Tables 3.16 through 3.18 of the IPEEE submittal list HCLPF values for two groups of components. Table 3.16 provides HCLPF capacities for NSSS related items and distribution systems (i.e., piping, HVAC ductwork, and electrical raceways). Tables 3.17 and 3.18 provide HCLPF capacities for components on the SMA Component List. Table 3.17 lists HCLPF capacities that are greater than 0.5g, and Table 3.18 lists HCLPF capacities for components that are less than 0.5g.

In the IPEEE submittal, Subsection 3.1.4.2.1 provides a discussion of HCLPF values given in Table 3.16, and Subsection 3.1.4.2.2 provides a discussion of HCLPF values given in Tables 3.17 and 3.18.

Plant HCLPF Capacity

The plant HCLPF capacity was developed through the min-max approach and considerations of plant modifications and vulnerabilities. The SMA logic models were quantified to determine seismic initiated sequence cutsets. The HCLPF of each cutset was determined by using the highest element HCLPF present in the cutset. The minimum of the cutset HCLPFs was identified as the plant HCLPF.

As concluded in Section 3.1.4.3 of the IPEEE submittal, the plant HCLPF capacity is 0.25g, as long as certain detailed evaluations and/or modifications as summarized in Table 3.19 of the submittal are performed to address vulnerabilities identified. The HCLPF capacity of 0.25g is governed by the potential for soil liquefaction outside the area of Category I structures. This potential soil failure may adversely affect the adequacy of many of the components in the yard and in the Turbine Building, which may lose adequate soil foundation support.

HCLPF Evaluations Review Conclusion

HCLPF evaluations were performed using the methodology in EPRI NP-6041-SL and followed the guidelines of NUREG-1407; therefore, they are considered adequate for screening purposes.

B.4.5 Walkdowns

Per the IPEEE submittal, a walkdown of structures and components was performed by SRTs. Since FCS is an A-46 plant, the walkdowns were performed concurrently for A-46 and IPEEE purposes. The Seismic Capability Engineers (SCEs), who formed the SRTs for performing the plant walkdowns, were highly qualified and experienced engineers and met the requirements of the Generic Implementation Procedure (GIP) Section 2.1.2. Each SRT consisted of at least two SCEs, with one having a Professional Engineer's license.

The IPEEE submittal states that an electronic database was used to track and record the data from the walkdowns. The SRTs recorded notable comments in the electronic database for the components walked down. For components that are common between the A-46 and IPEEE component lists, conclusions were drawn from the evaluations and documentation performed for A-46.

For the IPEEE components that share the A-46 component list, signed Seismic Evaluation Work Sheets (SEWS) are given in Appendix F to Sargent & Lundy Report No. SL-4902 (Reference 15).

Walkdowns Review Conclusion

Per the IPEEE submittal, the walkdowns were performed by highly qualified and experienced engineers following guidance in EPRI NP-6041-SL and GIP. Therefore, the walkdown methodology meets the requirements in NUREG-1407, and walkdown results are adequate for screening purposes.

B.4.6 Fragility Evaluations

For the seismic IPEEE evaluation, the NRC Seismic Margins Assessment (SMA) Methodology, as documented in NUREG/CR-4334, was used along with additional guidance provided in NUREG-1407. To evaluate seismic margins of structures and components, HCLPF calculations were performed, in accordance with the guidance provided in EPRI NP-6041 utilizing the conservative deterministic failure margin (CDFM) approach.

Due to the deterministic nature of the CDFM approach used for the seismic IPEEE evaluation, no Core Damage Frequency (CDF) result was presented for the seismic event, since it is inappropriate to present SMA-based CDFs as if they were PRA-generated CDFs.

Therefore, no fragility evaluation was required or performed for the seismic IPEEE.

Fragility Evaluations Review Conclusion

Fragility evaluation was not required nor performed for the FCS seismic IPEEE.

B.4.7 System Modeling

The fault based SMA methodology within NUREG/CR-4334 and additional guidance within NUREG-1407 was followed for the FCS IPEEE. The FCS SMA adheres to the guidance within NUREG-1407 indicating that the fault based SMA methodology can be followed with several enhancements; FCS SMA enhancements did indeed include modeling of non-seismic failures and human actions within the SMA. Following the fault based SMA approach, the development of the systems, structures, and components to be considered in the SMA and determination of which accident sequences and combinations of equipment failures required examination were primarily based on the methodology and models used in the FCS IPE (Reference 30) with additional input from plant staff.

The IPE utilized a fault tree linking approach that allowed explicit modeling of system and/or component dependencies. This enabled a direct capability to propagate seismic failures through the front line mitigation systems and to maintain non-seismic failures within the SMA model. The SMA also included a simplified containment performance model, which was developed to address scenarios leading to significant containment releases during a seismic event. This approach is consistent with NUREG-1407, which emphasizes large early releases (References 3 and 10).

Some types of accidents were screened from the seismic analysis at the start, based on earlier insights that seismic-induced severe accidents generally involve loss of offsite power and small LOCAs. The FCS SMA utilized the FCS IPE event tree models for transients and small LOCA, with the addition of a seismic event tree to address the major structural failures and seismic-induced failures that challenge front-line mitigation systems and could lead to core damage. Other scenarios, such as large LOCAs, were not considered (i.e., screened out) based on the earlier PRA insights and with verification of no unique FCS vulnerabilities during the plant walkdowns. Notice that screening out Large LOCAs is consistent with the insights from modern seismic PRAs, which indicate that such events have limited relevance in seismic risk.

Additionally, identification of important accident sequences and contributing combinations of structure/component failures were screened using PRA, such that insignificant plant features did not have to be analyzed in detail. For example, if a "weak" component is predicted to fail in combination with a probabilistically insignificant set of random failures of equipment involving robust devices, the "weak" component does not require detailed evaluation nor does it significantly contribute to the overall plant HCLPF. This screening was particularly applied as part of the systems reanalysis to obtain the plant level HCLPF.

The logic model assumed that offsite power (including recovery) and instrument air are unavailable regardless of earthquake magnitude, which in turn makes potential success paths having to do with the PCS and the closed-loop shutdown cooling mode of the shutdown cooling system also unavailable. Primary cooldown was assumed to be accomplished via the secondary system using one AFW train and local/manual operation of an atmospheric steam dump valve for the associated steam generator. The loss of offsite power and LOCA event trees address failure of reactivity control, heat removal, inventory control, and long-term cooling (Reference 10).

The model was developed using a seismic event tree model and the IPE event trees. The IPE model was used to generate the list of equipment for seismic evaluation. From this evaluation, an SMA model was developed to quantify the impact of the seismic CDF or significant radiological release. Seismic failures for unscreened components (HCLPF of less than 0.5g PGA) were included in the SMA model by mapping the seismically-induced events with the impact of internal random events in the IPE model. Correlation of equipment failures and spatial interactions due to a seismic event were also modeled. The seismic-induced events and new random events were mapped to their corresponding IPE random events. The screened components (those with HCLPF greater than 0.5g PGA) were grouped and modeled through one surrogate event, which was assigned a HCLPF of 0.5g PGA. The surrogate events were determined as not significant to the overall seismic risk profile of the plant (Reference 31). Figure B.4-3 illustrates the plant fragility curve with a HCLPF of 0.25g (driven by soil failure) compared to the surrogate fragility curve with a HCLPF of 0.5g. A βC value of 0.18 was selected for the plant HCLPF, which is retrieved from the βC associated with the soil failure; a βC of 0.35 is used for the surrogate equipment, as per the most recent guidance (Reference 1). Notice that the surrogate event is more robust than the bounding soil failure of the plant, thus the surrogate failures are non-significant. The failure probabilities used in the FCS IPE were also used for the non-seismic failures in the SMA model. With the exception of human failure events that occur after a seismic event, the failure probabilities for non-seismic events were assumed to be independent of the seismic initiating event.

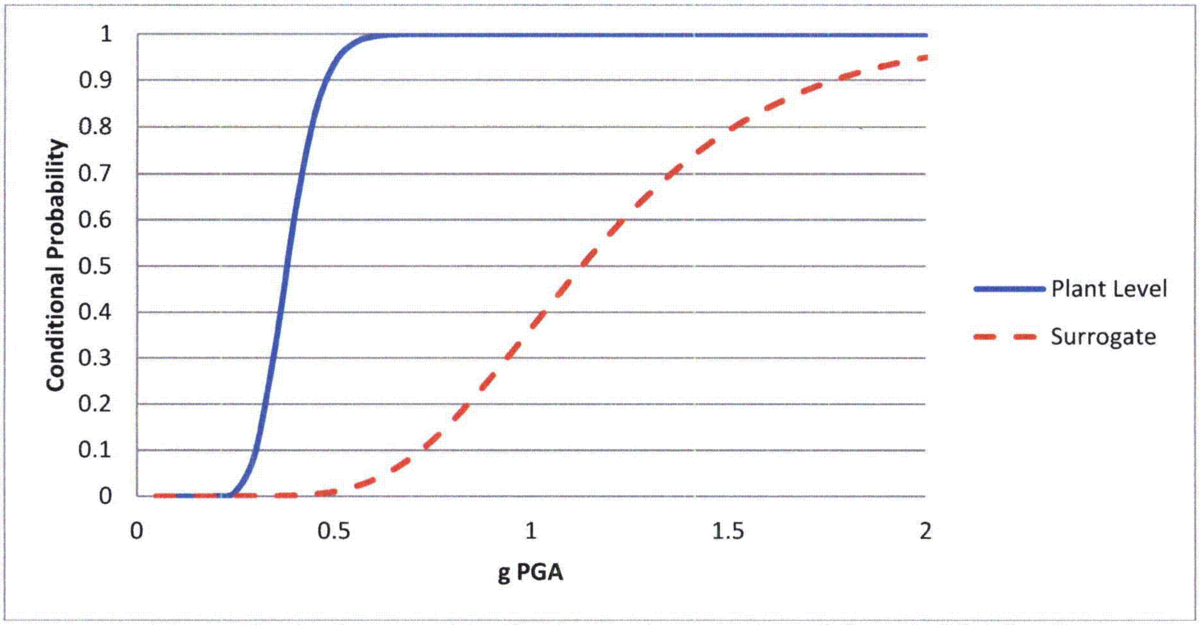

Figure B.4-3. Surrogate Fragility Insignificant in Overall Seismic Risk Profile

Human actions were also considered for seismic modification. Pre-initiators maintained their IPE failure probabilities due to their occurrence before an earthquake. Seismic post-initiator human error probabilities (HEPs) were approximated by increasing the HEP as function of seismic hazard level. For levels less than or equal to the SSE (0.15g), the seismic HEP was set to the internal events PRA value with the consideration that conditions would be similar to the IPE at this magnitude. For earthquakes between 0.15g and 0.5g, the HEPs were increased to twice the internal events PRA value. Lastly, for earthquakes greater than 0.5g, the seismic HEPs were assumed to fail and thus set to 1.0. The seismic HEP events were mapped to the equivalent IPE events using the same process as the other seismic failures. The SMA found initiation of long-term EFWST makeup to be the most important action, which results from the assumption of loss of instrument air and unrecoverable loss of offsite power.

NUREG-1407, Section 3.2.5.1 states that for IPEEE purposes, it is desirable that to the maximum extent possible, the alternate path involve operational sequences, systems, piping runs and components different from those used in the preferred path. The FCS IPEEE model utilizes the fault based SMA methodology to develop a detailed model beyond the requirements of NUREG-1407 by incorporating seismic failures into the internal events PRA model from the FCS IPE. The treatment of non-seismic failures and human actions in the FCS IPEEE meets the requirements of Section 3.2.5.8 of NUREG-1407.

System Modeling Review Conclusion

The system modeling methodology used is in compliance with NUREG-1407 and the seismic IPEEE system modeling results are adequate for screening purposes.

B.4.8 Containment Performance

As stated in Section 3.2.6 of NUREG-1407, the purpose of the containment performance evaluation for a seismic event is to identify vulnerabilities that involve early failure of containment functions. The potential vulnerabilities in a seismic event include containment integrity, containment isolation, prevention of bypass functions, and support systems. Active seals of isolation hatches and cooling functions of penetrations are to be reviewed if these are required features.

Section 3.1.5 of the IPEEE submittal discusses the analysis of containment performance. A simplified Containment Performance event tree based model was developed to assess sequences leading to large early releases during a seismic event (i.e., 0 to 2 hours with greater than 10% Noble Gas Release), owing to containment bypass or isolation failure. Due to high structural capacity of the containment, the containment structure was screened out. Nine core damage sequences leading to large early release were evaluated in the submittal.

Investigation of these containment failure modes as part of the seismic analysis revealed that the probability of a seismic-induced core damage event leading to an early significant release from containment is quite small. Considering both containment isolation and bypass failure modes, it is concluded that there is a less than 1% probability of an early large release from containment given a seismic-induced core damage event at or below the RLE (0.3g).

Containment Performance Review Conclusion

An event tree based containment performance analysis under seismic conditions was performed. It considered possible severe accidents and meets the intent of Supplement 4 to Generic Letter 88-20. The guidance in NUREG-1407 was followed, thus IPEEE containment performance analysis is considered adequate for screening purposes.

B.4.9 Peer Review

According to Supplement 4 to Generic Letter 88-20, each licensee should conduct a peer review by individuals who are not associated with the initial evaluation. Section 7 of NUREG-1407 requires that the IPEEE submittal should include description of the review performed, the results of the review, and a list of review team members. It is recommended that the peer review team have combined experience in the areas of systems engineering and the specific external event being analyzed and include licensee personnel.

As stated in Section 2.2 of the IPEEE submittal (Reference 9), the results of the IPEEE effort were independently peer reviewed by:

- Yankee Atomic Electric Company/Engineering Services, Duke Engineering Services, and ABB/CE
- Personnel from SAIC, Sargent & Lundy, Stevenson & Associates, and other utilities
- Drs. R. Budnitz and J. D. Stevenson in the area of the seismic IPEEE

Section 2.2 of the IPEEE submittal also states that all parts of the IPEEE were reviewed internally by the PRA staff and seismic staff.

Dr. R. Budnitz of Future Resources Associates, Inc. was peer reviewer of the systems engineering analysis, and Dr. J. D. Stevenson of Stevenson & Associates was peer reviewer of the seismic capacity analysis. The two expert peer reviewers were not associated with the initial IPEEE evaluation and have combined experience in the areas of systems engineering and the specific external event being analyzed.

Dr. R. Budnitz, who was the chairman from 1984 to1987 of the NRC Expert Panel that developed the NRC Seismic Margins Assessment (SMA) Methodology, as documented in NUREG/CR-4334, as well as NRC's principal consultant in 1988-1990 on the enhancement guidance in NUREG-1407, peer reviewed the SAIC report titled "Individual Plant Examination of External Events, Seismic Margins Summary Report", Revision 0, dated 28 March 1994 (Reference 13). This report later became part of Sargent & Lundy Report No. SL-4910 "Individual Plant Examination for External Events, Seismic Margin Assessment, Final Technical Report" (Reference 14), which is a key report supporting the IPEEE submittal. Since the SAIC report, follows the fault based SMA methodology (Reference 4), with key enhancements required for a focused-scope plant by NRC in NUREG-1407, Dr. R. Budnitz was the most qualified to perform peer review. Results of his review are documented in the Reference 21 peer review report, and his key overview findings are summarized below:

- All of the issues raised by Dr. Budnitz over the course of 10 months since his peer review activity began have been satisfactorily addressed and review comments/advice in several key places have been followed.
- The SAIC analysts fully understand the NRC guidance on the IPEEE, based on his review of the subject report, his conversations with SAIC's engineers and his own extensive understanding of what NRC requires.
- The systems analysis has been done professionally and is considered a "state of the art" seismic-margin analysis.
- Integration of the systems analysis with the seismic-capacity analysis has been done correctly.
- The subject report has been clearly written and the documentation is adequate and satisfies the NRC's requirements for IPEEE.
- The subject report is of very high quality.

Dr. J. D. Stevenson of Stevenson & Associates, considered the most qualified to perform peer review in the seismic/structural areas, peer reviewed the seismic/structural analysis parts of the SAIC report titled "Individual Plant Examination of External Events, Seismic Margin Summary Report", Revision 0, dated March 28, 1994 (Reference 13). Results and findings of his review are documented in Reference 22 peer review report. His activities during the conduct of his peer review were the following:

- Observed the conduct of the seismic walkdowns on August 16-17 and October 13, 1993
- Discussed details of the seismic evaluation process with members of the Seismic Review Teams at that time
- Reviewed the subject SAIC Report
- Performed a review at S&L offices of block wall, structural and liquefaction calculations on March 30, 1994

He concluded that (1) the individuals performing the seismic IPEEE analyses understood the requirements and implemented these requirements correctly and (2) the written reports reflect the work that was done and address the issues pertinent to the seismic IPEEE program. All seven of his comments on the subject SAIC Report were addressed to his satisfaction.

Peer Review Conclusion

In conclusion, the peer review performed to review the IPEEE results is competent and is considered adequate for screening purposes by the guidance in NUREG-1407.

B.5. Conclusions

The NRC 50.54(f) letter (Reference 42) requested all nuclear power plant licensees to conduct seismic hazard re-evaluations using updated seismic hazard information and present-day methods. FCS is performing the seismic hazard and screening per the EPRI SPID (Reference 1) guidance. A new GMRS has been developed for FCS using the SPID methodology. The GMRS can be compared to the IHS to screen out of further seismic risk assessments using the SPID guidelines. In order to perform the GMRS to IHS screening, the FCS IPEEE has been subjected to an adequacy review to ensure that the IPEEE is of sufficient quality. This report documents the adequacy review performed following the guidance provided in Section 3.3.1 of the SPID (Reference 1).

The SPID defines four categories, which must be addressed in order to use the IHS for seismic hazard screening. The four categories are:

- General Considerations
- Prerequisites
- Adequacy Demonstration
- Documentation

FCS is a focused-scope plant with a 0.3g PGA NUREG/CR-0098 soil site spectrum. The calculated plant-level high confidence of low probability of failure (HCLPF) for FCS resulting from performance of the IPEEE was 0.25g.

The IPEEE seismic assessment was performed using a fault based SMA per NUREG/CR-4334 and EPRI NP-6041-SL methodology. The SPID IPEEE adequacy "General Considerations" requires that focused-scope plants perform full-scope evaluations of soil failure modes and relay chatter. NEI Letter "Relay Chatter Reviews for Seismic Hazard Screening" dated October 3, 2013 (Reference 8) states that full-scope relay chatter reviews will be performed later on a schedule consistent with high frequency evaluations. Therefore, relay chatter is not addressed in this report and will be evaluated later. Even though FCS was a focused-scope plant, a complete soil failure evaluation was performed for the IPEEE. The soil failure evaluation was reviewed as part of this IPEEE adequacy assessment.

The four IPEEE adequacy Prerequisites were reviewed. Prerequisites 1 to 3 were found to be met. Prerequisite 4 required reviews of major plant modifications, which could degrade/impact the conclusions, reached in the seismic IPEEE. A review of the plant DBDs indicates that a number of modifications have been performed, but they do not have an adverse impact on the IPEEE conclusions.

The nine Adequacy Demonstration items defined in the SPID were reviewed based on available information from the IPEEE submittal (Reference 9) and additional available backup reference information. All of the adequacy demonstration items were found to have methods in compliance with NUREG-1407 and were determined to be adequate for seismic hazard screening purposes.

Therefore, the overall Fort Calhoun IPEEE SMA was determined to be adequate for seismic hazard screening, and the IHS can be used for screening of the new GMRS in accordance with the SPID (Reference 1).

B.6. References

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