Enclosure D
L-14-120

NTTF 2.1 Seismic Hazard and Screening Report
for Perry Nuclear Power Plant
Lake County, Ohio
(83 pages follow)

ABS Consulting

2734298-R-009
Revision 1

PCR
Paul C. Rizzo Associates, Inc.
ENGINEERS/CONSULTANTS/CM

NTTF 2.1 Seismic Hazard and Screening Report Perry Nuclear Power Plant Lake County, Ohio

March 20, 2014

Prepared for:

FirstEnergy Nuclear Operating Company

ABSG Consulting Inc. • 300 Commerce Drive, Suite 200 • Irvine, California 92602

REVISION 1 REPORT

NTTF 2.1 SEISMIC HAZARD AND SCREENING REPORT
PERRY NUCLEAR POWER PLANT
LAKE COUNTY, OHIO

ABSG CONSULTING INC. REPORT NO. 2734298-R-009
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MARCH 20, 2014

ABSG CONSULTING INC.
PAUL C. RIZZO ASSOCIATES, INC.

APPROVALS

Report Name: NTTF 2.1 Seismic Hazard and Screening Report
Perry Nuclear Power Plant
Lake County, Ohio

Date: March 20, 2014

Revision No.: 1

Approval by the responsible manager signifies that the document is complete, all required reviews are complete, and the document is released for use.

Originators:

Digitally signed by Richard Quittmeyer
DN: cn=Richard Quittmeyer, o=Paul C. Rizzo Associates, Inc., ou=Seismology, email=richard.quittmeyer@rizzoassoc.com, c=US
Date: 2014.03.20 16:26:22 -04'00'

Jeffrey K. Kimball
Principal Seismologist

03/20/2014
Date

Digitally signed by Jose E Blanco Beltran
DN: cn=Jose E Blanco Beltran, o=Paul C Rizzo Associates, ou=Seismic, email=jose.blanco@rizzoassoc.com, c=US
Date: 2014.03.20 17:00:42 -04'00'

José E. Blanco, Ph.D.
Technical Director

03/20/2014
Date

Digitally signed by Nishikant Vaidya
DN: cn=Nishikant Vaidya, o=Paul C. Rizzo Associates, ou=V.P. Advanced Engineering Projects, email=nish.vaidya@rizzoassoc.com, c=US
Date: 2014.03.20 17:08:12 -04'00'

Nishikant R. Vaidya, Ph.D., P.E.
Vice President – Advanced Engineering Projects

03/20/2014
Date

Independent Technical Reviewer:

Digitally signed by Richard Quittmeyer
DN: cn=Richard Quittmeyer, o=Paul C. Rizzo Associates, Inc., ou=Seismology, email=richard.quittmeyer@rizzoassoc.com, c=US
Date: 2014.03.20 16:26:44 -04'00'

Richard C. Quittmeyer, Ph.D.
Vice President – Seismology

03/20/2014
Date

Project Manager:

Digitally signed by Nishikant Vaidya
DN: cn=Nishikant Vaidya, o=Paul C. Rizzo Associates, ou=V.P. Advanced Engineering Projects, email=nish.vaidya@rizzoassoc.com, c=US
Date: 2014.03.20 17:07:24 -04'00'

Nishikant R. Vaidya, Ph.D., P.E.
Vice President – Advanced Engineering Projects

03/20/2014
Date

Approver:

Thomas R. Roche, P.E.
Vice President

03/20/2014
Date

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Lake County, Ohio

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LIST OF ACRONYMS

AHEX	ATLANTIC HIGHLY EXTENDED CRUST
ASCE	AMERICAN SOCIETY OF CIVIL ENGINEERING
BDB	BEYOND DESIGN BASIS
BE	BEST ESTIMATE
CEUS	CENTRAL AND EASTERN UNITED STATES
CEUS-SSC	CENTRAL AND EASTERN UNITED STATES SEISMIC SOURCE CHARACTERIZATION
COV	COEFFICIENT OF VARIATION
DF	DESIGN FACTOR
ECC-AM	EXTENDED CONTINENTAL CRUST – ATLANTIC MARGIN
EL	ELEVATION
EPRI	ELECTRIC POWER RESEARCH INSTITUTE
ERM-N	EASTERN RIFT MARGIN FAULT NORTHERN SEGMENT
ERM-S	EASTERN RIFT MARGIN FAULT SOUTHERN SEGMENT
FENOC	FIRSTENERGY NUCLEAR OPERATING COMPANY
ft	FEET
ft/s	FEET PER SECOND
g	GRAVITY
GMM	GROUND MOTION MODEL
GMPE	GROUND MOTION PREDICTION EQUATIONS
GMRS	GROUND MOTION RESPONSE SPECTRUM
HCLPF	HIGH CONFIDENCE OF LOW PROBABILITY OF FAILURE
HZ	HERTZ
IBEB	ILLINOIS BASIS EXTENDED BASEMENT
IHS	IPEEE HCLPF SPECTRUM
IPEEE	INDIVIDUAL PLANT EXAMINATION OF EXTERNAL EVENTS
ISRS	IN-STRUCTURE RESPONSE SPECTRA
km	KILOMETERS
km/s	KILOMETER PER SECOND

LIST OF ACRONYMS (CONTINUED)

LR	LOWER RANGE
M	MAGNITUDE
MAFE	MEAN ANNUAL FREQUENCY EXCEEDANCE
MESE-N	MESOZOIC AND YOUNGER EXTENDED PRIOR – NARROW
MESE-W	MESOZOIC AND YOUNGER EXTENDED PRIOR – WIDE
MIDC-A	MIDCONTINENT-CRATON ALTERNATIVE A
MIDC-B	MIDCONTINENT-CRATON ALTERNATIVE B
MIDC-C	MIDCONTINENT-CRATON ALTERNATIVE C
MIDC-D	MIDCONTINENT-CRATON ALTERNATIVE D
MMI	MODIFIED MERCALLI INTENSITY
NAP	NORTHERN APPALACHIANS SEISMOTECTONIC SOURCE ZONE
NEI	NUCLEAR ENERGY INSTITUTE
NFSM	NEW MADRID FAULT SYSTEM
NMESE-N	NON-MESOZOIC AND YOUNGER EXTENDED PRIOR – NARROW
NMESE-W	NON-MESOZOIC AND YOUNGER EXTENDED PRIOR – WIDE
NPP	NUCLEAR POWER PLANT
NRC	UNITED STATES NUCLEAR REGULATORY COMMISSION
NTTF	NEAR-TERM TASK FORCE
NUREG	NUCLEAR REGULATORY GUIDE
PEZ_N	PALEOZOIC EXTENDED CRUST NARROW
PEZ_W	PALEOZOIC EXTENDED CRUST WIDE
Pf	TARGET PERFORMANCE LEVEL
PGA	PEAK GROUND ACCELERATION
PNPP	PERRY NUCLEAR POWER PLANT
PSHA	PROBABILISTIC SEISMIC HAZARD ANALYSIS
RB	REACTOR BUILDING
RG	REGULATORY GUIDE
RLE	REVIEW LEVEL EARTHQUAKE
RLME	REPEAT LARGE MAGNITUDE EARTHQUAKE

LIST OF ACRONYMS (CONTINUED)

RR-RCG	REELFOOT RIFT INCLUDING THE ROUGH CREEK GRABEN
RVT	RANDOM VIBRATION THEORY
s	SECONDS
SER	SAFETY EVALUATION REPORT
SEWS	SEISMIC EVALUATION WORKSHEETS
SI	SYSTEM INTERACTION
SLR	ST. LAWRENCE RIFT ZONE
SMA	SEISMIC MARGIN ASSESSMENT
SPID	SCREENING, PRIORITIZATION, AND IMPLEMENTATION DETAILS
SPRA	SEISMIC PROBABILISTIC RISK ASSESSMENT
SPT	STANDARD PENETRATION TEST
SQUG	SEISMIC QUALIFICATION UTILITY GROUP
SRT	SEISMIC REVIEW TEAM
SSCs	SYSTEM, STRUCTURE, AND COMPONENTS
SSE	SAFE SHUTDOWN EARTHQUAKE
STUDY-R	STUDY REGION
UB	UPPER BOUND
UHRS	UNIFORM HAZARD RESPONSE SPECTRA
UR	UPPER RANGE
USAR	UPDATED SAFETY ANALYSIS REPORT
V_p	COMPRESSION WAVE VELOCITY
V_s	SHEAR WAVE VELOCITY

NTTF 2.1 SEISMIC HAZARD AND SCREENING REPORT
PERRY NUCLEAR POWER PLANT
LAKE COUNTY, OHIO

1.0 INTRODUCTION

Following the accident at the Fukushima Daiichi Nuclear Power Plant (NPP) resulting from the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami, the United States Nuclear Regulatory Commission (NRC) established a Near-Term Task Force (NTTF) to conduct a systematic review of NRC processes and regulations and to determine if the agency should make additional improvements to its regulatory system. The NTTF developed a set of recommendations intended to clarify and strengthen the regulatory framework for protection against natural phenomena. Subsequently, the NRC issued a 50.54(f) letter (NRC, 2012b) that requests information to assure that these recommendations are addressed by all United States NPPs. The 50.54(f) letter requests that licensees and holders of construction permits under 10 CFR Part 50 reevaluate the seismic hazards at their sites against present-day NRC requirements. Depending on the comparison between the reevaluated seismic hazard and the current design basis, the result is either no further risk evaluation or the performance of a seismic risk assessment. Risk assessment approaches acceptable to the NRC staff include a seismic probabilistic risk assessment (SPRA), or a seismic margin assessment (SMA). Based upon the information the NRC receives, they 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 Perry Nuclear Power Plant (PNPP). PNPP is located on Lake Erie in Lake County, Ohio. The plant consists of a 1,261 MWe BWR/6, with a Mark III containment. The nuclear steam supply system was designed by General Electric and Gilbert Associates, Inc., Reading, Pennsylvania served as architect-engineer. The operating license for Unit 1 was issued in March 1986. Commercial operation of Unit 1 commenced in November 1987. The FirstEnergy Nuclear Operating Company (FENOC) is authorized to act as agent and has

exclusive responsibility and control over the physical construction, operation, and maintenance of the facility.

In providing the information contained here, FENOC has 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* (Electric Power Research Institute [EPRI], 2013a). The Augmented Approach, *Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima NTTF Recommendation 2.1: Seismic* (EPRI, 2013b), has been developed as the process for evaluating critical plant equipment prior to performing a complete plant seismic risk evaluation, if required.

Reference is made to FENOC's Partial Submittal (FENOC, 2013) summarizing the geologic and geotechnical information. The "Description of Subsurface Materials and Properties," and the "Development of Base Case Profiles and Nonlinear Material Properties" from FENOC, (2013a), are repeated here for completeness.

1.1 Summary of Licensing Basis

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

The Category I SSCs are identified in Table 3.2-1 of the Updated Safety Analysis Report (USAR) (FENOC, 2011).

1.2 Summary of Ground Motion Response Spectrum and Screening Results

In response to the 50.54(f) letter and following the guidance provided in the SPID (EPRI, 2013a), a seismic hazard reevaluation for PNPP was performed. For screening purposes, a Ground Motion Response Spectrum (GMRS) was developed. Based on the results of the screening evaluation, PNPP screens in for risk evaluation, a Spent Fuel Pool evaluation, and a

High Frequency Confirmation. In the 1 to 10 Hertz (Hz) part of the response spectrum, the GMRS exceeds the horizontal SSE and above 10 Hz the GMRS also exceeds the horizontal SSE.

1.3 ORGANIZATION OF THIS REPORT

The remainder of this Report is organized as follows: ***Section 2.0*** provides the Seismic Hazard Reevaluation that was performed for the PNPP Site, including the probabilistic seismic hazard analysis (PSHA) for hard rock site conditions, the site response evaluation, seismic hazard at the SSE control point, and the derivation of the GMRS. ***Section 3.0*** provides a summary of the PNPP SSE ground motion. ***Section 4.0*** provides the screening evaluation, including a comparison between the GMRS and SSE, and the screening evaluation outcome. ***Section 5.0*** describes interim actions completed for PNPP and ***Section 6.0*** provides conclusions.

2.0 SEISMIC HAZARD RE-EVALUATION

The PNPP Site is located in the central part of the Eastern Stable Platform Tectonic Province. Based on the studies reported in the USAR, only two zones of moderate seismic activity are identified within a 200 mile radius of the site. "...The first is located 160 miles away, in the same province, and is correlated to the Clarendon-Linden structure while the second, in the Central Province, about 185 miles away, near Anna, Ohio, is probably tied to local basement structures in that area."

The review of regional seismicity (USAR, Section 2.5.2.1) concludes that "...the historical record does not reveal the occurrence of large earthquakes in the PNPP site region..." Additionally, "...the shallow focal depths presently observed in the site region for moderate earthquakes (mb 5.0) such as at Leroy and St. Marys, Ohio, or for low level microseismicity (mb <1.5), do not match the greater focal depth range usually associated with large intraplate earthquakes...."

Within the above context the earthquake potential at the site is low. Based on the maximum earthquake, not correlated to structure, experienced in the site province, the USAR postulates a hypothetical occurrence of a Modified Mercalli Intensity (MMI) VI. Category I SSCs are designed for SSE ground motions associated with a peak ground acceleration (PGA) of 0.15g at the top of bedrock. This PGA exceeds the mean value of intensity versus acceleration given by Trifunac and Brady for a MMI VII.

2.1 REGIONAL AND LOCAL GEOLOGY

The central part of the Eastern Stable Platform Tectonic Province is a wide region characterized by an Upper Precambrian crystalline basement complex overlain unconformably by a sequence of Paleozoic sedimentary formations with little tectonic deformation. Basement rocks in the Site province are comprised largely of high-grade, regionally metamorphosed schists, gneisses, marbles, and calc-silicate granulites, which were consolidated to a discrete crustal block during the Grenvillian Orogeny, 950-150 million years ago.

Bedrock directly beneath the Site belongs to the Ohio Shale Formation (Upper Devonian). In the Site region, the bedrock dips gently to the south at a gradient of approximately 20 to 40 feet (ft) per mile. This paleotopographic surface was eroded as a consequence of continental glaciation forming Lake Erie along with the other Great Lakes during the Pleistocene Epoch. Bedrock exposures are sparse particularly in proximity to the local area of the PNPP Site since all of Ohio, except the southeastern part, has been extensively mantled by Pleistocene glacial deposits.

Post-consolidation tectonic deformation in the Site province is of minor extent, limited to the development of broad northeast-trending arches of epeirogenic origin along the western portion during the early to middle Paleozoic Era, with localized faulting activity on or near the arches in the middle to late Paleozoic Era. The only tectonic structure within the Site province interpreted to be active is the Clarendon-Linden Fault Zone in western New York, about 160 miles northeast of the Site.

Local geologic investigations revealed no faults in the bedrock beneath the foundations of the PNPP structures. The field and literature studies in the site area also did not reveal any faults in the Site vicinity.

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 PSHA was completed using the recently developed Central and Eastern United States Seismic Source Characterization (CEUS-SSC) for Nuclear Facilities (NRC, 2012a). The PSHA uses a minimum moment magnitude cutoff of 5.0, as specified in the 50.54(f) letter.

The CEUS-SSC model consists of distributed seismicity sources and repeated large magnitude earthquake (RLME) sources. Distributed seismicity sources are characterized following two approaches; the Mmax approach and the seismotectonic approach.

The PNPP PSHA accounts for the CEUS-SSC distributed seismicity source zones out to a distance of at least 400 miles (640 kilometer [km]) around the PNPP. This distance exceeds the

200 mile (320 km) recommendation contained in NRC (2007a) and was chosen for completeness. Distributed seismicity source zones included in this Site PSHA are the following:

- Mesozoic and younger extended crust – narrow and wide (MESE-N and MESE-W)
- Non-Mesozoic and younger extended crust – narrow and wide (NMESE-N and NMESE-W)
- Study Region (STUDY_R)
- Atlantic Highly Extended Crust (AHEX)
- Extended Continental Crust-Atlantic Margin (ECC-AM)
- Illinois Basin Extended Basement (IBEB)
- Midcontinent-Craton (MidC-A, MidC-B, MidC-C, and MidC-D)
- Northern Appalachian (NAP)
- Paleozoic Extended Crust – narrow and wide (PEZ-N and PEZ-W)
- Reelfoot Rift (RR and RR-RCG)
- St. Lawrence Rift, including the Ottawa and Saguenay grabens (SLR)

RLME seismic sources within or near 1,000 km from the Site are included in the PSHA as follows:

- Charlevoix
- Charleston
- New Madrid Fault System (NFSM)
- Eastern Rift Margin Fault northern and southern segments (ERM-N and ERM-S)
- Marianna Zone
- Commerce Fault
- Wabash Valley

For each of the above distributed seismicity and RLME sources, the mid-continent version of the updated EPRI Ground Motion Model (GMM) was used (EPRI, 2013c).

2.2.2 Base Rock Seismic Hazard Curves

While the SPID (EPRI, 2013a) does not require that base rock seismic hazard curves be provided, they are included here as background information. These were developed by FENOC as part of an on-going SPRA effort. ***Figure 2-1 and Table 2-1*** present the mean hard rock hazard curves at the PNPP Site resulting from the PSHA. The hazard curves show mean annual frequency of exceedance for spectral acceleration at the seven response spectral frequencies (100 Hz, 25 Hz, 10 Hz, 5.0 Hz, 2.5 Hz, 1.0 Hz, and 0.5 Hz) for which the updated EPRI GMM (2013c) is defined.

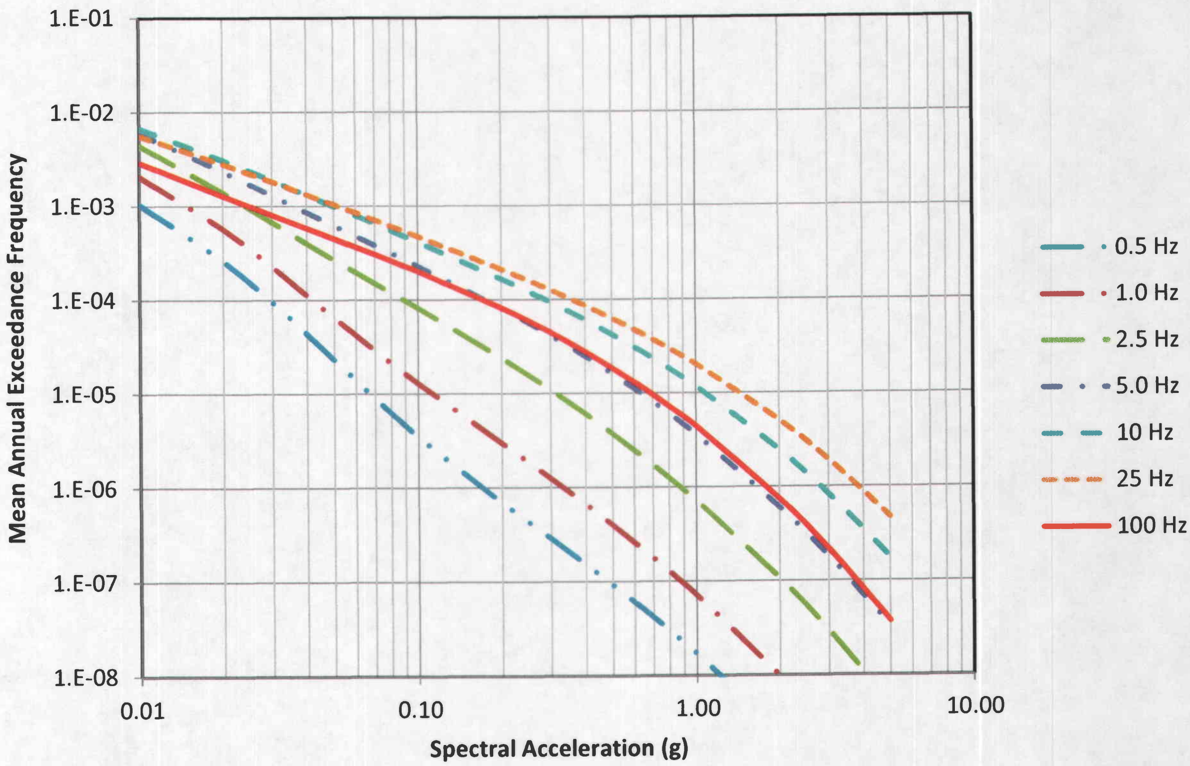


FIGURE 2-1
PNPP MEAN SEISMIC HAZARD AT HARD ROCK

Consistent with the SPID (EPRI, 2013a), Approach 3 of NUREG/CR-6728 (McGuire et al., 2001) is used to calculate the seismic hazard curves at the SSE control point elevation (EL) (the base of the Reactor Building [RB] Foundation). This method uses the mean and standard

deviations of the site amplification factors developed as described in ***Section 2.3***. The control point hazard curves are presented in ***Section 2.4.4***.

TABLE 2-1
MEAN SEISMIC HAZARD AT HARD ROCK
PNPP SITE

GROUND MOTION LEVEL [g]	MEAN ANNUAL FREQUENCY OF EXCEEDANCE FOR SPECTRAL FREQUENCIES						
	0.5 Hz	1 Hz	2.5 Hz	5 Hz	10 Hz	25 Hz	100 Hz
0.01	1.03E-03	2.06E-03	4.37E-03	5.95E-03	6.68E-03	5.57E-03	2.91E-03
0.02	2.58E-04	5.67E-04	1.38E-03	2.32E-03	3.05E-03	2.78E-03	1.28E-03
0.03	9.42E-05	2.26E-04	6.66E-04	1.29E-03	1.87E-03	1.81E-03	8.01E-04
0.04	4.32E-05	1.12E-04	3.97E-04	8.54E-04	1.31E-03	1.32E-03	5.78E-04
0.05	2.31E-05	6.51E-05	2.68E-04	6.19E-04	9.89E-04	1.03E-03	4.49E-04
0.06	1.38E-05	4.19E-05	1.95E-04	4.76E-04	7.86E-04	8.42E-04	3.66E-04
0.07	9.00E-06	2.91E-05	1.50E-04	3.82E-04	6.47E-04	7.08E-04	3.06E-04
0.08	6.25E-06	2.13E-05	1.19E-04	3.15E-04	5.46E-04	6.08E-04	2.63E-04
0.09	4.57E-06	1.64E-05	9.76E-05	2.66E-04	4.70E-04	5.33E-04	2.29E-04
0.10	3.49E-06	1.30E-05	8.15E-05	2.29E-04	4.11E-04	4.72E-04	2.02E-04
0.20	6.95E-07	2.99E-06	2.39E-05	8.10E-05	1.66E-04	2.11E-04	8.22E-05
0.25	4.28E-07	1.87E-06	1.57E-05	5.65E-05	1.21E-04	1.60E-04	5.94E-05
0.30	2.88E-07	1.26E-06	1.09E-05	4.15E-05	9.37E-05	1.27E-04	4.49E-05
0.40	1.53E-07	6.70E-07	6.06E-06	2.48E-05	6.06E-05	8.63E-05	2.80E-05
0.50	9.21E-08	4.01E-07	3.74E-06	1.62E-05	4.23E-05	6.28E-05	1.87E-05
0.60	6.02E-08	2.60E-07	2.48E-06	1.12E-05	3.10E-05	4.77E-05	1.32E-05
0.70	4.16E-08	1.79E-07	1.73E-06	8.13E-06	2.35E-05	3.74E-05	9.74E-06
0.80	2.99E-08	1.27E-07	1.26E-06	6.06E-06	1.83E-05	3.00E-05	7.33E-06
0.90	2.22E-08	9.41E-08	9.38E-07	4.64E-06	1.46E-05	2.46E-05	5.67E-06
1.00	1.69E-08	7.13E-08	7.18E-07	3.63E-06	1.18E-05	2.04E-05	4.46E-06
2.00	2.44E-09	9.63E-09	1.05E-07	6.00E-07	2.45E-06	5.06E-06	7.45E-07
3.00	6.82E-10	2.57E-09	2.91E-08	1.79E-07	8.28E-07	1.92E-06	2.17E-07
5.00	1.16E-10	4.08E-10	4.80E-09	3.24E-08	1.74E-07	4.74E-07	3.69E-08

2.3 SITE RESPONSE EVALUATION

Category I structures of the PNPP are founded in the Chagrin Shale bedrock (Section 3.7.2.6 of the USAR) at elevations varying from 561 ft for the RB and the Auxiliary Building, to 564 ft for the Intermediate Building and the Control Complex. The shale bedrock is characterized by V_s (100 ft) of about 5,000 ft per second (ft/s). Following the guidance contained in Seismic Enclosure 1 of the 50.54(f) Request for Information and in the SPID (EPRI, 2013a) for nuclear

power plants that are not sited on hard rock (defined as 2.83 km/sec), a site response analysis was performed for the PNPP site. The following sections describe the various inputs to the site response analysis. These inputs are summarized in ***Appendix A***.

2.3.1 Description of Subsurface Materials and Properties

The site stratigraphy presented here is based in part on site-specific geotechnical investigations reported in the USAR (Section 2.5.4.2 and Appendix 2E). Of the borings advanced as part of the site investigation, two deep borings penetrated to depths of 395 ft and 730 ft and were terminated in the Huron Shale formation. Other borings terminated in the overlying Chagrin Shale bedrock.

The geologic profile below the reported subsurface investigation depth is based on the analysis of formation tops and bottoms from available deep well logs in the vicinity of the site (within 4 miles), obtained from the Ohio Geological Survey. The geologic profile between 730 ft and 2,500 ft was estimated from the deep alkali Well No. 202, which provided information down to Middle Silurian Lockport Dolomite. The information down to the Precambrian Basement was obtained by deep wells located within seven miles of the Site. Due to the relative proximity of these deep wells to the site, and the flat lying (low dip) nature of the deposits, the unit lithologies and thicknesses can be reliably assumed to be very similar to those below the site.

The USAR does not make reference to the well data. However, the site stratigraphy constructed here on the basis of the well data is consistent with the Regional and Local Geology discussed in the USAR (Section 2.5.1.2). ***Figure 2-2*** presents the stratigraphic soil/rock column underlying the site, and ***Table 2-2*** presents the stratigraphy extending to Precambrian age deposits, identifying unit thickness as estimated from the subsurface investigations reported in the USAR and available well logs in the site vicinity.

Legend	Epoch or Period	Lithology
	Pleisto-cene	Pleistocene Lacustrine Deposits: Very fine sandy, clayey silt and silty clay
		Pleistocene: Glacial drift
	Devonian	Devonian Ohio Shale. Chagrin Shale: Gray silty to clayey shale with sand shale laminae.
		Devonian Ohio Shale. Heron Shale: Black to brown shale with silty and sandy laminae.
		Devonian Delaware and Columbus Formations: Hard, dense, cherty limestone, or a dolomitic limestone
		Devonian Oriskany Sandstone: Fine to medium-grained sandstone
		Lower Devonian to U. Silurian Helderberg Limestone.
	U.Silurian	Upper Silurian Bass Island Group: argillaceous, dolomitic limestone and calcareous dolomite
		Upper Silurian Salina Group: interbedded evaporite and carbonate rocks
	M.Silurian	Middle Silurian Lockport Group: Dolomite
		Middle Silurian Rochester "Packer" Shale
		Middle Silurian Clinton Group: Dolomite, limestone and shale
		Middle Silurian Medina Formation: Sandstone
	Ordivician	Upper Ordivician Queenstown Formation: Shale, siltstone and sandstone
		Middle to Upper Ordovician Reedsville Formation: Fine-grained shale, limestones and lolomites
		Middle Ordivician Trenton Limestone and Dolomite
		Middle Ordivician Chazy Formation (Black River/Gull River/ Glenwood): Limestone
		Lower Ordivician Copper Ridge Formation: Dolomite
	Up-Mid Cambrian	Upper Cambrian Conasauga Formation: Limestone and sandstone
		Middle Cambrian Rome Formation: Dolomite
		Middle Cambrian Shady formation: Dolomite
		Middle Cambrian Mt. Simon Formation: Sandstone
	PreC	Precambrian regionally-metamorphosed schists, gneisses, marbles, and calc-silicate granulites

FIGURE 2-2
STRATIGRAPHIC COLUMN UNDERLYING THE PNPP SITE

TABLE 2-2
SUBSURFACE STRATIGRAPHY AND UNIT THICKNESSES AT THE PNPP SITE

TOP EL [ft]	BOTTOM EL [ft]	LITHOLOGY	TOP DEPTH [ft]	BOTTOM DEPTH [ft]
625	594	Pleistocene Lacustrine deposits: very fine sandy, clayey silt and silty clay	0	31
594	565	Pleistocene: glacial drift	31	60
565	-135	Devonian Ohio Shale. Chagrin Shale: gray silty to clayey shale with sand shale laminae	60	760
-135	-660	Devonian Ohio Shale. Huron Shale: black to brown shale with silty and sandy laminae	760	1285
-660	-970	Devonian Delaware and Columbus formations: hard, dense, cherty limestone, or a dolomitic limestone	1285	1595
-970	-980	Devonian Oriskany Sandstone: fine- to medium-grained sandstone	1595	1605
-980	-1030	Lower Devonian to Upper Silurian Helderberg Limestone	1605	1655
-1030	-1130	Upper Silurian Bass Island Group: argillaceous, dolomitic limestone, and calcareous dolomite	1655	1755
-1130	-1830	Upper Silurian Salina Group: interbedded evaporite and carbonate rocks	1755	2455
-1830	-2080	Middle Silurian Lockport Group: dolomite	2455	2705
-2080	-2110	Middle Silurian Rochester "Packer" Shale	2705	2735
-2110	-2290	Middle Silurian Clinton Group: dolomite, limestone, and shale	2735	2915
-2290	-2305	Middle Silurian Medina Formation: sandstone	2915	2930
-2305	-2505	Upper Ordovician Queenstown Formation: shale, siltstone, and sandstone	2930	3130
-2505	-3945	Middle to Upper Ordovician Reedsville Formation: fine-grained shale, limestones, and dolomites	3130	4570
-3945	-4435	Middle Ordivician Trenton Limestone and Dolomite	4570	5060
-4435	-4615	Middle Ordivician Chazy Formation (Black River/Gull River/ Glenwood): limestone	5060	5240
-4615	-4715	Lower Ordivician Copper Ridge Formation: dolomite	5240	5340
-4715	-4930	Upper Cambrian Conasauga Formation: limestone and sandstone	5340	5555
-4930	-4970	Middle Cambrian Rome Formation: dolomite	5555	5595
-4970	-5160	Middle Cambrian Shady formation: dolomite	5595	5785
-5160	-5300	Middle Cambrian Mt. Simon Formation: sandstone	5785	5925
-5300	--	Precambrian regionally-metamorphosed schists, gneisses, marbles, and calc-silicate granulites	5925	--

The lacustrine deposits below surface soils average 25 ft in thickness of and are composed of a very fine sandy, clayey silt, and silty clay. The underlying soil layer is a very dense Pleistocene glacial drift till composed of native material with some ice-transported granitic erratics. Composition of the till varies from place to place, but in general is heterogeneous, dense, clay with interspersed rock fragments ranging from large boulders, cobbles, and pebbles down to sand size. This unit is an average of 30 ft thick and overlies the uppermost bedrock.

The bedrock immediately beneath the site belongs to the Upper Devonian Ohio Shale Formation extending to a depth of about 1,250 ft. Because the Site sits on the northwestern flank of the Appalachian geosyncline, the rocks dip gently to the south at an angle of about 5 degrees. The members of the Ohio Shale are, from oldest to youngest, the Plum Brook, Huron, Chagrin, Cleveland, and Bedford shale members. In the PNPP Site area, the upper members have been eroded away to expose the Chagrin Shale. The Chagrin Shale member is about 700 ft thick and is composed of dark-gray to medium-gray silty or clayey shale occasionally containing light gray sandy shale laminae. The underlying Huron Shale is a black to dark brown shale with lesser amounts of thinly bedded light gray silty and sandy laminae than the Chagrin Shale and is estimated to be about 525 ft thick below the site.

The stratigraphy below the Huron Shale consists of an approximately 2,250 ft thick sequence of various sedimentary rocks, predominantly limestones and dolomites, with interbedded shales and sandstones of various thicknesses. These formations overlay the Precambrian granite basement located at approximate EL -5300 ft.

2.3.2 Development of Base Case Profiles and Non-Linear Material Properties

Most major structures of the PNPP are founded in the Chagrin Shale bedrock at foundation elevations varying between 561 ft for the Reactor Building and the Auxiliary Building to 564 ft for the Intermediate Building and the Control Complex. Accordingly, the base of the RB foundation level (EL 561 ft) is defined as the control point elevation where the GMRS is developed.

The shear and compression wave velocities of the overburden soils and the shale bedrock are based on the subsurface investigations reported in the USAR. The geophysical measurements included seven seismic refraction lines, in situ cross-hole velocity measurements in seven

borings, and one down-hole measurement in Boring 1-33. Measured values of the compressional (V_P) and shear wave (V_s) velocities and unit weight values were then used to calculate the elastic moduli values. These measurements were substantiated and supplemented by dynamic testing of soil and rock samples to obtain the dynamic compression and shear modulus, damping, and Poisson's ratios.

Variabilities in the V_S of the bedrock material and the overburden soil are estimated respectively, from velocity measurements and lab tests, and the Standard Penetration Test (SPT) data. In the Site area, the V_S and V_P of the bedrock are essentially uniform with the average V_p of about 10,500 ft/s and the average V_S of about 5,000 ft/s.

Below the investigation depth, the deep rock stratigraphy and seismic velocities of the strata rely on sonic logs recorded in the wells in the Site vicinity (within 4 miles).

The sonic data were converted to V_p V_s based on published literature (Pickett, 1963; Rafavich, 1984; Miller, 1990; and Castagna, 1993) reflecting the material type (limestone and dolomite, anhydrites and salts), porosity and density, and to a lesser extent, the lithology. Additionally, based on published literature, V_p/V_s ratios for these types of geologic units were used to define the epistemic uncertainty for V_S.

Table 2-3 presents the summary geotechnical profile identifying the layer thicknesses, V_S, and uncertainties in these parameters. From ***Table 2-3*** the SSE control point is about 5 ft below the top of bedrock, or at EL 561 ft within the Chagrin Shale bedrock with best-estimate (BE) V_s of 4,772 ft/s.

TABLE 2-3
SUBSURFACE STRATIGRAPHY AND UNIT THICKNESSES - PNPP SITE

ELEVATION [ft]	LAYER NO.	SOIL/ROCK DESCRIPTION	γ_{total} [pcf] [F]	V_S [ft/s]	μ [G]
620	**Plant Grade (Ground Surface EL)**				
625 to 612 [D]	1a	Lacustrine Deposits	122 [C]	827±207 [B]	0.33 [A]
613 to 624	**Ground Water EL**				
615 to 605	1b	Lacustrine Deposits	122 [C]	827±207 [B]	0.49 [A]
605 to 594	1c	Lacustrine Deposits	129 [C]	827±207 [B]	0.47 [A]
594 to 586	2a	Glacial Drift - Upper Till	132 [C]	890±225 [B]	0.44 [A]
589 to 565	2b	Glacial Drift - Lower Till	141 [C]	1785±446 [B]	0.44 [A]
565 to 510	3a	Devonian Chagrin Shale	152	4772±477	0.36 [A]
561	**GMRS EL - SSE Control Point at Base of Nuclear Island Foundation**				
565 to 510	3a	Devonian Chagrin Shale	152	4772±477 [B]	0.36 [A]
510 to 392 [E]	3b	Devonian Chagrin Shale	152	5273	0.32
510 to 392	3c	Devonian Chagrin Shale	152	5203	0.30
392 to -135	4a	Devonian Huron Shale	152	5203	0.30
-135 to -470	4b	Devonian Huron Shale	152	6187	0.28
-660	5a	Devonian D&C Limestone	168	6187	0.28
-709	5b	D&C Limestone	168	10540	0.30
-970	6	Devonian Oriskany Sandstone	157	10540	0.30
-980	7	Dev-Sil Helderberg Limestone	168	10540	0.30
-1030	8	Silurian Limestone Dolomite	168	10540	0.30
-1130	9a	Silurian Salina Carbonate Rocks	150	10540	0.30
-1193	9b	Silurian Salina Carbonate Rocks	150	8577	0.26
-1455	9c	Silurian Salina Carbonate Rocks	150	7152	0.30
-1830	10a	Silurian Lockport Group	170	11784	0.30
-2015	10b	Silurian Lockport Group	170	7979	0.30
-2110	12	Silurian Dolomite, Limestone, Shale	170	7979	0.30
-2290	13	Silurian Medina Sandstone	157	7979	0.30
-2305	14	Ordivician Queenstown Shale-	157	7979	0.30

Notes:

A. Crosshole test; B. Back-calculation from stiffness parameters adopted in USAR; C. In-situ test results. D. Table 2.5-61 of the USAR; E. From this elevation down, soil parameters are estimates from sonic velocities of deep wells except unit weight. Unit weights are typical values from literature. Coefficient of variation (COV) = 0.1for seismic wave velocities. Poisson's ratio and G_{max} are calculated by following formula: $\nu = ([Vp/V_s]^2 - 2) / (2[Vp/V_s]^2 - 2)$. $G_{max} = \rho V_s^2$; F. Unit weight; G. Poisson's ratio.

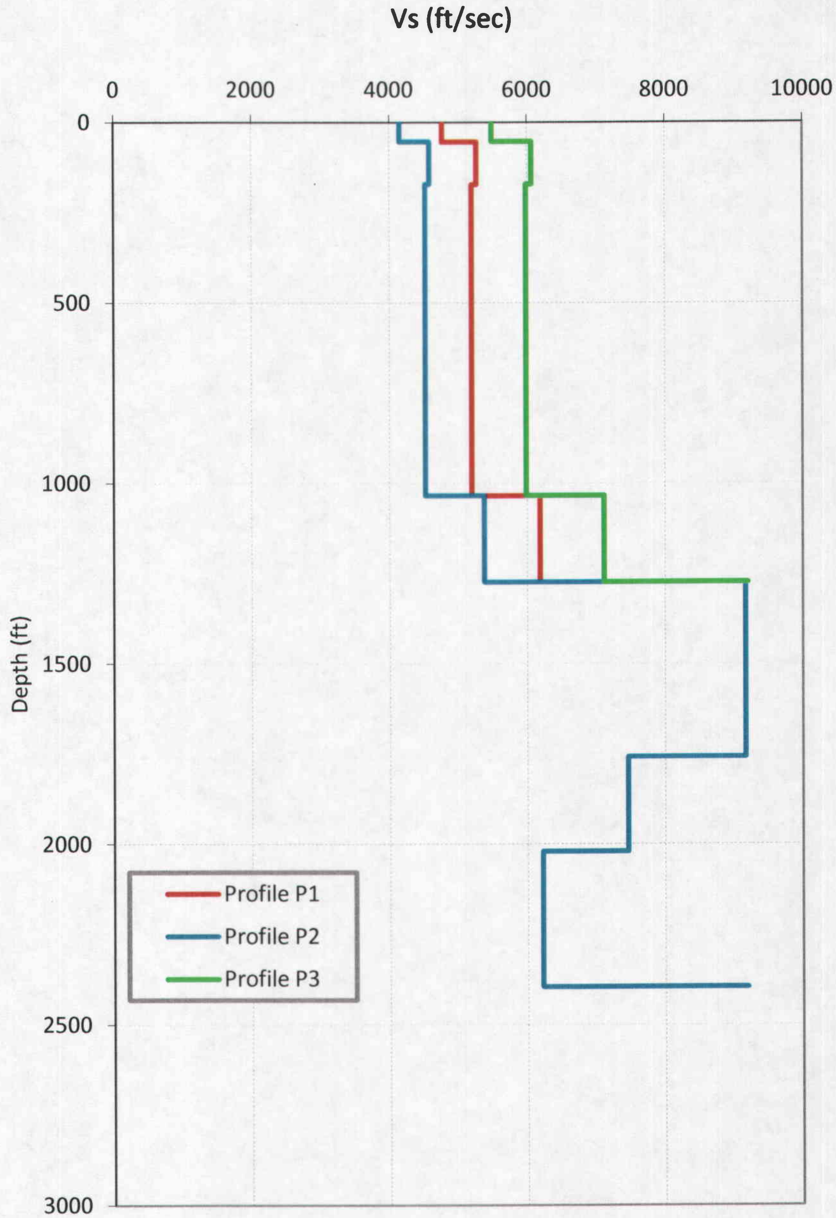
2.3.2.1 Base Case Shear Wave Velocity Profiles

Based on the well characterized nature of the site, the generally flat lying geologic units, and the geology-specific V_P-to-V_S conversions, a scale factor of 1.15 is used for developing upper and lower range base-cases to reflect epistemic uncertainty in V_S. The scale factor of 1.15 reflects a realistic range in Poisson's ratio for the type of geologic units found in the Paleozoic rocks underlying the site. The V_s profiles determined using the scale factor represent the epistemic uncertainty in the soil column from the D & C Limestone Formation at EL -709 ft to the top of the Chagrin Shale bedrock underlying the base of the RB foundation mat.

Using the best estimate V_S specified in ***Table 2-3***, three base-profiles were developed using the scale factor of 1.15. The specified V_S profiles were taken as the mean or BE base-case profile (P1) with lower and upper range base-case profiles P2 and P3 respectively. Consistent with the guidance in the SPID (EPRI, 2013a), the upper range base-case profile is constrained to not exceed a V_S of 9,200 ft/s.

Profiles P1 and P3 extend to hard rock conditions at a depth of 1,274 ft below the base of the RB foundation while Profile P2 extends to a depth of 2,395 ft, and includes possible lower velocity layers at a depth range of 1,760 to 2,395 ft.

The base-case profiles (P1, P2, and P3) are shown on ***Figure 2-3*** and listed in ***Table 2-4***.



*Depth 0 ft corresponds to EL 561 ft

FIGURE 2-3
BASE CASE V_S PROFILES, PNPP SITE

TABLE 2-4
BASE CASE V_S PROFILES, PNPP SITE

LAYER ELEVATION [ft]	PROFILE P1		PROFILE P2		PROFILE P3	
	V_s [ft/s]	DEPTH [ft]	V_s [ft/s]	DEPTH [ft]	V_s [ft/s]	DEPTH [ft]
561	4772	0	4150	0	5488	0
510	4772	55	4150	55	5488	55
510	5273	55	4585	55	6064	55
392	5273	173	4585	173	6064	173
392	5203	173	4524	173	5983	173
-470	5203	1035	4524	1035	5983	1035
-470	6187	1035	5380	1035	7115	1035
-660	6187	1225	5380	1225	7115	1225
-660	6187	1225	5380	1225	7115	1225
-709	6187	1274	5380	1274	7115	1274
-709	9200	1274	9165	1274	9200	1274
-1193			9165	1758		
-1193			7458	1758		
-1455			7458	2020		
-1455			6219	2020		
-1830			6219	2395		
			9200	2395		

2.3.2.2 Shear Modulus and Damping Curves

Consistent with the SPID (EPRI, 2013a), uncertainty and variability in material dynamic properties are included in the site response analysis. For the rock material over the upper 500 ft uncertainty is represented by modeling the material as either linear or non-linear in its dynamic behavior. This material includes the Chagrin Shale Formation. To represent the epistemic uncertainty in shear modulus and damping, two sets of shear modulus reduction and hysteretic damping curves were used. Consistent with the SPID (EPRI, 2013a), the EPRI rock curves (model M1) were used to represent the upper range nonlinearity likely in the materials at this Site, and linear behavior (model M2) was assumed to represent an equally plausible alternative rock response across loading level. For the linear analyses, the low strain damping from the EPRI rock curves was used as the constant damping value in the upper 500 ft. Below a depth of 500 ft linear material behavior is assumed for both models, with the damping value specified

consistent with the kappa estimates for the site (values discussed in ***Section 2.3.2.3*** and shown on ***Table 2-5***).

2.3.2.3 Kappa

Near-surface site damping is often described in terms of the parameter kappa (EPRI, 2013a). Section B-5.1.3.1 of the SPID (EPRI, 2013a) recommends the following procedure for evaluating kappa:

1. Kappa for a firm rock site with at least 3,000 ft (1 km) of sedimentary rock may be estimated from the time averaged V_S over the upper 100 ft (V_{s100}) of the subsurface profile.

2. Kappa for a site with less than 3,000 ft (1 km) of firm rock may be estimated with Q_s of 40 below 500 ft combined with the low strain damping from the EPRI rock curves and an additional kappa of 0.006 seconds(s) for the underlying hard rock.

For the PNPP Site, kappa was estimated using the second of the above approaches because the thickness of the sedimentary rock overlying hard rock is less than 3000 ft. There is confidence, based on deep well sonic log data from the vicinity of the Site, that the hard rock horizon is no more than about 2,395 ft below the top of rock. For each V_s profile, kappa was estimated using the low-strain damping from the EPRI rock curves in the top 500 ft and Q=40 below that depth to the base of the profile. Using the range of kappa values obtained for the three velocity profiles described above in ***Section 2.3.2.1***, and including a kappa of 0.006s for the underlying hard rock the total site kappa is estimated to be 0.0157s for profile P1, 0.0209s for profile P2, and 0.0145s for profile P3.

To complete the representation of the uncertainty in kappa and, at the same time, reduce computational demands, a 50 percent variation to the base-case kappa estimates was added for profiles P2 and P3. For profile P2, the softest profile, the base-case kappa estimate of 0.0209s was augmented with 50 percent increase in kappa to a value of 0.0314s, resulting in two sets of analyses for profile P2. Similarly, uncertainty in kappa for profile P3, the stiffest profile, was augmented with a 50 percent reduction in kappa, resulting in analyses with low-strain kappa values of 0.0145s and 0.0097s. The suite of kappa estimates and associated weights is listed in ***Table 2-5***. The base-case kappa estimates were judged to be more likely (by 50 percent) and assessed weights of 0.6 compared to the augmented values with weights of 0.4. To maintain

consistency in the site response analyses the low-strain damping values are adjusted consistent with the kappa value associated with each profile.

TABLE 2-5
KAPPA VALUES AND WEIGHTS USED IN SITE RESPONSE ANALYSIS

VELOCITY PROFILE	PROFILE WEIGHT	KAPPA [s]	KAPPA WEIGHT
P1 Base-Case	0.4	0.0157 (Kappa 1)	1.0
P2 Lower Range	0.3	0.0209 (Kappa 1)	0.6
		0.0314 (Kappa 2)	0.4
P3 Upper Range	0.3	0.0145 (Kappa 1)	0.6
		0.0097 (Kappa 2)	0.4

This unsymmetric approach results in an appropriate representation of the epistemic uncertainty in site response. It also significantly reduces computational demands relative to specifying three alternative kappa values for each velocity profile. When uncertainty and variability in other inputs are also considered, it results in 6,600 site response analyses (5 combinations of profiles and kappa values, 2 material behavior models [linear and nonlinear for the upper 500 ft], 2 source models [single and double corner inputs], 11 loading levels, and 30 soil profile realizations). The range of kappa values presented in ***Table 2-5*** is utilized in the site response analysis that is combined with the hard-rock seismic hazard to obtain the control point seismic hazard and the GMRS.

2.3.3 Aleatory Variability in Dynamic Material Properties

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 V_S profiles and shear-strain-dependent shear modulus and damping curves are incorporated in the site response calculations.

2.3.3.1 Randomization of Shear-wave Velocity Profile

For the PNPP site, aleatory variability in the V_s profile for the Site is represented by 30 randomized profiles developed from each of the base case profiles shown on ***Figure 2-3***.

These randomized V_S profiles were generated using a natural log standard deviation of 0.25 over the top 50 ft and a value of 0.15 below a depth of 50 ft. As specified in the SPID (EPRI, 2013a), correlation of V_S 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. Additionally, the profiles were constrained to not exceed a V_s of 9,200 ft/s.

2.3.3.2 Randomization of Modulus Reduction and Hysteretic Damping Curves

For the PNPP Site, aleatory variability in dynamic material property curves is represented using 30 randomizations based on the base-case for each alternative model. The random generation of G/Gmax and damping ratio values are limited to the upper and lower bounds of the best estimate ± two standard deviations, consistent with the SPID (EPRI, 2013a). The damping ratio values are limited to 15 percent. Also consistent with the SPID (EPRI, 2013a), a log normal distribution is used with a natural log standard deviation of 0.15 and 0.30 for modulus reduction and hysteretic damping, respectively.

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 models for the shape of the seismic source spectrum (single-corner and double-corner). By selecting appropriate distances and depths, a suite of 11 different input amplitudes (median PGA ranging from 0.01 to 1.5g) were modeled for use in the site response analyses. The characteristics of the seismic source and upper crustal attenuation properties used for the analysis of the PNPP 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 Site Response Methodology

The site response analysis reported here implements an equivalent linear method using the random vibration theory (RVT) approach. This approach utilizes a simple, efficient method 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 V_S, kappa, dynamic material properties, and source spectra was followed for the PNPP Site.

2.3.6 Amplification Factors

The results of the site response analysis consist of factors (5-percent damped pseudo absolute acceleration response spectra) that describe the amplification (or de-amplification) of reference hard-rock response spectra as a function of frequency and input reference hard-rock PGA amplitude. Amplification is determined for the SSE control point elevation at the base of the RB foundation level. Because of uncertainty and variability incorporated in the site response analysis, a distribution of amplification factors is produced. The amplification factors (AFs) are represented by a median (i.e., log-mean) amplification value and an associated log standard deviation (sigma ln) for each oscillator frequency and input rock amplitude. Consistent with the SPID (EPRI, 2013a), median amplification was constrained not to fall below 0.5 to avoid extreme de-amplification that may reflect limitations of the methodology.

Figure 2-4 presents the median and +/- 1 standard deviation in the predicted amplification factors developed for the 11 loading levels parameterized by the reference (hard-rock) PGA (0.01 to 1.50g) for profile P1 and EPRI rock G/G_{max}, and hysteretic damping curves. Further, the amplification factors shown on ***Figure 2-4*** are developed for the hard-rock input motion based on the single-corner frequency source model. The variability in the amplification factors results from the variability in the V_s and modulus reduction and hysteretic damping curves. ***Figure 2-5*** presents similar information for profile P1 using the linear dynamic material property assumptions.

Comparison of amplification factors, including the effects of material nonlinearity in the PNPP Site firm rock layers (model M1),with the corresponding amplification factors developed with linear site response analyses (model M2) shows only minor effects of non-linearity for frequencies below about 20 Hz and a loading level less than about 0.5g. Above about the 0.5g loading level, the differences increase, but only for spectral frequencies in excess of about 20 Hz.

Appendix A provides several tables that summarize the site response uncertainty analysis including the development of the site response logic tree (V_s models, kappa, dynamic properties) and a summary of the numerical values of the amplification factors at seven spectral frequencies

and 11 input PGA values at hard-rock. Additionally, ***Appendix A*** provides examples of the amplification factors for three loading levels consistent with the information shown on ***Figures 2-4 and 2-5.***

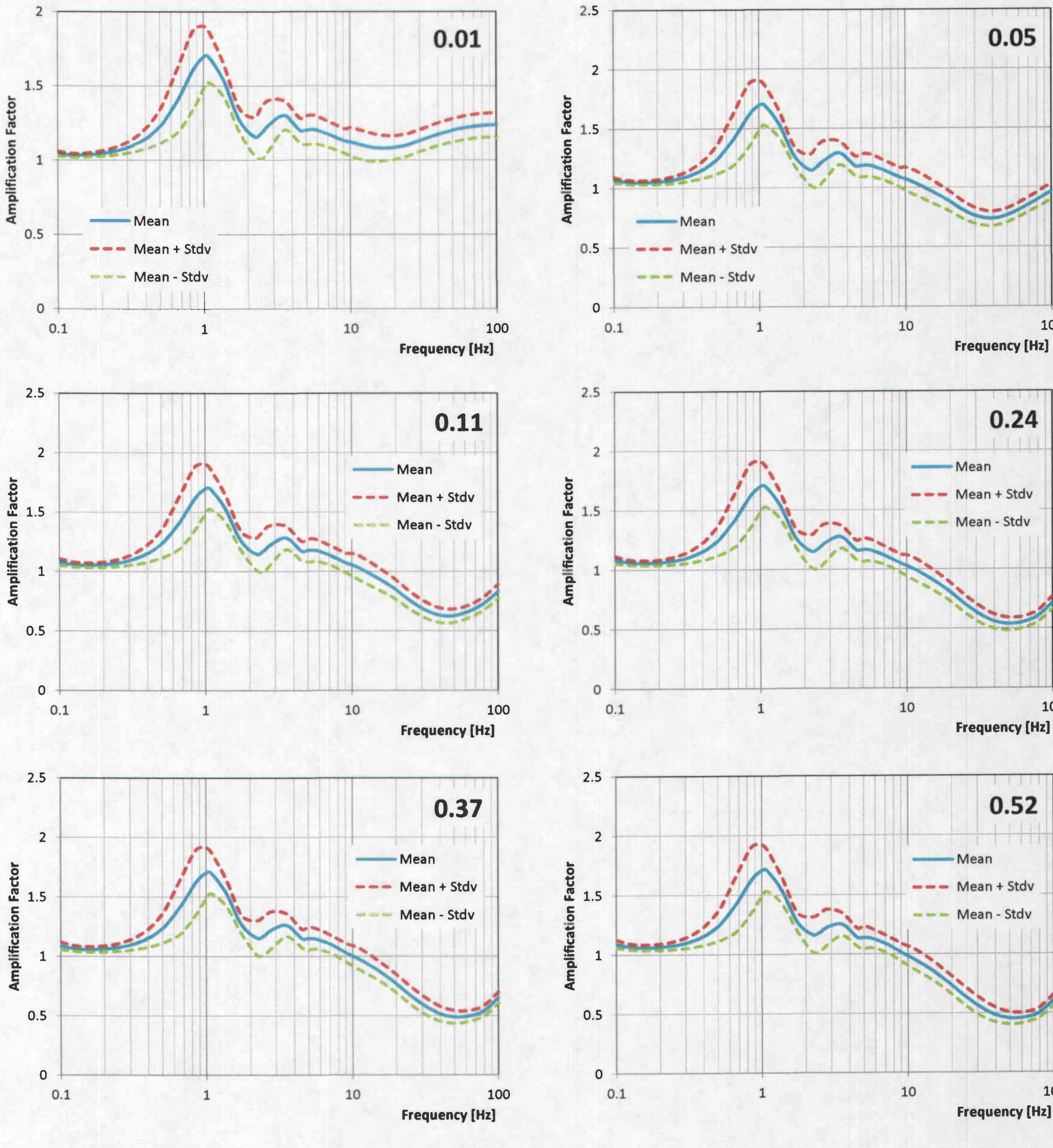


FIGURE 2-4
PNPP SITE AMPLIFICATION FACTORS, BASE-CASE PROFILE (P1), EPRI ROCK G/GMAX AND DAMPING, KAPPA 1, 1-CORNER SOURCE MODEL

Note:
Quantities in the upper right hand corner represent the hard rock input 100 Hz spectral acceleration in g's.

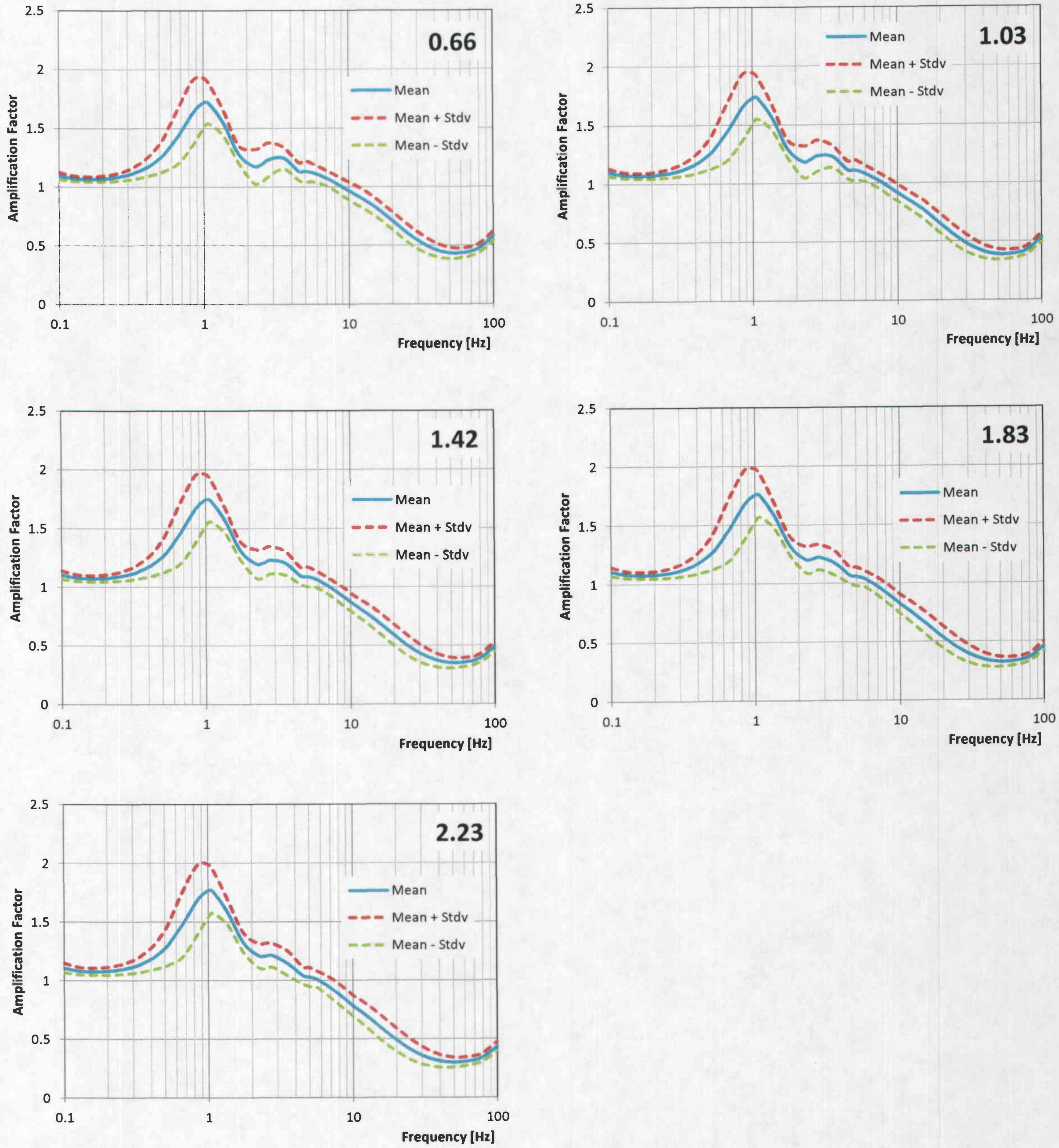


FIGURE 2-4
(CONTINUED)
PNPP SITE AMPLIFICATION FACTORS, BASE-CASE PROFILE (P1), EPRI ROCK G/GMAX AND DAMPING, KAPPA 1, 1-CORNER SOURCE MODEL

Note:

Quantities in the upper right hand corner represent the hard rock input 100 Hz spectral acceleration in g's.

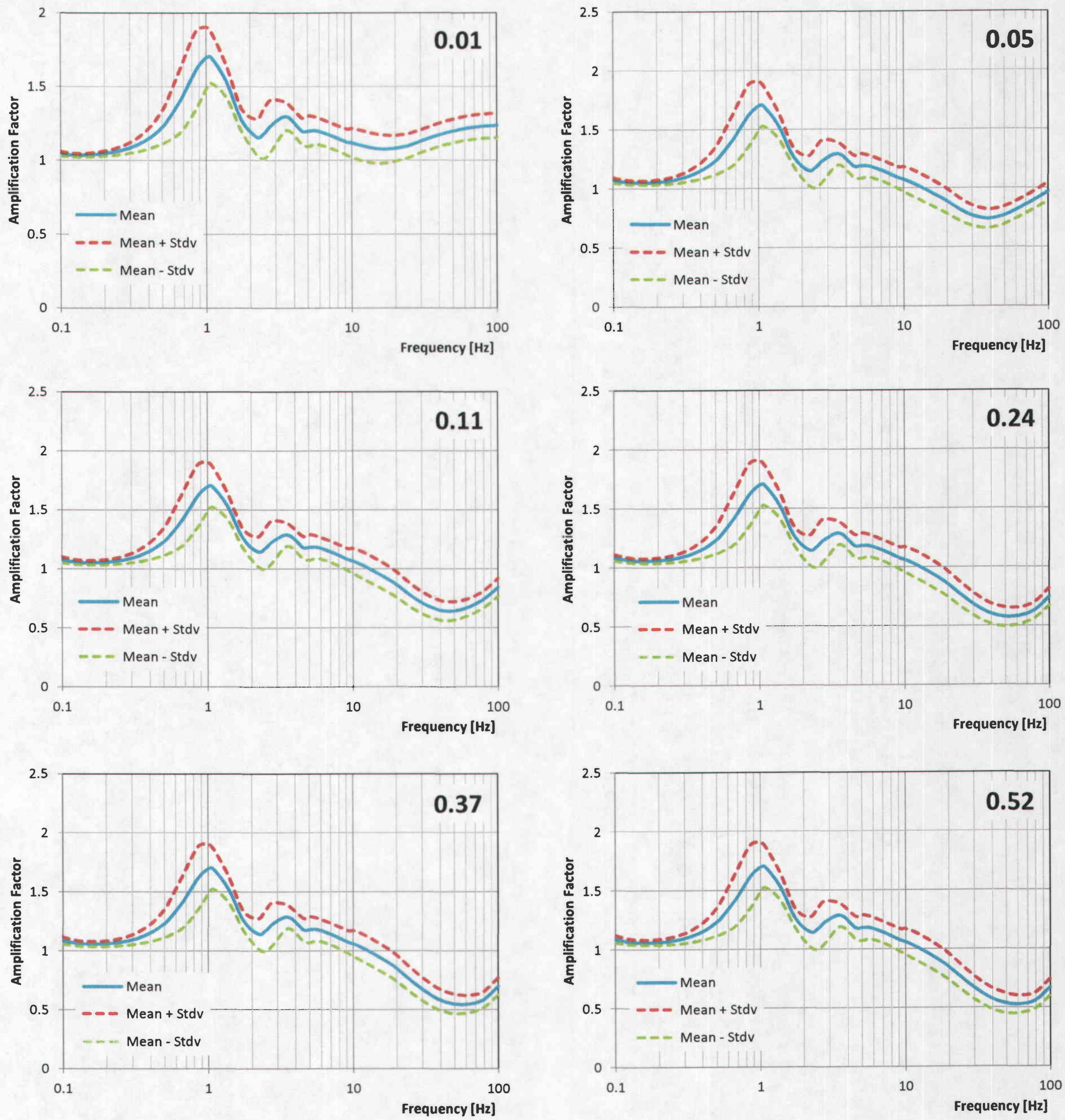


FIGURE 2-5
PNPP SITE AMPLIFICATION FACTORS, BASE-CASE PROFILE (P1), LINEAR ROCK G/GMAX AND DAMPING, KAPPA 1, 1-CORNER SOURCE MODEL

Note:

Quantities in the upper right hand corner represent the hard rock input 100 Hz spectral acceleration in g's.

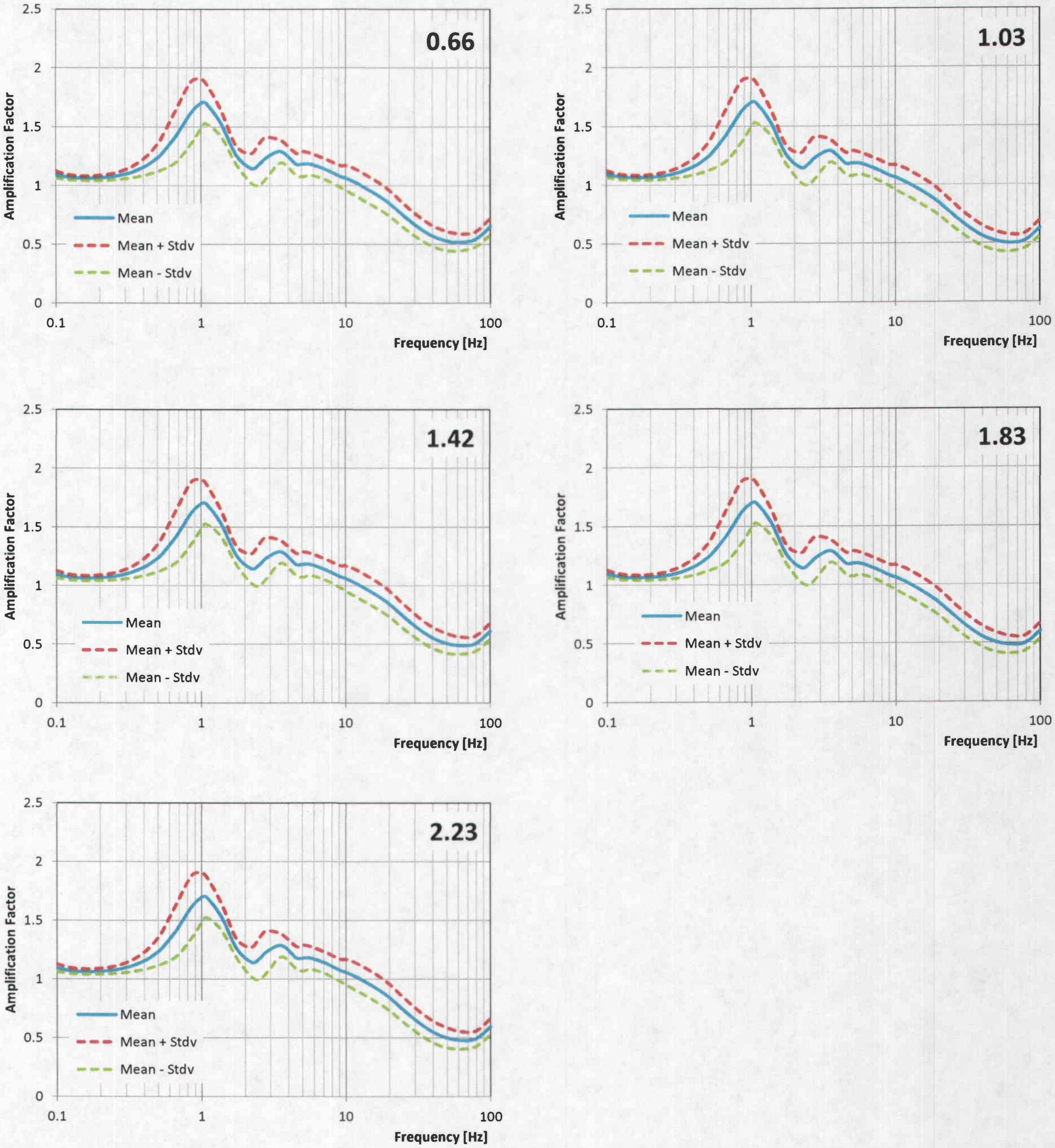


FIGURE 2-5
(CONTINUED)
PNPP SITE AMPLIFICATION FACTORS, BASE-CASE PROFILE (P1), LINEAR ROCK G/GMAX AND DAMPING, KAPPA 1, 1-CORNER SOURCE MODEL

Note:

Quantities in the upper right hand corner represent the hard rock input 100 Hz spectral acceleration in g's.

2.4 Control Point Seismic Hazard Curves

As presented in ***Section 3.2*** below, the control point elevation is taken to be the base of the RB foundation level (EL 561 ft). The procedure to develop probabilistic site-specific control point hazard curves follows the methodology described in Section B-6.0 of the SPID (EPRI, 2013a). This procedure (referred to as Approach 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 specified spectral frequencies for which the EPRI (2013c) ground motion model is defined.

The dynamic response of the rock column below the control point elevation is represented by the frequency and amplitude-dependent amplification factors (median values and ln standard deviations) developed and described in the previous section. The resulting control point mean hazard curves for the PNPP Site are shown on ***Figure 2-6 and Table 2-6*** for the seven spectral frequencies. Tabulated values of the site response amplification functions and control point hazard curves for various fractiles are provided in ***Appendix C***.

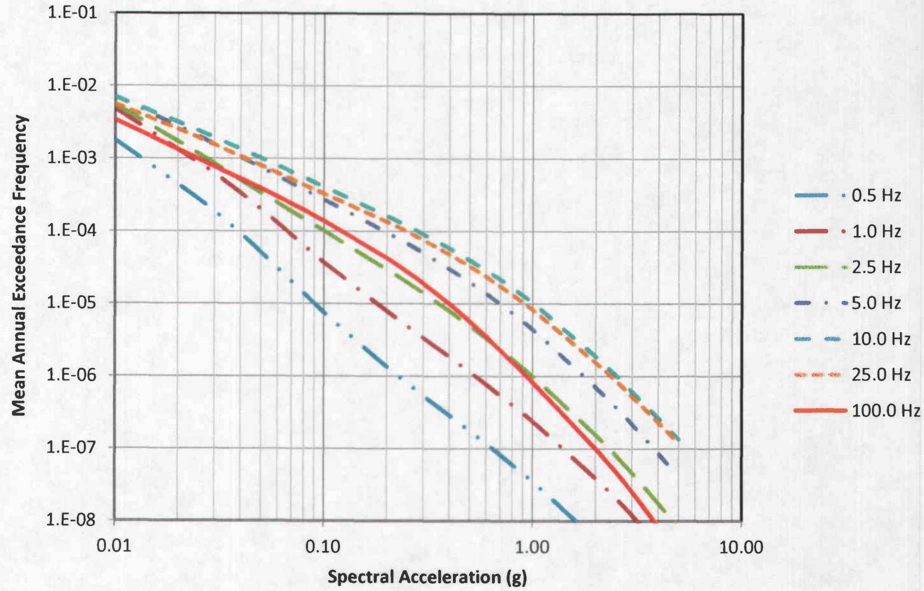


FIGURE 2-6
PNPP MEAN CONTROL POINT (RB FOUNDATION) SEISMIC HAZARD AT SELECTED SPECTRAL FREQUENCIES

TABLE 2-6
PNPP MEAN CONTROL POINT (RB FOUNDATION) SEISMIC HAZARD AT SELECTED SPECTRAL FREQUENCIES

GROUND MOTION LEVEL [g]	MEAN ANNUAL FREQUENCY OF EXCEEDANCE FOR SPECTRAL FREQUENCIES						
	0.5 Hz	1.0 Hz	2.5 Hz	5.0 Hz	10 Hz	25 Hz	100 Hz
0.02	4.44E-04	1.33E-03	1.71E-03	2.77E-03	3.17E-03	2.53E-03	1.33E-03
0.03	1.86E-04	6.19E-04	8.43E-04	1.56E-03	1.94E-03	1.53E-03	7.68E-04
0.04	9.18E-05	3.34E-04	5.01E-04	1.03E-03	1.35E-03	1.06E-03	5.23E-04
0.05	5.11E-05	1.99E-04	3.36E-04	7.43E-04	1.01E-03	7.94E-04	3.86E-04
0.06	3.11E-05	1.29E-04	2.44E-04	5.70E-04	8.00E-04	6.27E-04	2.98E-04
0.07	2.03E-05	8.83E-05	1.86E-04	4.56E-04	6.55E-04	5.14E-04	2.38E-04
0.08	1.40E-05	6.37E-05	1.48E-04	3.76E-04	5.51E-04	4.34E-04	1.95E-04
0.09	1.01E-05	4.79E-05	1.21E-04	3.17E-04	4.73E-04	3.73E-04	1.63E-04
0.10	7.57E-06	3.73E-05	1.01E-04	2.72E-04	4.12E-04	3.27E-04	1.38E-04
0.20	1.36E-06	7.93E-06	2.98E-05	9.62E-05	1.63E-04	1.34E-04	4.29E-05
0.25	8.16E-07	4.95E-06	1.98E-05	6.78E-05	1.19E-04	9.82E-05	2.78E-05
0.30	5.44E-07	3.38E-06	1.40E-05	5.01E-05	9.13E-05	7.52E-05	1.90E-05
0.40	2.91E-07	1.85E-06	7.89E-06	3.02E-05	5.84E-05	4.81E-05	9.94E-06
0.50	1.78E-07	1.15E-06	4.96E-06	1.99E-05	4.03E-05	3.30E-05	5.74E-06
0.60	1.19E-07	7.74E-07	3.34E-06	1.38E-05	2.92E-05	2.36E-05	3.55E-06
0.70	8.34E-08	5.50E-07	2.36E-06	9.99E-06	2.19E-05	1.75E-05	2.31E-06
0.80	6.11E-08	4.07E-07	1.74E-06	7.47E-06	1.68E-05	1.34E-05	1.58E-06
0.90	4.62E-08	3.10E-07	1.31E-06	5.73E-06	1.31E-05	1.04E-05	1.13E-06
1.00	3.58E-08	2.42E-07	1.01E-06	4.48E-06	1.04E-05	8.27E-06	8.34E-07
2.00	5.74E-09	3.94E-08	1.57E-07	7.12E-07	1.90E-06	1.56E-06	1.02E-07
3.00	1.79E-09	1.22E-08	4.66E-08	2.20E-07	6.22E-07	5.34E-07	2.58E-08
5.00	3.47E-10	2.37E-09	8.25E-09	4.17E-08	1.37E-07	1.21E-07	3.52E-09

2.5 CONTROL POINT RESPONSE SPECTRUM

The control point hazard curves described above have been used to develop uniform hazard response spectra (UHRS) and the ground motion response spectrum (GMRS). To ensure that important site response frequencies are accurately modeled, the control point response spectra are based on smoothed UHRS developed at the hard-rock boundary using the approach described by NRC (2007a) and McGuire et al., (2001). The UHRS were obtained through linear interpolation in log-log space to estimate the spectral acceleration at each oscillator frequency for the 1E-4 and 1E-5 per year hazard levels.

The 1E-4 and 1E-5 UHRS, along with a design factor (DF) are used to compute the GMRS at the control point using the criteria in Regulatory Guide (RG) 1.208. ***Table 2-7 and Figure 2-7*** present the control point 1E-4 and 1E-5 UHRS and the GMRS, and Figure 2-7 graphically illustrates the GMRS relative to the UHRS.

TABLE 2-7
PNPP 5-% DAMPED UHRS AND GMRS AT THE SSE CONTROL POINT

FREQUENCY [Hz]	HORIZONTAL SPECTRAL ACCELERATION [g] AT THE RB FOUNDATION		
	$1x10^{-4}$ MAFE UHRS	$1x10^{-5}$ MAFE UHRS	GMRS
0.10	0.0027	0.0059	0.0030
0.13	0.0038	0.0087	0.0044
0.16	0.0055	0.0128	0.0065
0.20	0.0079	0.0188	0.0095
0.26	0.0116	0.0276	0.0139
0.33	0.0174	0.0414	0.0209
0.42	0.0270	0.0640	0.0323
0.50	0.0386	0.0906	0.0458
0.53	0.0408	0.0968	0.0488
0.67	0.0498	0.1240	0.0620
0.85	0.0601	0.1571	0.0778
1.00	0.0666	0.1801	0.0886
1.08	0.0723	0.1999	0.0978
1.37	0.0844	0.2498	0.1206
1.74	0.0834	0.2650	0.1262
2.21	0.0907	0.3097	0.1453
2.50	0.1006	0.3551	0.1656
2.81	0.1179	0.4172	0.1944
3.56	0.1500	0.5336	0.2484
4.52	0.1816	0.6471	0.3011
5.00	0.1950	0.6984	0.3247
5.74	0.2128	0.7652	0.3554
7.28	0.2406	0.8697	0.4036
9.24	0.2687	0.9731	0.4514
10.00	0.2787	1.0092	0.4681
11.72	0.2796	1.0206	0.4726
14.87	0.2714	1.0070	0.4648
18.87	0.2658	0.9971	0.4593
23.95	0.2467	0.9307	0.4282
25.00	0.2423	0.9145	0.4207
30.39	0.2252	0.8347	0.3854
38.57	0.2025	0.7534	0.3476
48.94	0.1803	0.6948	0.3183
62.10	0.1554	0.5764	0.2661
78.80	0.1300	0.4344	0.2048
100.00	0.1211	0.3983	0.1883

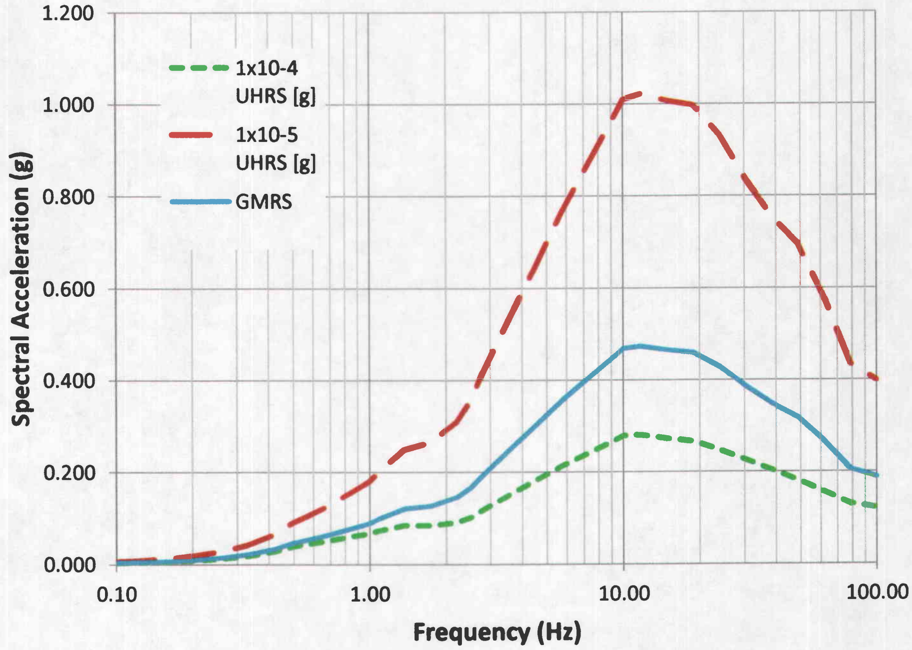


FIGURE 2-7
CONTROL POINT UNIFORM HAZARD RESPONSE SPECTRA AT MEAN ANNUAL FREQUENCIES OF EXCEEDANCE OF $1X10^{-4}$ AND $1X10^{-5}$, AND GROUND MOTION RESPONSE SPECTRA AT PNPP RB FOUNDATION

3.0 PLANT DESIGN BASIS GROUND MOTION

The design basis for PNPP is identified in the USAR (FENOC, 2011).

3.1 SSE DESCRIPTION OF SPECTRAL SHAPE

The PNPP SSE was developed in accordance with 10 CFR Part 100, Appendix A through an evaluation of the maximum earthquake potential for the region surrounding the Site.

The PNPP USAR (Section 2.5.2.1 and Section 2.5.2.2) describes the local and regional seismicity, and provides the geologic basis for the tectonic provinces of the region. The deterministic analysis reported in the USAR identifies the maximum earthquake potential at the site from estimates of the highest seismic intensity experienced at the site based on historical data, and the maximum intensity at the site expected from the occurrence of maximum hypothetical earthquakes in controlling tectonic provinces. The largest intensity assessed using these two methods provides the basis for selecting the maximum earthquake potential for the site.

Based on the reported studies, a Modified Mercalli Intensity (MMI) of VII is selected for the maximum earthquake potential. This Site Intensity corresponds to a PGA in the range of 0.07g to 0.13g using the intensity-acceleration relationships of Gutenberg and Richter, Neumann, and Trifunac and Brady.

The PNPP Site SSE ground motion is conservatively defined by a PGA of 0.15g and the RG 1.60 spectral shape. The 5%-damped horizontal SSE spectral accelerations are presented in ***Table 3-1***. The corresponding vertical spectrum for the SSE is as defined in RG 1.60. ***Figure 3-1*** presents the horizontal and vertical SSE 5%-damped response spectrum.

TABLE 3-1
SSE HORIZONTAL GROUND MOTION RESPONSE SPECTRUM FOR PNPP

FREQUENCY [Hz]	SPECTRAL ACCELERATION [g]
0.10	0.013
0.25	0.070
2.50	0.470
9.00	0.390
33.00	0.150
100.00	0.150

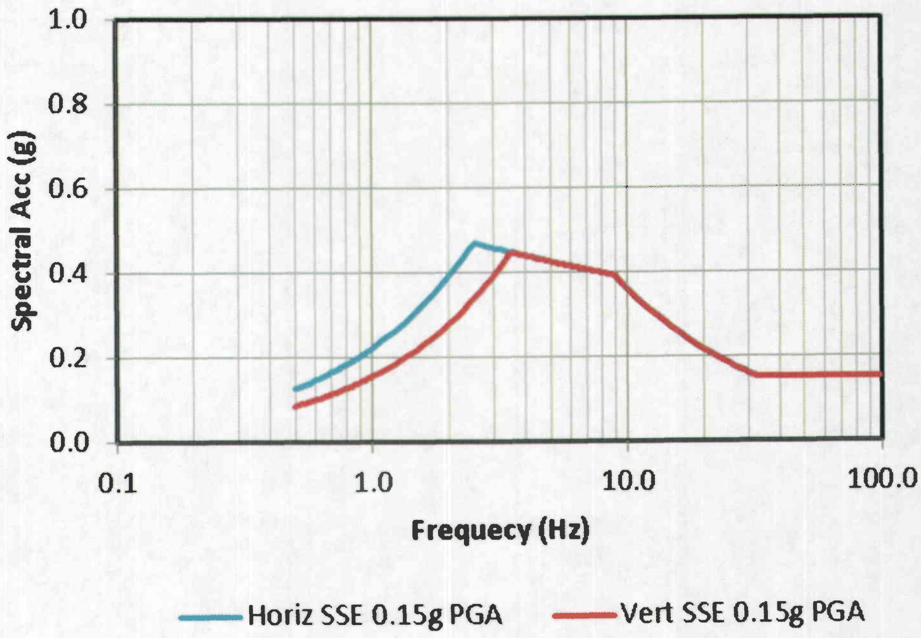


FIGURE 3-1
SAFE SHUTDOWN EARTHQUAKE 5%-DAMPED RESPONSE SPECTRUM

3.2 SSE CONTROL POINT ELEVATION

The horizontal and vertical SSE response spectra represent the design basis ground motion input applied at the base of the foundation levels of the PNPP structures. At PNPP, the top of bedrock is at EL 565 ft and the foundation elevation of the RB is 561 ft. Other major structures supported on rock are founded at somewhat higher elevations. The SSE control point elevation is taken to be the base of the RB foundation, and the SSE response spectra are, therefore, compared to the GMRS at EL 561 ft.

4.0 SCREENING EVALUATION

In accordance with SPID, Section 3 (EPRI, 2013a), a screening evaluation was performed as described below.

The screening process determines if a seismic risk evaluation is needed. The horizontal GMRS determined from the hazard reevaluation is used to characterize the amplitude of the updated evaluation of seismic hazard at the PNPP Site. The screening evaluation is based upon a comparison of the GMRS with the horizontal SSE ground motion spectrum.

4.1 RISK EVALUATION SCREENING (1 TO 10 HZ)

In the 1 to 10 Hz part of the response spectrum, the GMRS exceeds the horizontal SSE (at frequencies above about 6 Hz). Therefore, the plant screens in for a risk evaluation.

The GMRS exceedance relative to the SSE spectrum above about 6.0 Hz is characterized as broad banded. Spectral accelerations at some frequencies in the 1.0 to 10 Hz frequency range exceed 0.4g. Therefore the PNPP is not classified as a Low Hazard site. However, the SSE spectrum envelops the GMRS below 6.0 Hz. Accordingly, failure modes associated with low frequencies are not affected by the GMRS. As discussed in the SPID (EPRI, 2013a), these SSCs and failure modes include flexible distribution systems, sliding and rocking of unanchored components, fuel assemblies inside the reactor vessel, soil liquefaction, and liquid sloshing in atmospheric pressure storage tanks. Accordingly, no new high confidence of low probability of failure (HCLPF) analysis of low frequency SSCs and failure modes is planned.

4.2 HIGH FREQUENCY SCREENING (> 10 HZ)

For a portion of the range above 10 Hz, the GMRS exceeds the horizontal SSE. The high frequency exceedances can be addressed in the risk evaluation discussed in ***Section 4.1*** above.

Although safety equipment in PNPP was evaluated in the IPEEE program, the review level earthquake (RLE) ground motions considered in the IPEEE does not have significant frequency content above 10 Hz. Moreover, the consideration of high-frequency vulnerability of

components in the IPEEE was focused on "bad actor" relays mutually agreed to by the industry and the NRC, with known earthquake or shock sensitivity. These specific model relays, designated as low ruggedness relays, were identified in EPRI Report 7148 (EPRI, 1990), and EPRI Report NP-7147-SL (EPRI, 1991a).Rather than considering high frequency capacity vs. demand screening, "bad actor" relays were considered program outliers and were evaluated using circuit analysis, operator actions, or component replacement.

The response of components to the high frequency ground motion associated with the GMRS will be addressed as part of the on-going SPRA. EPRI Report NP-7498 (EPRI, 1991), as well as more recent studies related to licensing activities for new plants (EPRI, 2007a and 2007b), summarize the basis and conclude that "...high-frequency vibratory motions above about 10 Hz are not damaging to the large majority of NPP structures, components, and equipment. An exception to this is the functional performance of vibration sensitive components, such as relays and other electrical and instrumentation devices whose output signals could be affected by high-frequency excitation."

The SPRA will utilize the information from EPRI's on-going test program to develop estimates of fragility for potential high-frequency sensitive components. The test program is expected to "... use accelerations or spectral levels that are sufficiently high to address the anticipated high-frequency in-structure and in-cabinet responses of various plants."

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 horizontal SSE. Therefore, the plant screens in for a spent fuel pool evaluation.

5.0 INTERIM ACTIONS

Based on the screening evaluation, the expedited seismic evaluation described in EPRI (2013b) is being performed as proposed in a letter to NRC dated April 9, 2013 (ML131 01A379) and agreed to by NRC in a letter dated May 7, 2013 (ML13106A331).

Consistent with NRC letter dated February 20, 2014, [ML14030A046] the seismic hazard reevaluations presented herein are distinct from the current design and licensing bases of the PNPP. 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," and10 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 CEUS. These risk estimates continue to support the following conclusions of the NRC GI-199 Safety/Risk Assessment (NRC, 2010a):

> 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 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.

PNPP 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.

Additionally, as requested in Enclosure 1 of the 50.54(f) letter (Item 5) the following paragraphs provide insights from the PNPP NTTF Recommendation 2.3 walkdowns, and the IPEEE program. These programs further illustrate the plant seismic capacity.

5.1 NTTF 2.3 WALKDOWNS

In response to NTTF Recommendation 2.3, FENOC completed Seismic 2.3 walkdowns in September 2012 (FENOC, 2012). This walkdown identified no major anomalies. Condition reports were initiated as appropriate. Items that were not accessible during the initial walkdown were subsequently walked down during the following refueling outage. The walkdown of these additional items identified no potentially adverse findings (FENOC, 2013b).

The 2.3 walkdown at one of FENOC's plants (Beaver Valley) was subsequently audited by NRC staff. The staff concurred with the process, as well as the findings and conclusions.

5.2 IPEEE DESCRIPTION AND CAPACITY RESPONSE SPECTRUM

The IPEEE for PNPP is characterized as a focused-scope SMA using the EPRI approach. It is based on the RLE ground motion defined by the NUREG/CR-0098 median rock spectral shape anchored to a PGA of 0.3g. The RLE spectrum is taken to represent the input ground motion at the foundation levels of major structures.

The IPEEE HCLPF spectrum (IHS) is not used for screening. However, it is provided here for reference and to document the level of the beyond design basis (BDB) seismic ground motion for which the plant SSCs have been evaluated. ***Appendix B*** summarizes the elements of the IPEEE, following the IPEEE adequacy requirements in the SPID (EPRI, 2013a).

The IPEEE concludes that the plant level HCLPF, controlled by the Diesel Generator Auxiliary Module and the Emergency Service Water Pump anchorage, is 0.30g PGA. ***Table 3-2*** presents the 5-percent damped horizontal IHS spectral accelerations. The SSE spectrum and the IHS in the horizontal direction are shown on ***Figure 5-1***.

TABLE 5-1
IPEEE HORIZONTAL GROUND MOTION RESPONSE SPECTRUM FOR PNPP

FREQUENCY [Hz]	SPECTRAL ACCELERATION [g]
0.10	0.015
0.25	0.098
1.64	0.635
8.00	0.635
33.00	0.300
100.00	0.300

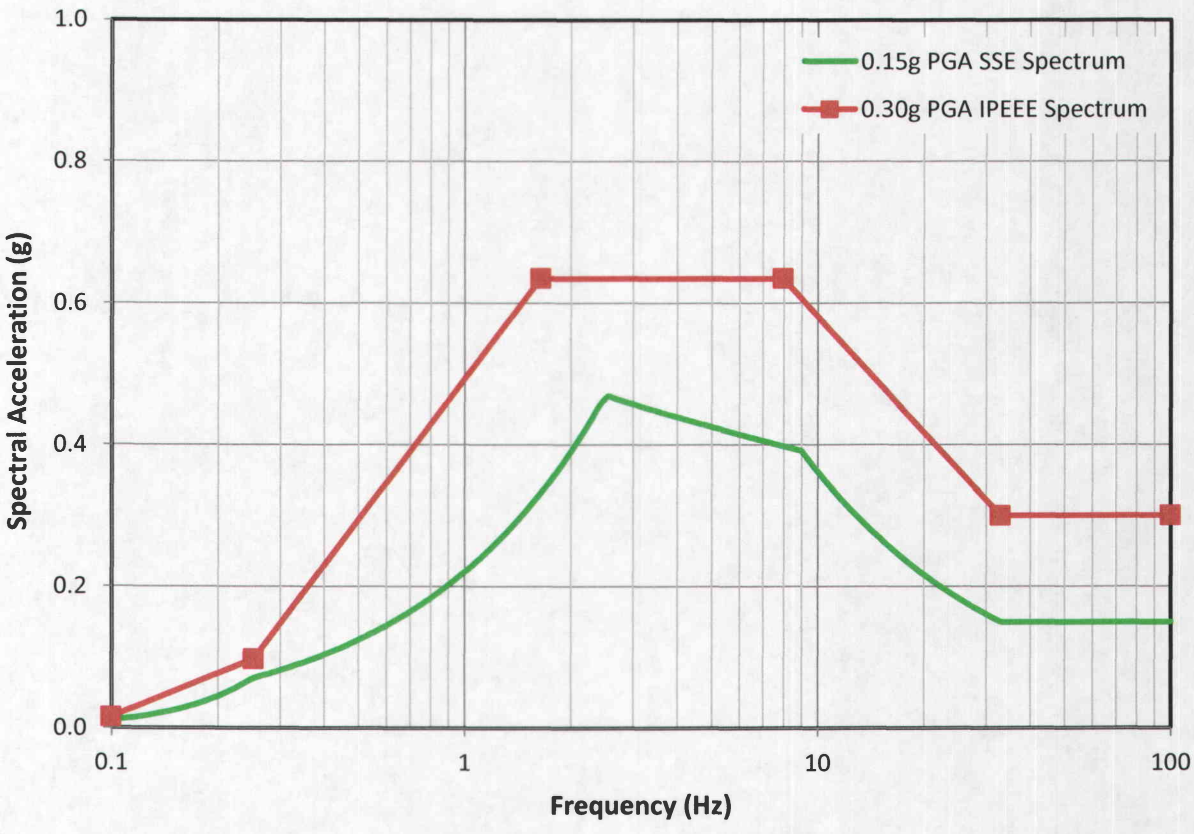


FIGURE 5-1
SSE AND IPEEE RESPONSE SPECTRA FOR PNPP

6.0 CONCLUSIONS

In accordance with the 50.54(f) request for information letter a seismic hazard and screening evaluation was performed for PNPP. This reevaluation followed the guidance provided in the SPID (EPRI, 2013a) and developed the control point GMRS for the Site. The screening evaluation compares the horizontal SSE spectrum to the control point GMRS.

Based on the results of the screening evaluation, PNPP screens in for risk evaluation, a Spent Fuel Pool evaluation, and a High Frequency Confirmation. The GMRS exceeds the horizontal SSE both in the 1 to 10 Hz part of the response spectrum and above 10 Hz.

Although the PNPP IPEEE is a focused scope SMA, and is not used for screening, this report (***Appendix B***) performs the evaluation of the completed IPEEE. As demonstrated in ***Appendix B***, the evaluation concludes that the IPEEE is of good quality and meets all the pre-requisites and the adequacy requirements in accordance with the SPID. The Report compares the GMRS to the IPEEE spectrum for reference and to illustrate the robustness in the plant design relative to the design basis for new plants.

The SPRA is currently on-going and is expected to be completed in accordance with the schedule for CEUS nuclear plants provided in the April 9, 2013, letter from industry to the NRC (NEI, 2013) and agreed to by NRC in a letter dated May 7, 2013, (ML13106A331).

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APPENDIX A

NTTF 2.1 SITE RESPONSE ANALYSIS
PNPP SITE

APPENDIX A – NTTF 2.1 SITE RESPONSE ANALYSIS INPUTS AND RESULTS, PERRY NPP SITE

Uncertainty and variability in inputs to the site response analysis are addressed as follows:

1. Epistemic uncertainty in shear wave velocity (V_S) is modeled using three V_s profiles. The derivation of upper range (UR) and lower range (LR) V_s profiles is based on using a factor of 1.15, which is derived from a range of reasonable V_p/V_s ratios based on literature review for the type of Paleozoic rocks that exist at the site.

2. The randomized site profile realizations use a coefficient of variation of 0.1 for the entire depth of the profile. Based on the review of sonic log data from the three FirstEnergy Nuclear Operating Company (FENOC) sites, an upper and lower V_s limit is defined by a factor of 1.3 relative to the base case V_s for each of the three V_s profiles.

3. The Screening, Prioritization, and Implementation Details (SPID) (EPRI, 2013a) specifies the use of the Electric Power Research Institute (EPRI) (1993) rock degradation curves for rock units such as found at the FENOC Site. These curves are used for the top 500 ft of rock. Below 500 ft damping for the bedrock is derived consistent with kappa estimates.

4. Consistent with the SPID, kappa is estimated for each site profile. For both the lower and upper range V_s profiles, uncertainty is represented using a secondary kappa value by applying a factor of 1.5 (multiplied by 1.5 for LR profile and divided by 1.5 for UR profile). For profiles less than 3,000 ft thick the SPID document specifies use of a Q of 40 to estimate kappa; all three profiles at Perry are less than 3,000 ft thickness. In the top 500 ft the kappa estimates are based on using the low strain damping values from the EPRI rock curves.

5. For the secondary kappa profiles the rock damping in the top 500 ft is modified by the same factor of 1.5 used to characterize uncertainty in kappa. Below 500 ft rock damping was adjusted to preserve the total kappa for the profile.

6. ***Tables A-1 to A-7*** provide the site response inputs consistent with these assessments of uncertainty and variability.

7. ***Table A-8*** lists the resulting median amplification factors and the related sigma for seven selected frequencies and 11 values of input hard rock peak ground acceleration (PGAs).

8. ***Tables A-9 to A-11*** list the resulting median amplification factors and the related sigma for three loading levels associated with ***Figures 2-6 and 2-7***.

TABLE A-1
SITE RESPONSE INPUT

Input Parameter		Value					
Seismic Source Input		M = 6.5 with distances and depths resulting in at 11 peak ground acceleration values from 0.01 g to 1.5 g at the Site					
		Single-corner Table B-4 SPID	Double-corner Table B-6 SPID	Single-corner Table B-4 SPID	Double-corner Table B-6 SPID	Single-corner Table B-4SPID	Double-corner Table B-6 SPID
Source Model		Additional parameters used in the point source model found below Table B-4 SPID					
Profile		Best Estimate (P1)		Lower Range (P2)		Upper Range (P3)	
Vs		Table A-2 (P1) W = 0.40 30 Randomized Realizations		Table A-2 (P2) BE divided by 1.15 W = 0.30 30 Randomized Realizations		Table A-2 (P3) BE multiplied by 1.15 W = 0.30 30 Randomized Realizations	
Site Kappa (k1)		Total Thickness 1274 ft (k1) = .0157s (see Table A-3) W = 1.0		Total Thickness 2395 ft (k1) = .0209s (see Table A-4) W = 0.60		Total Thickness 1274 ft (k1) = .0145s (see Table A-6) W = 0.60	
Shear Modulus and Damping With (k1)	Top 500 ft	EPRI Rock	3.2% Linear damping	EPRI Rock	3.2% Linear damping	EPRI Rock	3.2% Linear damping
	501 ft to profile base	1.25% Linear damping	1.25% Linear damping	1.25% Linear damping	1.25% Linear damping	1.25% Linear damping	1.25% Linear damping
	Weight	W = 0.50	W = 0.50	W = 0.50	W = 0.50	W = 0.50	W = 0.50
Site Kappa (k2)		Not Applicable		Total Thickness 2395 ft (k2) = .0314s (see Table A-5) W = 0.40		Total Thickness 1274 ft (k2) = .0097s (see Table A-7) W = 0.40	
Shear Modulus and Damping With (k2)	Top 500 ft	Not Applicable		EPRI Rock scaled up to get low strain damping of 4.8%	4.8% Linear Damping	EPRI Rock scaled up to get low strain damping of 1.6%	1.6% Linear damping
	501 ft to profile base	Not Applicable		2.3% Linear damping	2.3% Linear damping	0.4% Linear damping	0.4% Linear damping
	Weight	Not Applicable		W = 0.50	W = 0.50	W = 0.50	W = 0.50

TABLE A-2
SHEAR WAVE VELOCITY [ft/s] PROFILES

LAYER ELEVATION [ft]	PROFILE P1	DEPTH [ft]	PROFILE P2	DEPTH [ft]	PROFILE P3	DEPTH [ft]
565	4772	0	4150	0	5488	0
510	4772	55	4150	55	5488	55
510	5273	55	4585	55	6064	55
392	5273	173	4585	173	6064	173
392	5203	173	4524	173	5983	173
-470	5203	1035	4524	1035	5983	1035
-470	6187	1035	5380	1035	7115	1035
-660	6187	1225	5380	1225	7115	1225
-660	6187	1225	5380	1225	7115	1225
-709	6187	1274	5380	1274	7115	1274
-709	9200	1274	9165	1274	9200	1274
-970			9165	1535		
-970			9165	1535		
-980			9165	1545		
-980			9165	1545		
-1030			9165	1595		
-1030			9165	1595		
-1130			9165	1695		
-1130			9165	1695		
-1193			9165	1758		
-1193			7458	1758		
-1455			7458	2020		
-1455			6219	2020		
-1830			6219	2395		
			9200	2395		

TABLE A-3
KAPPA (k1) USED WITH BEST ESTIMATE PROFILE P1

V_s [ft/s] P1	T[ft]	DEPTH TO TOP [ft]	DAMP [%] k1	Q	k1 [s]
4772	55	0	3.20	15.63	0.000738
5273	118	55	3.20	15.63	0.001432
5203	327	173	3.20	15.63	0.004022
5203	535	500	1.25	40.00	0.002571
6187	190	1035	1.25	40.00	0.000768
6187	49	1225	1.25	40.00	0.000198
Halfspace	-	1274			0.006000
Total kappa					0.0157

TABLE A-4
KAPPA (k1) USED WITH LOWER RANGE PROFILE P2

V_s [ft/s] P2	T[ft]	DEPTH TO TOP [ft]	DAMP [%] k1	Q	k1 [s] (0.6)
4150	55	0	3.20	15.63	0.000848
4585	118	55	3.20	15.63	0.001647
4524	327	173	3.20	15.63	0.004626
4524	535	500	1.25	40.00	0.002956
5380	190	1035	1.25	40.00	0.000883
5380	49	1225	1.25	40.00	0.000228
9165	261	1274	1.25	40.00	0.000712
9165	10	1535	1.25	40.00	0.000027
9165	50	1545	1.25	40.00	0.000136
9165	100	1595	1.25	40.00	0.000273
9165	63	1695	1.25	40.00	0.000172
7458	262	1758	1.25	40.00	0.000878
6219	375	2020	1.25	40.00	0.001507
Halfspace		2395	1.25		0.006000
Total kappa					0.0209

TABLE A-5
KAPPA (k2) USED WITH LOWER RANGE PROFILE P2

V_S [ft/s] P2	T[ft]	DEPTH TO TOP [ft]	DAMP [%] k2	Q	k2 [s] (0.4)
4150	55	0	4.80	10.42	0.001272
4585	118	55	4.80	10.42	0.002471
4524	327	173	4.80	10.42	0.006939
4524	535	500	2.30	21.74	0.005439
5380	190	1035	2.30	21.74	0.001625
5380	49	1225	2.30	21.74	0.000419
9165	261	1274	2.30	21.74	0.001310
9165	10	1535	2.30	21.74	0.000050
9165	50	1545	2.30	21.74	0.000251
9165	100	1595	2.30	21.74	0.000502
9165	63	1695	2.30	21.74	0.000316
7458	262	1758	2.30	21.74	0.001616
6219	375	2020	2.30	21.74	0.002774
Halfspace		2395			0.006000
Total kappa					0.0310

TABLE A-6
KAPPA (k1) USED WITH UPPER RANGE PROFILE P3

V_S [ft/s] P3	T[ft]	DEPTH TO TOP [ft]	DAMP [%] k1	Q	k1 [s] (0.6)
5488	55	0	3.20	15.63	0.000641
6064	118	55	3.20	15.63	0.001245
5983	327	173	3.20	15.63	0.003498
5983	535	500	1.25	40.00	0.002235
7115	190	1035	1.25	40.00	0.000668
7115	49	1225	1.25	40.00	0.000172
Halfspace	-	1274		-	0.006000
Total kappa					0.0145

TABLE A-7
KAPPA (k2) USED WITH UPPER RANGE PROFILE P3

V_S [ft/s] P3	T[ft]	Depth to Top [ft]	Damp [%] k2	Q	k2 [s] (0.4)
5488	55	0	1.60	31.25	0.000321
6064	118	55	1.60	31.25	0.000623
5983	327	173	1.60	31.25	0.001749
5983	535	500	0.40	125.00	0.000715
7115	190	1035	0.40	125.00	0.000214
7115	49	1225	0.40	125.00	5.51E-05
Halfspace	-	1274			0.006000
Total kappa					0.0097

TABLE A-8
AMPLIFICATION FUNCTIONS FOR PNPP SITE

100 Hz SA [g]	Median AF	Sigma Ln(AF)	25 Hz SA [g]	Median AF	Sigma Ln(AF)	10 Hz SA [g]	Median AF	Sigma Ln(AF)	5 Hz SA [g]	Median AF	Sigma Ln(AF)
1.02E-02	1.15E+00	9.28E-02	1.31E-02	1.01E+00	1.33E-01	2.07E-02	1.04E+00	1.34E-01	2.35E-02	1.15E+00	9.91E-02
5.45E-02	8.98E-01	1.40E-01	1.07E-01	7.34E-01	2.51E-01	1.13E-01	1.00E+00	1.54E-01	9.41E-02	1.14E+00	1.03E-01
1.15E-01	7.73E-01	1.69E-01	2.26E-01	6.91E-01	2.79E-01	2.10E-01	9.92E-01	1.58E-01	1.64E-01	1.13E+00	1.03E-01
2.52E-01	6.71E-01	1.93E-01	4.73E-01	6.59E-01	2.99E-01	4.04E-01	9.78E-01	1.62E-01	3.02E-01	1.12E+00	1.05E-01
3.97E-01	6.20E-01	2.07E-01	7.19E-01	6.39E-01	3.11E-01	5.93E-01	9.67E-01	1.67E-01	4.35E-01	1.12E+00	1.06E-01
5.48E-01	5.88E-01	2.18E-01	9.70E-01	6.22E-01	3.22E-01	7.83E-01	9.56E-01	1.71E-01	5.68E-01	1.11E+00	1.08E-01
7.03E-01	5.64E-01	2.27E-01	1.22E+00	6.07E-01	3.32E-01	9.75E-01	9.46E-01	1.77E-01	7.02E-01	1.11E+00	1.11E-01
1.10E+00	5.26E-01	2.44E-01	1.86E+00	5.77E-01	3.55E-01	1.45E+00	9.22E-01	1.91E-01	1.03E+00	1.10E+00	1.17E-01
1.51E+00	5.01E-01	2.58E-01	2.53E+00	5.52E-01	3.77E-01	1.95E+00	9.01E-01	2.06E-01	1.38E+00	1.09E+00	1.23E-01
1.95E+00	4.82E-01	2.73E-01	3.23E+00	5.28E-01	4.00E-01	2.47E+00	8.79E-01	2.22E-01	1.74E+00	1.07E+00	1.30E-01
2.37E+00	4.66E-01	2.86E-01	3.89E+00	5.08E-01	4.22E-01	2.97E+00	8.59E-01	2.39E-01	2.09E+00	1.06E+00	1.39E-01
2.5 Hz SA [g]	**Median AF**	**Sigma Ln(AF)**	**1 Hz SA [g]**	**Median AF**	**Sigma Ln(AF)**	**0.5 Hz SA [g]**	**Median AF**	**Sigma Ln(AF)**			
2.16E-02	1.13E+00	1.53E-01	1.46E-02	1.58E+00	1.19E-01	8.44E-03	1.28E+00	1.93E-01			
6.85E-02	1.13E+00	1.54E-01	3.72E-02	1.58E+00	1.18E-01	1.87E-02	1.28E+00	1.91E-01			
1.14E-01	1.13E+00	1.53E-01	5.86E-02	1.58E+00	1.18E-01	2.84E-02	1.29E+00	1.91E-01			
2.03E-01	1.13E+00	1.51E-01	1.01E-01	1.58E+00	1.18E-01	4.77E-02	1.29E+00	1.91E-01			
2.88E-01	1.13E+00	1.48E-01	1.41E-01	1.58E+00	1.18E-01	6.59E-02	1.29E+00	1.91E-01			
3.73E-01	1.13E+00	1.46E-01	1.81E-01	1.59E+00	1.19E-01	8.39E-02	1.29E+00	1.92E-01			
4.59E-01	1.13E+00	1.45E-01	2.21E-01	1.59E+00	1.19E-01	1.02E-01	1.29E+00	1.92E-01			
6.71E-01	1.14E+00	1.41E-01	3.20E-01	1.60E+00	1.20E-01	1.47E-01	1.30E+00	1.93E-01			
8.92E-01	1.14E+00	1.40E-01	4.23E-01	1.60E+00	1.21E-01	1.93E-01	1.30E+00	1.94E-01			
1.12E+00	1.14E+00	1.40E-01	5.31E-01	1.61E+00	1.23E-01	2.42E-01	1.30E+00	1.96E-01			
1.34E+00	1.14E+00	1.41E-01	6.34E-01	1.62E+00	1.24E-01	2.88E-01	1.30E+00	1.98E-01			

TABLE A-9
AMPLIFICATION FUNCTIONS AT SPECIFIC LOADING LEVELS FOR PERRY SITE
100 Hz SPECTRAL ACCELERATION = 0.11g

FREQUENCY [Hz]	PROFILE P1 KAPPA 1 EPRI ROCK NONLINEAR CURVES 1-CORNER GROUND MOTION MODEL		PROFILE P1 KAPPA 1 LINEAR ROCK CURVES 1-CORNER GROUND MOTION MODEL	
	MEDIAN AF	SIGMA LN(AF)	MEDIAN AF	SIGMA LN(AF)
0.1	1.08E+00	2.51E-02	1.08E+00	2.49E-02
0.13	1.06E+00	1.95E-02	1.06E+00	1.93E-02
0.16	1.05E+00	1.89E-02	1.05E+00	1.87E-02
0.2	1.06E+00	2.18E-02	1.06E+00	2.16E-02
0.26	1.07E+00	2.93E-02	1.07E+00	2.90E-02
0.33	1.10E+00	4.32E-02	1.10E+00	4.29E-02
0.42	1.16E+00	6.72E-02	1.16E+00	6.66E-02
0.5	1.22E+00	9.51E-02	1.22E+00	9.43E-02
0.53	1.25E+00	1.06E-01	1.25E+00	1.05E-01
0.67	1.40E+00	1.58E-01	1.40E+00	1.57E-01
0.85	1.59E+00	1.65E-01	1.59E+00	1.65E-01
1	1.68E+00	1.24E-01	1.68E+00	1.24E-01
1.08	1.69E+00	1.03E-01	1.69E+00	1.03E-01
1.37	1.52E+00	7.57E-02	1.52E+00	7.58E-02
1.74	1.26E+00	6.65E-02	1.26E+00	6.65E-02
2.21	1.14E+00	1.18E-01	1.14E+00	1.12E-01
2.5	1.16E+00	1.49E-01	1.16E+00	1.51E-01
2.81	1.21E+00	1.34E-01	1.22E+00	1.44E-01
3.56	1.28E+00	7.75E-02	1.28E+00	7.53E-02
4.52	1.17E+00	7.08E-02	1.18E+00	8.14E-02
5	1.17E+00	8.25E-02	1.18E+00	9.26E-02
5.74	1.17E+00	7.97E-02	1.18E+00	8.08E-02
7.28	1.13E+00	7.38E-02	1.13E+00	7.98E-02
9.24	1.06E+00	7.88E-02	1.07E+00	8.91E-02
10	1.05E+00	9.23E-02	1.06E+00	1.02E-01
11.72	1.01E+00	1.01E-01	1.02E+00	1.13E-01
14.87	9.40E-01	1.00E-01	9.54E-01	1.20E-01
18.87	8.63E-01	9.84E-02	8.79E-01	1.27E-01
23.95	7.69E-01	1.01E-01	7.84E-01	1.31E-01
25	7.52E-01	1.02E-01	7.67E-01	1.32E-01
30.39	6.85E-01	1.02E-01	7.00E-01	1.34E-01
38.57	6.32E-01	9.96E-02	6.46E-01	1.32E-01
48.94	6.24E-01	9.16E-02	6.37E-01	1.24E-01
62.1	6.58E-01	8.07E-02	6.69E-01	1.08E-01
78.8	7.23E-01	7.49E-02	7.34E-01	9.66E-02
100	8.28E-01	7.25E-02	8.38E-01	9.02E-02

TABLE A-10
AMPLIFICATION FUNCTIONS AT SPECIFIC LOADING LEVELS FOR PERRY SITE
100 Hz SPECTRAL ACCELERATION = 0.37g

FREQUENCY [HZ]	PROFILE P1 KAPPA 1 EPRI ROCK NONLINEAR CURVES 1-CORNER GROUND MOTION MODEL		PROFILE P1 KAPPA 1 LINEAR ROCK CURVES 1-CORNER GROUND MOTION MODEL	
	MEDIAN AF	SIGMA LN(AF)	MEDIAN AF	SIGMA LN(AF)
0.1	1.09E+00	2.86E-02	1.09E+00	2.75E-02
0.13	1.06E+00	2.22E-02	1.06E+00	2.11E-02
0.16	1.06E+00	2.12E-02	1.06E+00	2.01E-02
0.2	1.06E+00	2.38E-02	1.06E+00	2.26E-02
0.26	1.08E+00	3.11E-02	1.08E+00	2.97E-02
0.33	1.11E+00	4.52E-02	1.11E+00	4.34E-02
0.42	1.16E+00	6.96E-02	1.16E+00	6.70E-02
0.5	1.23E+00	9.82E-02	1.22E+00	9.46E-02
0.53	1.26E+00	1.10E-01	1.25E+00	1.06E-01
0.67	1.41E+00	1.63E-01	1.40E+00	1.57E-01
0.85	1.60E+00	1.67E-01	1.59E+00	1.64E-01
1	1.69E+00	1.25E-01	1.68E+00	1.24E-01
1.08	1.69E+00	1.03E-01	1.69E+00	1.03E-01
1.37	1.53E+00	7.40E-02	1.52E+00	7.60E-02
1.74	1.27E+00	6.33E-02	1.26E+00	6.67E-02
2.21	1.15E+00	1.25E-01	1.14E+00	1.13E-01
2.5	1.17E+00	1.37E-01	1.16E+00	1.51E-01
2.81	1.21E+00	1.25E-01	1.22E+00	1.44E-01
3.56	1.26E+00	7.60E-02	1.28E+00	7.54E-02
4.52	1.15E+00	6.76E-02	1.18E+00	8.19E-02
5	1.15E+00	8.23E-02	1.18E+00	9.30E-02
5.74	1.14E+00	7.43E-02	1.18E+00	8.09E-02
7.28	1.09E+00	6.88E-02	1.13E+00	8.02E-02
9.24	1.02E+00	7.68E-02	1.07E+00	8.99E-02
10	1.00E+00	8.51E-02	1.06E+00	1.03E-01
11.72	9.57E-01	9.39E-02	1.02E+00	1.14E-01
14.87	8.81E-01	9.36E-02	9.46E-01	1.23E-01
18.87	7.90E-01	9.77E-02	8.66E-01	1.31E-01
23.95	6.86E-01	1.12E-01	7.62E-01	1.38E-01
25	6.67E-01	1.15E-01	7.42E-01	1.40E-01
30.39	5.90E-01	1.23E-01	6.61E-01	1.47E-01
38.57	5.20E-01	1.21E-01	5.84E-01	1.54E-01
48.94	4.89E-01	1.08E-01	5.44E-01	1.52E-01
62.1	4.95E-01	9.10E-02	5.42E-01	1.34E-01
78.8	5.37E-01	7.86E-02	5.79E-01	1.15E-01
100	6.50E-01	7.16E-02	6.93E-01	1.02E-01

TABLE A-11
AMPLIFICATION FUNCTIONS AT SPECIFIC LOADING LEVELS FOR PERRY SITE
100 Hz SPECTRAL ACCELERATION = 1.03g

FREQUENCY [Hz]	PROFILE P1 KAPPA 1 EPRI ROCK NONLINEAR CURVES 1-CORNER GROUND MOTION MODEL		PROFILE P1 KAPPA 1 LINEAR ROCK CURVES 1-CORNER GROUND MOTION MODEL	
	MEDIAN AF	SIGMA LN(AF)	MEDIAN AF	SIGMA LN(AF)
0.1	1.10E+00	3.18E-02	1.09E+00	2.88E-02
0.13	1.07E+00	2.50E-02	1.07E+00	2.21E-02
0.16	1.07E+00	2.38E-02	1.06E+00	2.08E-02
0.2	1.07E+00	2.64E-02	1.06E+00	2.31E-02
0.26	1.09E+00	3.40E-02	1.08E+00	3.01E-02
0.33	1.12E+00	4.88E-02	1.11E+00	4.36E-02
0.42	1.17E+00	7.46E-02	1.16E+00	6.72E-02
0.5	1.24E+00	1.05E-01	1.23E+00	9.48E-02
0.53	1.27E+00	1.17E-01	1.25E+00	1.06E-01
0.67	1.42E+00	1.72E-01	1.40E+00	1.57E-01
0.85	1.63E+00	1.71E-01	1.59E+00	1.64E-01
1	1.71E+00	1.27E-01	1.68E+00	1.24E-01
1.08	1.72E+00	1.05E-01	1.69E+00	1.03E-01
1.37	1.55E+00	7.12E-02	1.52E+00	7.61E-02
1.74	1.29E+00	6.11E-02	1.26E+00	6.68E-02
2.21	1.18E+00	1.15E-01	1.14E+00	1.13E-01
2.5	1.19E+00	1.15E-01	1.16E+00	1.52E-01
2.81	1.23E+00	1.10E-01	1.22E+00	1.44E-01
3.56	1.22E+00	7.98E-02	1.28E+00	7.55E-02
4.52	1.11E+00	7.08E-02	1.18E+00	8.21E-02
5	1.11E+00	8.43E-02	1.17E+00	9.32E-02
5.74	1.09E+00	7.06E-02	1.18E+00	8.10E-02
7.28	1.02E+00	6.68E-02	1.13E+00	8.03E-02
9.24	9.41E-01	8.29E-02	1.07E+00	9.03E-02
10	9.12E-01	8.28E-02	1.05E+00	1.03E-01
11.72	8.57E-01	9.08E-02	1.01E+00	1.15E-01
14.87	7.72E-01	1.06E-01	9.42E-01	1.23E-01
18.87	6.66E-01	1.27E-01	8.61E-01	1.32E-01
23.95	5.59E-01	1.51E-01	7.53E-01	1.41E-01
25	5.41E-01	1.55E-01	7.33E-01	1.43E-01
30.39	4.71E-01	1.62E-01	6.47E-01	1.53E-01
38.57	4.10E-01	1.49E-01	5.61E-01	1.64E-01
48.94	3.83E-01	1.25E-01	5.09E-01	1.66E-01
62.1	3.87E-01	1.02E-01	4.93E-01	1.49E-01
78.8	4.20E-01	8.53E-02	5.14E-01	1.26E-01
100	5.25E-01	7.51E-02	6.22E-01	1.09E-01

APPENDIX B

EVALUATION OF PNPP IPEEE SUBMITTAL

APPENDIX B – EVALUATION OF PNPP IPEEE SUBMITTAL

The Individual Plant Examination of External Events (IPEEE) performed for the Perry Nuclear Power Station (PNPP) was a focused-scope Electric Power Research Institute (EPRI) Seismic Margin Assessment (SMA). Therefore, in accordance with *Seismic Evaluation Guidance, Screening Prioritization, and Implementation Details* (SPID) *for the Resolution of the Fukushima Near-Term Task Force Recommendation 2.1: Seismic* (EPRI, 2013a), it is not eligible for use in screening. Nevertheless, it is summarized here for information, and because the IPEEE findings indicate that the plant design is seismically robust and exhibits significant margins in excess of the design basis. The IPEEE was performed in accordance with the guidelines in Nuclear Regulatory Commission Technical Report (NUREG)-1407. The plant HCLPF is reported to be 0.30g and is controlled by the Diesel Generator Auxiliary Module and the Emergency Service Water Pump anchorage.

B.1 IPEEE Pre-Requisites

The SPID document guidelines require that the following pre-requisites be documented prior to the possible use of the IPEEE for screening.

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 U.S. Nuclear Regulatory Commission (NRC) Safety Evaluation Report (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 conclusions reached in the IPEEE.

As part of the Near-Term Task Force (NTTF) 2.3 Seismic walkdown effort, a sample of the vulnerabilities identified in the IPEEE was examined to verify that the corrective actions were implemented and documents closed. The resulting Report (FENOC, 2012) summarizes the closure as follows:

> The IPEEE submittal (July 22, 1996) states that "...four enhancements to reduce the threat of spatial interactions were identified and are in the process of being implemented. Section 3.1.4.3.1 "Spatial Interaction Results" documents the spatial interaction problems as housekeeping issues..." The 2.3 seismic walk-down "...treated the spatial interaction problems as commitments and wrote two condition reports documenting the failure to resolve the issues. Calculations were reviewed and the "enhancements," their reference, and final resolution are documented in Appendix F.
>
> Section 3.1.4.2.3 of the IPEEE report documents the relay chatter summary of results, and states in section 3.1.4.2.2 that "...there are 5 relays that require manual operator actions to reset post seismic event. The results of this evaluation are contained in Appendix F, and a condition report was generated for failure to modify the operation procedures to alert the operator that post seismic event, certain relays may need to be reset..."

Available Seismic Evaluation Worksheets (SEWS) generated during the IPEEE walkdowns were reviewed and included in the NTTF 2.3 report. The NTTF 2.3 walkdowns identified no potential adverse seismic conditions. Based on the NTTF 2.3 evaluations it is concluded that the IPEEE findings have been appropriately implemented and they do not introduce seismic interaction effects on other safety related SSCs.

B.2 IPEEE Adequacy Demonstration

Consistent with the guidelines in NUREG -1407, the PNPP IPEEE accomplished a focused scope SMA for the 0.3g Review Level Earthquake (RLE). The following paragraphs briefly summarize the IPEEE in accordance with the requirements of the SPID guidelines.

B.2.1 Building Seismic Analysis

The design seismic analysis of Category I structures of the PNPP, except for the cooling water tunnels, is based on the time history modal superposition method using simulated time history

compatible with the SSE spectra as input. Lumped mass models of the buildings were utilized in the seismic analysis. These models represent the building mass discretely at the points of physical mass concentration (e.g., heavy floors, and include the masses of floors, equipment and walls). The lumped masses are connected by story stiffnesses. Section 3.7 of the USAR describes the analysis methods and computer codes utilized in the analysis.

Most major structures of the PNPP are founded on shale bedrock. The rock structure interaction is incorporated in the seismic analysis by means of soil springs representative of the stiffness of the supporting rock mass. The Diesel Generator Building and Off-Gas Buildings are founded on backfill. The soil structure interaction for these buildings was represented by a two dimensional finite element models of the structure and the supporting soil medium.

The reported modes and frequencies extracted from the dynamic analysis of the models are reasonable and representative of the structures. The Structural response was obtained by superposition of modal responses of all significant modes. Time histories of structural responses, at mass points of interest, were used to generate the floor response spectra. A scaling method was used in lieu of the square-root-of-the-sum-of-the-squares (SRSS) method to account for coupling between horizontal and vertical responses. This method was shown to provide conservative results when compared to the SRSS spectra and the design spectra.

B.2.2 IPEEE Seismic Response

The RLE input motion is represented by the NUREG 0098 median shapes for rock and soil, both anchored at PGA of 0.3g. The seismic response for the IPEEE Seismic margin analysis is developed based on comparison of the RLE spectra to the SSE design spectra.

The linear scaling method in EPRI NP-6041 is used to scale the SSE in-structure floor response spectra developed as part of the design analysis. This method applies a single factor to the entire SSE in-structure response spectra to derive the in-structure response spectra associated with the RLE ground motion. This scaling factor is a combination of:

1. An amplification factor associated with an increase in the ground seismic demand from SSE to SME.

2. A reduction factor associated with the margin between the response spectra of the SSE synthetic time histories and SSE design ground spectra.

3. A reduction factor associated with an increase in the structural damping values.

These amplification and reduction factors identified above are determined at the dominant natural frequency of each building. This frequency usually coincides with the frequency where the in-structure response spectrum peaks. The reported IPEEE calculation considers only the first two items. The third factor is by definition 1.0 because 7% damping is used in the both the RLE spectrum and the SSE spectrum.

B.2.3 Screening of Components

As part of the walkdown preparation, a significant amount of plant specific information was reviewed and subsequently used in the SMA. This includes the PNPP USAR, PRA, drawings, procedures, seismic analyses, and seismic qualification test reports. This data was also used as basis for the screening of components. Initially, the Seismic Review Team (SRT) pre-screened a number of structures, components, and equipment using the screening criteria guidelines contained in EPRI NP-6041-SL (Tables 2-3 and 2-4) for spectral accelerations less than 0.8g.

Drawings and analysis models of structures were reviewed for details that might indicate seismic vulnerabilities in accordance with the requirements of a focused-scope SMA. This review confirmed that consistent good practice in design detail and analysis was utilized at PNPP. Therefore, a small sample of the details of connections, reinforcement bar placement, construction joints, etc. was justified in making the judgments on screening.

The screening sampling size for identical or very similar equipment, in a given equipment class, was one or greater and for similar equipment in a given class with identical or very similar anchorage was two or greater. The increased sample for anchorage is based on experience that anchorage installations are not always consistent. This approach is consistent with the guidance provided in Appendix D of EPRI NP-6041-SL. The screening was verified in the subsequent walkdowns.

B.2.4 Seismic Capability Walkdowns

Component selection walkdowns and the seismic capability walkdowns were performed following the recommendations of EPRI NP-6041-SL. As part of the walkdown preparation activities, the equipment and components of the systems in the preferred and alternate shutdown paths were identified by the system engineer. A system and element selection walkdown was then conducted by a seismic engineer and the system engineer to review a majority of components for any obvious seismic problems and to locate and arrange access for equipment for the subsequent seismic walkdown.

The seismic capability walkdowns were performed by the SRT. These walkdowns reviewed the equipment for seismic adequacy (both structural integrity and anchorage) and system interaction (SI). The SRT review consisted of detailed walkdown of representative equipment, and walk-by of similar equipment.

The seismic capability analyses of components and structures, including walkdown notes are documented in PNPP Screening Evaluation Work Sheets (SEWS). The SEWS are similar to those developed by SQUG.

The walkdown verified the caveats for pre-screening based on the judgment of the SRT, and issues which influence the screening such as redundancy provided by multi-train systems, similarity in design and location of redundant trains, treatment of single failures, access to components during walkdowns, and system interactions potential. The walkdown confirmed the similarities of most items in a given equipment class, and the vast majority of equipment was manufactured, and installed as specified.

The walkdowns and inspections of distribution systems that were installed in bulk, such as piping, cable trays, HVAC ductwork, electrical conduit, and instrumentation lines were performed on an area basis. Additionally, detailed walk downs of a portion of each of the types of distribution systems were performed. These walkdowns and the subsequent reviews of design data verified that all the inclusion rules were met.

B.3 GMRS and IHS Comparison

The IPEEE for PNPP is not used for plant screening evaluation. However, comparison of the IPEEE HCLPF spectrum (IHS) and the ground motion response spectra (GMRS) at the Reactor Building (RB) foundation level shows that the IHS substantially envelops the GMRS in the entire range of frequencies of interest.

APPENDIX C
REACTOR BUILDING MEAN AND FRACTILE HAZARD CURVES
PNPP SITE

APPENDIX C - REACTOR BUILDING MEAN AND FRACTILE HAZARD CURVES

TABLE C-1
100 Hz SPECTRAL ACCELERATION MEAN AND FRACTILE SEISMIC HAZARD AT PERRY RB FOUNDATION LEVEL

SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	3.40E-03	1.65E-03	2.06E-03	3.08E-03	4.62E-03	6.58E-03
0.02	1.33E-03	5.06E-04	6.78E-04	1.14E-03	1.90E-03	3.17E-03
0.03	7.68E-04	2.37E-04	3.36E-04	6.20E-04	1.17E-03	2.03E-03
0.04	5.23E-04	1.37E-04	2.03E-04	4.14E-04	8.17E-04	1.45E-03
0.05	3.86E-04	8.86E-05	1.36E-04	3.02E-04	6.22E-04	1.08E-03
0.06	2.98E-04	6.18E-05	9.66E-05	2.31E-04	4.94E-04	8.32E-04
0.07	2.38E-04	4.63E-05	7.28E-05	1.83E-04	4.03E-04	6.63E-04
0.08	1.95E-04	3.63E-05	5.75E-05	1.48E-04	3.35E-04	5.44E-04
0.09	1.63E-04	2.93E-05	4.68E-05	1.22E-04	2.83E-04	4.57E-04
0.10	1.38E-04	2.42E-05	3.89E-05	1.02E-04	2.43E-04	3.91E-04
0.20	4.29E-05	6.07E-06	1.05E-05	2.95E-05	7.87E-05	1.27E-04
0.25	2.78E-05	3.61E-06	6.40E-06	1.87E-05	5.15E-05	8.28E-05
0.30	1.90E-05	2.28E-06	4.13E-06	1.25E-05	3.56E-05	5.72E-05
0.40	9.94E-06	1.02E-06	1.95E-06	6.23E-06	1.89E-05	3.07E-05
0.50	5.74E-06	5.05E-07	1.01E-06	3.45E-06	1.10E-05	1.82E-05
0.60	3.55E-06	2.67E-07	5.57E-07	2.04E-06	6.78E-06	1.15E-05
0.70	2.31E-06	1.50E-07	3.25E-07	1.28E-06	4.42E-06	7.64E-06
0.80	1.58E-06	8.89E-08	2.00E-07	8.38E-07	3.02E-06	5.34E-06
0.90	1.13E-06	5.54E-08	1.30E-07	5.75E-07	2.15E-06	3.89E-06
1.00	8.34E-07	3.61E-08	8.74E-08	4.09E-07	1.59E-06	2.93E-06
2.00	1.02E-07	1.70E-09	5.18E-09	3.59E-08	1.83E-07	4.13E-07
3.00	2.58E-08	2.03E-10	7.15E-10	6.74E-09	4.33E-08	1.15E-07
5.00	3.52E-09	1.11E-11	4.65E-11	6.47E-10	5.48E-09	1.75E-08

TABLE C-2
25 Hz SPECTRAL ACCELERATION MEAN AND FRACTILE SEISMIC HAZARD AT PERRY RB FOUNDATION LEVEL

SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	5.56E-03	2.91E-03	3.63E-03	5.14E-03	7.52E-03	9.69E-03
0.02	2.53E-03	1.21E-03	1.54E-03	2.29E-03	3.46E-03	4.92E-03
0.03	1.53E-03	6.67E-04	8.72E-04	1.37E-03	2.13E-03	3.16E-03
0.04	1.06E-03	4.25E-04	5.66E-04	9.33E-04	1.51E-03	2.28E-03
0.05	7.94E-04	2.93E-04	4.00E-04	6.90E-04	1.17E-03	1.77E-03
0.06	6.27E-04	2.14E-04	3.00E-04	5.41E-04	9.42E-04	1.43E-03
0.07	5.14E-04	1.64E-04	2.34E-04	4.41E-04	7.85E-04	1.19E-03
0.08	4.34E-04	1.30E-04	1.88E-04	3.70E-04	6.72E-04	1.02E-03
0.09	3.73E-04	1.07E-04	1.56E-04	3.17E-04	5.87E-04	8.80E-04
0.10	3.27E-04	8.91E-05	1.32E-04	2.76E-04	5.21E-04	7.74E-04
0.20	1.34E-04	2.86E-05	4.49E-05	1.09E-04	2.31E-04	3.26E-04
0.25	9.82E-05	1.99E-05	3.18E-05	7.91E-05	1.73E-04	2.43E-04
0.30	7.52E-05	1.47E-05	2.38E-05	5.97E-05	1.35E-04	1.89E-04
0.40	4.81E-05	8.84E-06	1.46E-05	3.72E-05	8.74E-05	1.24E-04
0.50	3.30E-05	5.73E-06	9.61E-06	2.51E-05	6.04E-05	8.62E-05
0.60	2.36E-05	3.90E-06	6.63E-06	1.77E-05	4.36E-05	6.27E-05
0.70	1.75E-05	2.76E-06	4.75E-06	1.30E-05	3.25E-05	4.71E-05
0.80	1.34E-05	2.01E-06	3.50E-06	9.76E-06	2.48E-05	3.63E-05
0.90	1.04E-05	1.50E-06	2.64E-06	7.51E-06	1.94E-05	2.87E-05
1.00	8.27E-06	1.14E-06	2.04E-06	5.89E-06	1.54E-05	2.31E-05
2.00	1.56E-06	1.54E-07	2.98E-07	9.93E-07	2.94E-06	4.76E-06
3.00	5.34E-07	4.03E-08	8.32E-08	3.15E-07	1.02E-06	1.75E-06
5.00	1.21E-07	6.35E-09	1.44E-08	6.44E-08	2.31E-07	4.29E-07

TABLE C-3
10 Hz SPECTRAL ACCELERATION MEAN AND FRACTILE SEISMIC HAZARD AT PERRY RB FOUNDATION LEVEL

SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	6.98E-03	3.93E-03	4.79E-03	6.66E-03	9.21E-03	1.10E-02
0.02	3.17E-03	1.64E-03	2.04E-03	2.97E-03	4.32E-03	5.47E-03
0.03	1.94E-03	9.25E-04	1.19E-03	1.80E-03	2.68E-03	3.50E-03
0.04	1.35E-03	6.02E-04	7.88E-04	1.24E-03	1.90E-03	2.52E-03
0.05	1.01E-03	4.24E-04	5.65E-04	9.20E-04	1.45E-03	1.96E-03
0.06	8.00E-04	3.15E-04	4.29E-04	7.20E-04	1.17E-03	1.61E-03
0.07	6.55E-04	2.42E-04	3.37E-04	5.87E-04	9.69E-04	1.35E-03
0.08	5.51E-04	1.92E-04	2.73E-04	4.91E-04	8.25E-04	1.16E-03
0.09	4.73E-04	1.56E-04	2.25E-04	4.20E-04	7.18E-04	1.01E-03
0.10	4.12E-04	1.30E-04	1.89E-04	3.64E-04	6.35E-04	8.84E-04
0.20	1.63E-04	3.77E-05	5.79E-05	1.37E-04	2.76E-04	3.84E-04
0.25	1.19E-04	2.54E-05	3.98E-05	9.66E-05	2.06E-04	2.90E-04
0.30	9.13E-05	1.84E-05	2.93E-05	7.21E-05	1.61E-04	2.29E-04
0.40	5.84E-05	1.08E-05	1.76E-05	4.51E-05	1.06E-04	1.53E-04
0.50	4.03E-05	6.87E-06	1.16E-05	3.06E-05	7.32E-05	1.08E-04
0.60	2.92E-05	4.70E-06	8.00E-06	2.19E-05	5.32E-05	7.88E-05
0.70	2.19E-05	3.36E-06	5.76E-06	1.62E-05	4.02E-05	5.96E-05
0.80	1.68E-05	2.46E-06	4.27E-06	1.22E-05	3.12E-05	4.62E-05
0.90	1.31E-05	1.83E-06	3.23E-06	9.36E-06	2.46E-05	3.66E-05
1.00	1.04E-05	1.38E-06	2.48E-06	7.28E-06	1.96E-05	2.93E-05
2.00	1.90E-06	1.74E-07	3.39E-07	1.18E-06	3.62E-06	5.92E-06
3.00	6.22E-07	4.09E-08	8.82E-08	3.49E-07	1.18E-06	2.10E-06
5.00	1.37E-07	5.32E-09	1.36E-08	6.55E-08	2.56E-07	5.12E-07

TABLE C-4
5 Hz SPECTRAL ACCELERATION MEAN AND FRACTILE SEISMIC HAZARD AT PERRY RB FOUNDATION LEVEL

SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	7.11E-03	4.03E-03	4.90E-03	6.88E-03	9.36E-03	1.09E-02
0.02	2.77E-03	1.42E-03	1.80E-03	2.64E-03	3.77E-03	4.61E-03
0.03	1.56E-03	7.34E-04	9.54E-04	1.48E-03	2.19E-03	2.71E-03
0.04	1.03E-03	4.47E-04	5.97E-04	9.66E-04	1.48E-03	1.86E-03
0.05	7.43E-04	3.01E-04	4.12E-04	6.89E-04	1.08E-03	1.39E-03
0.06	5.70E-04	2.14E-04	3.01E-04	5.26E-04	8.43E-04	1.10E-03
0.07	4.56E-04	1.60E-04	2.30E-04	4.18E-04	6.88E-04	8.96E-04
0.08	3.76E-04	1.23E-04	1.81E-04	3.42E-04	5.78E-04	7.56E-04
0.09	3.17E-04	9.64E-05	1.47E-04	2.86E-04	4.94E-04	6.53E-04
0.10	2.72E-04	7.78E-05	1.21E-04	2.44E-04	4.30E-04	5.74E-04
0.20	9.62E-05	2.08E-05	3.24E-05	7.88E-05	1.66E-04	2.35E-04
0.25	6.78E-05	1.35E-05	2.14E-05	5.40E-05	1.21E-04	1.72E-04
0.30	5.01E-05	9.29E-06	1.53E-05	3.92E-05	9.06E-05	1.30E-04
0.40	3.02E-05	4.88E-06	8.51E-06	2.30E-05	5.51E-05	8.01E-05
0.50	1.99E-05	2.93E-06	5.16E-06	1.47E-05	3.69E-05	5.37E-05
0.60	1.38E-05	1.88E-06	3.36E-06	9.81E-06	2.61E-05	3.85E-05
0.70	9.99E-06	1.25E-06	2.29E-06	6.84E-06	1.92E-05	2.87E-05
0.80	7.47E-06	8.59E-07	1.62E-06	5.00E-06	1.44E-05	2.20E-05
0.90	5.73E-06	6.13E-07	1.17E-06	3.77E-06	1.11E-05	1.72E-05
1.00	4.48E-06	4.46E-07	8.66E-07	2.90E-06	8.65E-06	1.37E-05
2.00	7.12E-07	3.63E-08	8.55E-08	3.85E-07	1.42E-06	2.50E-06
3.00	2.20E-07	6.65E-09	1.84E-08	1.00E-07	4.31E-07	8.24E-07
5.00	4.17E-08	5.43E-10	1.82E-09	1.42E-08	7.71E-08	1.76E-07

TABLE C-5
2.5 Hz SPECTRAL ACCELERATION MEAN AND FRACTILE SEISMIC HAZARD AT PERRY RB FOUNDATION LEVEL

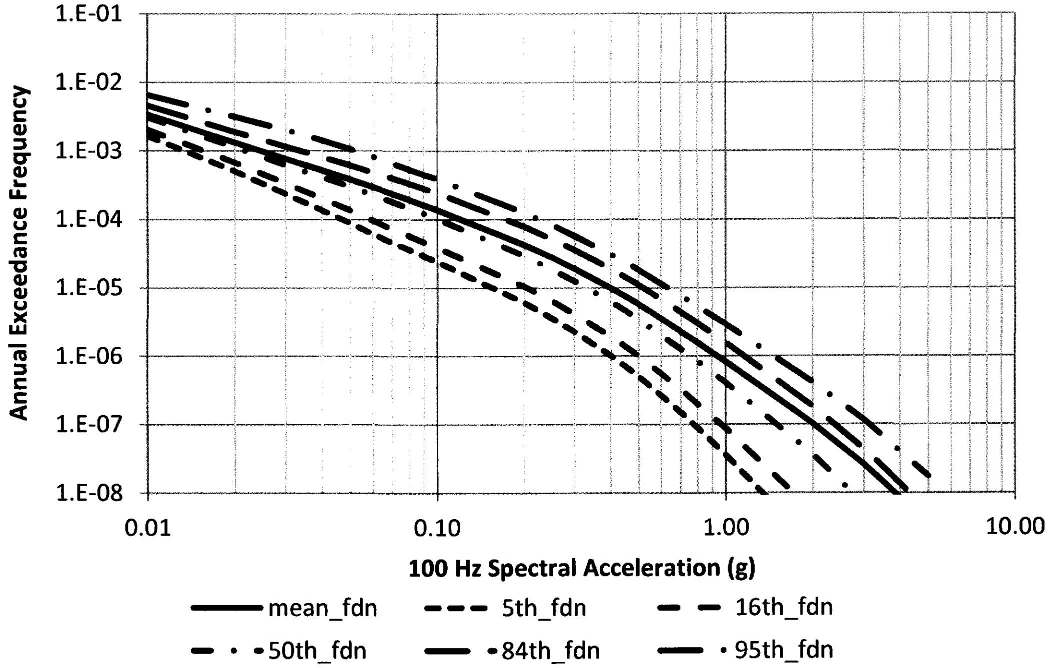
SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	5.42E-03	3.08E-03	3.73E-03	5.24E-03	7.17E-03	8.40E-03
0.02	1.71E-03	8.15E-04	1.05E-03	1.62E-03	2.41E-03	2.96E-03
0.03	8.43E-04	3.55E-04	4.77E-04	7.82E-04	1.22E-03	1.55E-03
0.04	5.01E-04	1.88E-04	2.64E-04	4.60E-04	7.47E-04	9.60E-04
0.05	3.36E-04	1.12E-04	1.64E-04	3.05E-04	5.16E-04	6.68E-04
0.06	2.44E-04	7.22E-05	1.09E-04	2.17E-04	3.85E-04	5.03E-04
0.07	1.86E-04	5.01E-05	7.75E-05	1.63E-04	3.02E-04	3.99E-04
0.08	1.48E-04	3.67E-05	5.77E-05	1.27E-04	2.46E-04	3.28E-04
0.09	1.21E-04	2.79E-05	4.46E-05	1.01E-04	2.04E-04	2.77E-04
0.10	1.01E-04	2.19E-05	3.55E-05	8.27E-05	1.73E-04	2.38E-04
0.20	2.98E-05	4.17E-06	7.58E-06	2.18E-05	5.43E-05	8.17E-05
0.25	1.98E-05	2.42E-06	4.55E-06	1.40E-05	3.68E-05	5.70E-05
0.30	1.40E-05	1.53E-06	2.94E-06	9.53E-06	2.65E-05	4.18E-05
0.40	7.89E-06	6.88E-07	1.43E-06	4.97E-06	1.52E-05	2.49E-05
0.50	4.96E-06	3.50E-07	7.86E-07	2.99E-06	9.60E-06	1.64E-05
0.60	3.34E-06	1.98E-07	4.61E-07	1.94E-06	6.46E-06	1.14E-05
0.70	2.36E-06	1.18E-07	2.89E-07	1.32E-06	4.59E-06	8.26E-06
0.80	1.74E-06	7.32E-08	1.90E-07	9.25E-07	3.40E-06	6.20E-06
0.90	1.31E-06	4.71E-08	1.29E-07	6.68E-07	2.59E-06	4.79E-06
1.00	1.01E-06	3.14E-08	8.95E-08	4.95E-07	2.01E-06	3.78E-06
2.00	1.57E-07	1.44E-09	5.62E-09	5.22E-08	3.11E-07	6.66E-07
3.00	4.66E-08	1.83E-10	8.69E-10	1.15E-08	8.70E-08	2.09E-07
5.00	8.25E-09	9.06E-12	5.49E-11	1.20E-09	1.32E-08	3.85E-08

TABLE C-6
1 Hz SPECTRAL ACCELERATION MEAN AND FRACTILE SEISMIC HAZARD AT PERRY RB FOUNDATION LEVEL

SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	4.84E-03	2.32E-03	2.96E-03	4.78E-03	6.86E-03	7.87E-03
0.02	1.33E-03	4.74E-04	6.49E-04	1.18E-03	2.05E-03	2.66E-03
0.03	6.19E-04	1.85E-04	2.65E-04	5.15E-04	1.00E-03	1.40E-03
0.04	3.34E-04	8.86E-05	1.31E-04	2.68E-04	5.53E-04	8.01E-04
0.05	1.99E-04	4.80E-05	7.27E-05	1.57E-04	3.35E-04	4.98E-04
0.06	1.29E-04	2.85E-05	4.43E-05	9.90E-05	2.20E-04	3.31E-04
0.07	8.83E-05	1.80E-05	2.88E-05	6.69E-05	1.54E-04	2.33E-04
0.08	6.37E-05	1.19E-05	1.96E-05	4.76E-05	1.12E-04	1.72E-04
0.09	4.79E-05	8.25E-06	1.38E-05	3.52E-05	8.52E-05	1.32E-04
0.10	3.73E-05	5.90E-06	1.01E-05	2.69E-05	6.66E-05	1.05E-04
0.20	7.93E-06	5.62E-07	1.20E-06	4.55E-06	1.48E-05	2.72E-05
0.25	4.95E-06	2.49E-07	5.87E-07	2.60E-06	9.34E-06	1.82E-05
0.30	3.38E-06	1.28E-07	3.28E-07	1.65E-06	6.42E-06	1.30E-05
0.40	1.85E-06	4.25E-08	1.27E-07	7.80E-07	3.53E-06	7.43E-06
0.50	1.15E-06	1.71E-08	5.82E-08	4.32E-07	2.20E-06	4.79E-06
0.60	7.74E-07	7.83E-09	3.02E-08	2.65E-07	1.47E-06	3.34E-06
0.70	5.50E-07	3.96E-09	1.70E-08	1.73E-07	1.03E-06	2.44E-06
0.80	4.07E-07	2.17E-09	1.02E-08	1.17E-07	7.48E-07	1.84E-06
0.90	3.10E-07	1.25E-09	6.37E-09	8.17E-08	5.62E-07	1.43E-06
1.00	2.42E-07	7.56E-10	4.16E-09	5.84E-08	4.32E-07	1.12E-06
2.00	3.94E-08	1.64E-11	1.59E-10	4.54E-09	5.84E-08	1.84E-07
3.00	1.22E-08	1.23E-12	1.77E-11	7.99E-10	1.54E-08	5.54E-08
5.00	2.37E-09	0.00E+00	7.81E-13	6.65E-11	2.29E-09	9.76E-09

TABLE C-7
0.5 Hz SPECTRAL ACCELERATION MEAN AND FRACTILE SEISMIC HAZARD AT PERRY RB FOUNDATION LEVEL

SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	1.78E-03	5.28E-04	7.54E-04	1.57E-03	3.00E-03	3.76E-03
0.02	4.44E-04	8.69E-05	1.34E-04	3.26E-04	7.88E-04	1.18E-03
0.03	1.86E-04	2.88E-05	4.66E-05	1.24E-04	3.37E-04	5.50E-04
0.04	9.18E-05	1.22E-05	2.05E-05	5.75E-05	1.67E-04	2.85E-04
0.05	5.11E-05	6.01E-06	1.05E-05	3.07E-05	9.38E-05	1.64E-04
0.06	3.11E-05	3.28E-06	5.89E-06	1.80E-05	5.79E-05	1.02E-04
0.07	2.03E-05	1.93E-06	3.57E-06	1.14E-05	3.84E-05	6.86E-05
0.08	1.40E-05	1.20E-06	2.29E-06	7.63E-06	2.68E-05	4.88E-05
0.09	1.01E-05	7.81E-07	1.54E-06	5.34E-06	1.95E-05	3.63E-05
0.10	7.57E-06	5.28E-07	1.07E-06	3.88E-06	1.47E-05	2.80E-05
0.20	1.36E-06	2.99E-08	7.82E-08	4.61E-07	2.41E-06	6.05E-06
0.25	8.16E-07	1.09E-08	3.19E-08	2.29E-07	1.38E-06	3.84E-06
0.30	5.44E-07	4.70E-09	1.50E-08	1.28E-07	8.82E-07	2.66E-06
0.40	2.91E-07	1.15E-09	4.22E-09	4.96E-08	4.34E-07	1.48E-06
0.50	1.78E-07	3.51E-10	1.46E-09	2.32E-08	2.48E-07	9.11E-07
0.60	1.19E-07	1.25E-10	5.85E-10	1.22E-08	1.53E-07	6.04E-07
0.70	8.34E-08	4.94E-11	2.63E-10	6.99E-09	9.99E-08	4.22E-07
0.80	6.11E-08	2.11E-11	1.29E-10	4.24E-09	6.78E-08	3.07E-07
0.90	4.62E-08	9.61E-12	6.72E-11	2.70E-09	4.77E-08	2.29E-07
1.00	3.58E-08	4.58E-12	3.71E-11	1.79E-09	3.45E-08	1.75E-07
2.00	5.74E-09	0.00E+00	5.08E-13	8.34E-11	3.01E-09	2.17E-08
3.00	1.79E-09	0.00E+00	3.03E-14	1.11E-11	6.12E-10	5.54E-09
5.00	3.47E-10	0.00E+00	0.00E+00	6.43E-13	6.59E-11	7.87E-10



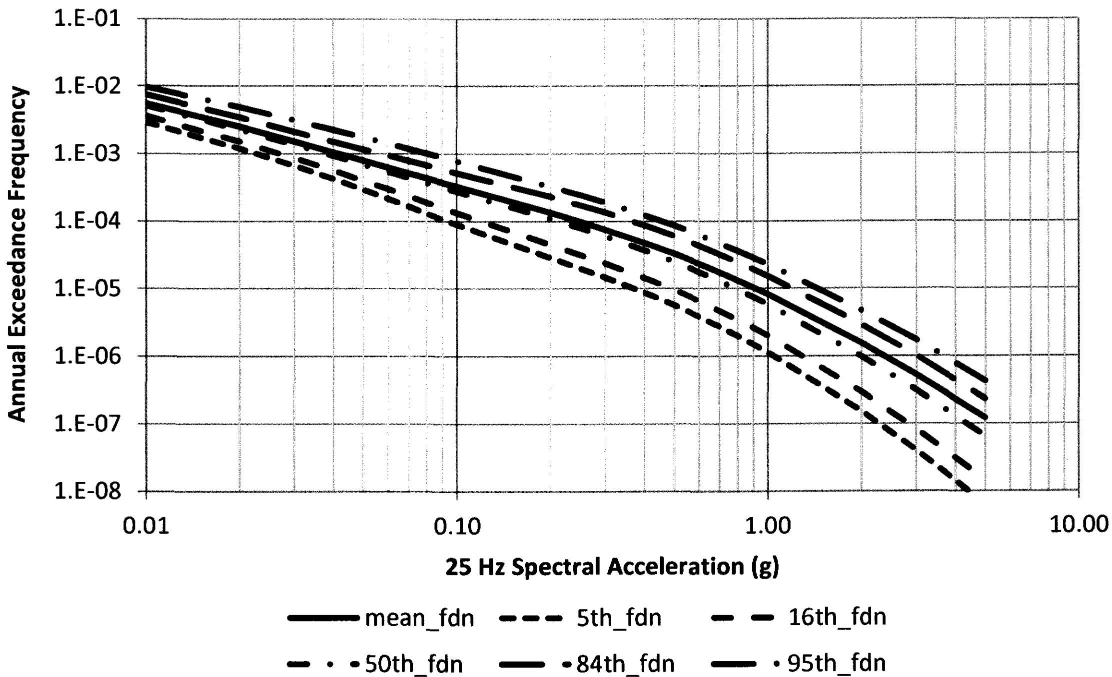
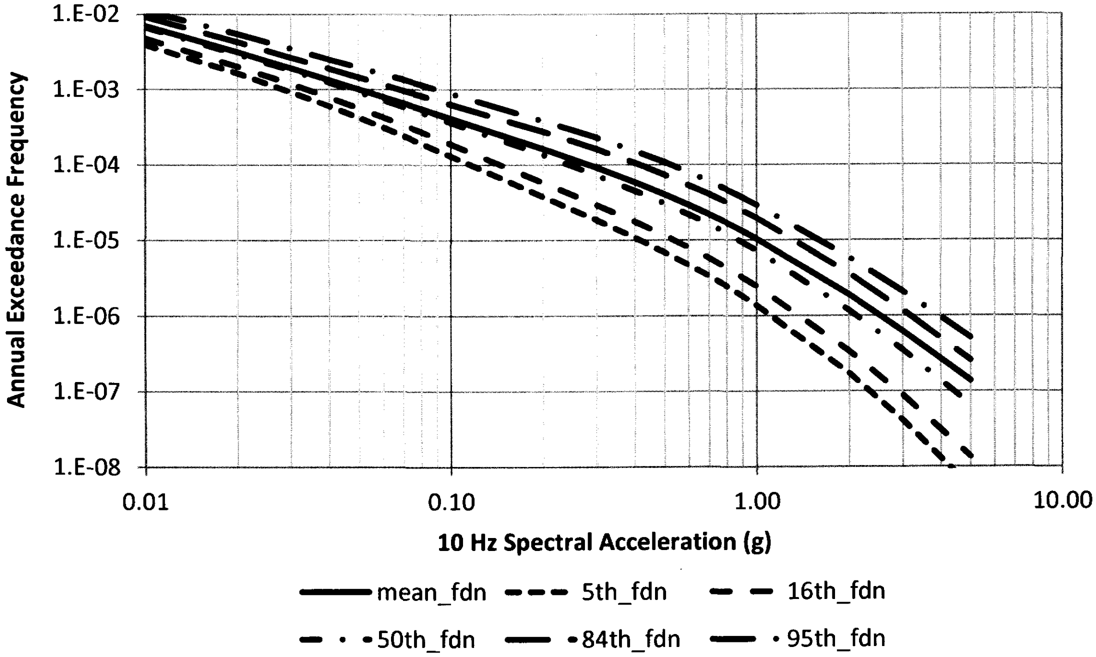


FIGURE C-1
PNPP MEAN AND FRACTILE HAZARD CURVES AT RB FOUNDATION LEVEL (SA AT 100 HZ AND 25 HZ)



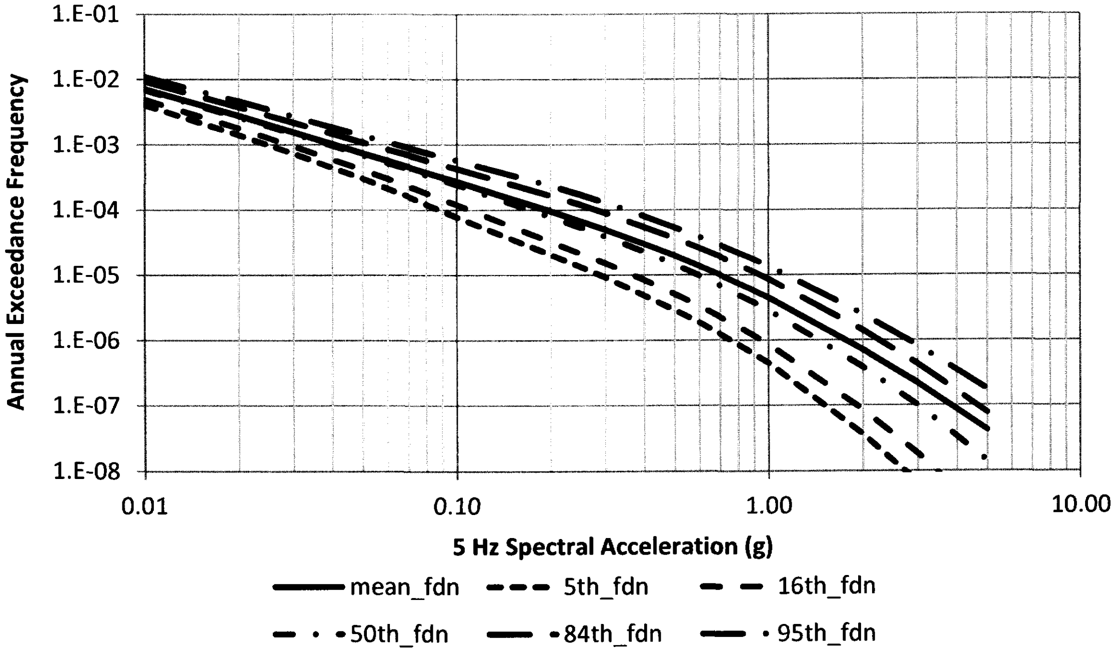
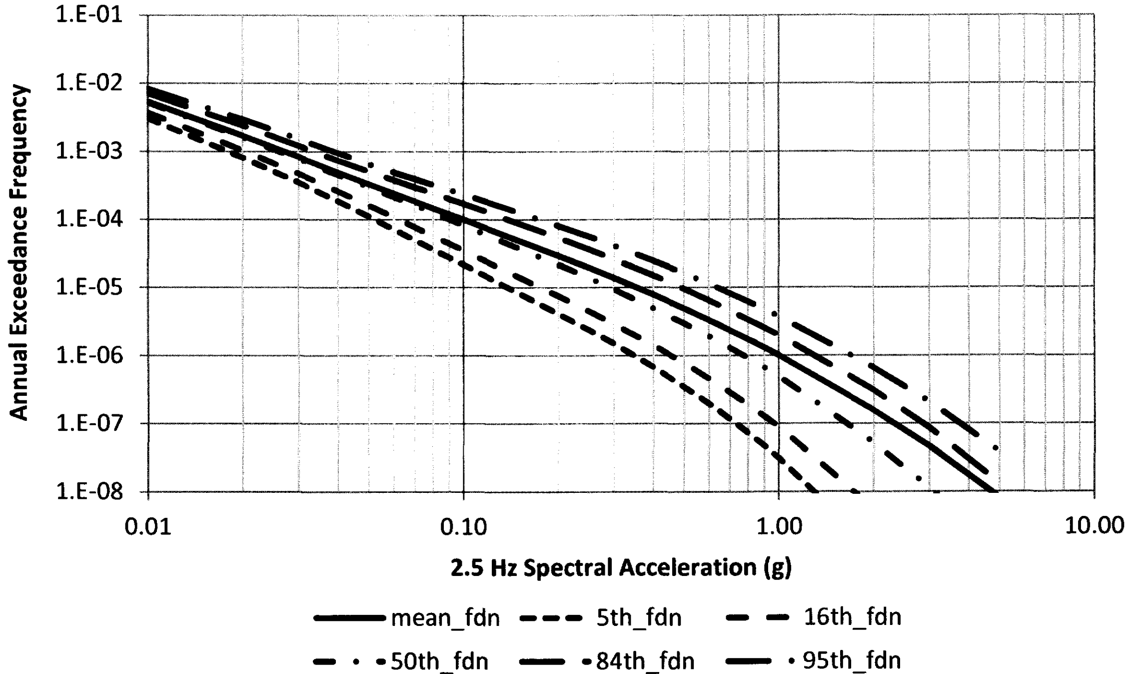


FIGURE C-2
PNPP MEAN AND FRACTILE HAZARD CURVES AT RB FOUNDATION LEVEL (SA AT 10 HZ AND 5.0 HZ)



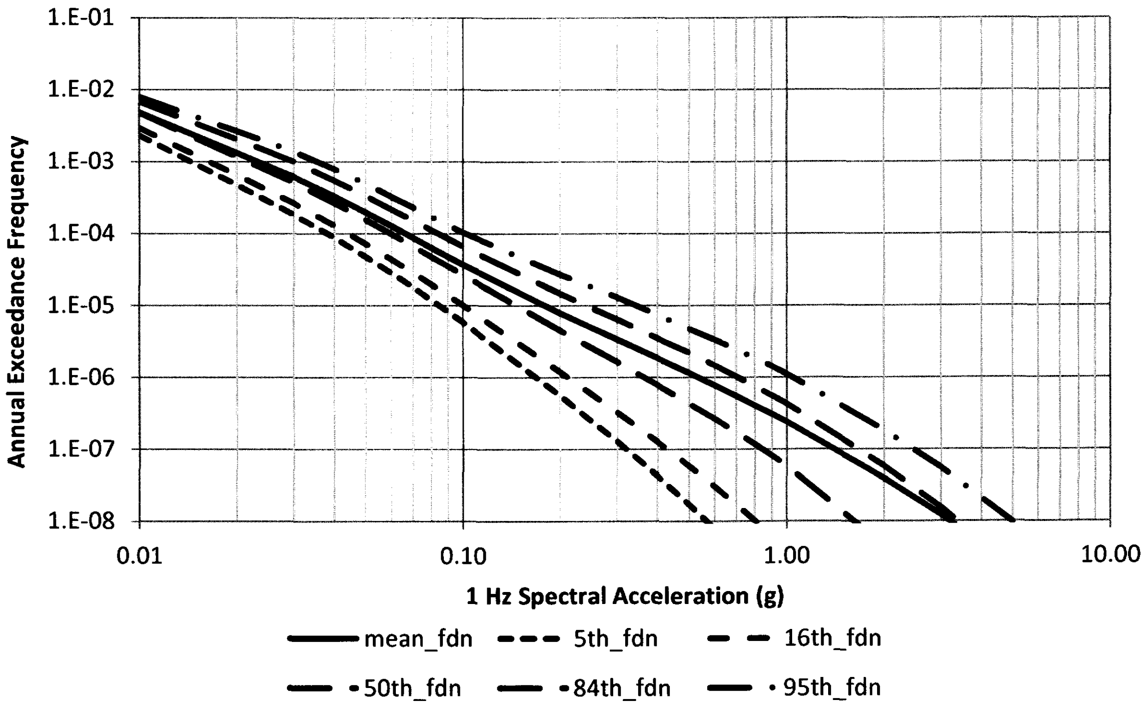


FIGURE C-3
PNPP MEAN AND FRACTILE HAZARD CURVES AT RB FOUNDATION LEVEL
(SA AT 2.5 HZ AND 1.0 HZ)

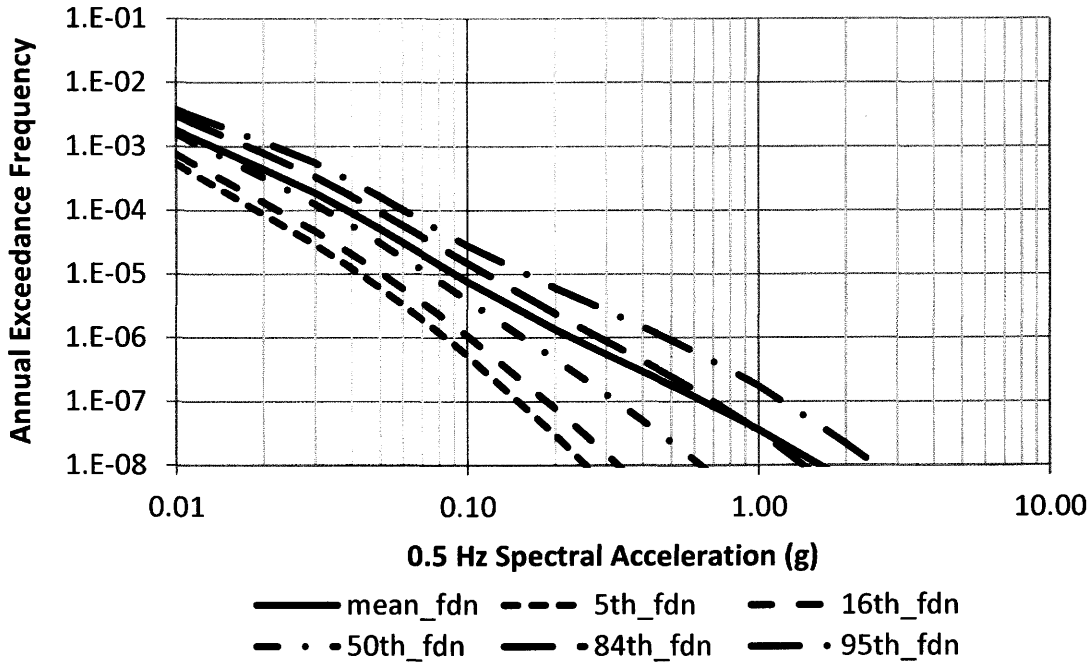


FIGURE C-4
PNPP MEAN AND FRACTILE HAZARD CURVES AT RB FOUNDATION LEVEL (SA AT 0.5 HZ)