NLS2014027

ENCLOSURE

Seismic Hazard Evaluation and Screening Report for Cooper Nuclear Station

ATTACHMENT 9.1 **ENGINEERING REPORT COVER SHEET & INSTRUCTIONS**

SHEET 1 OF 2

Engineering Report No. 14-003 Rev 0
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Engineering Report Cover Sheet

Engineering Report Title:
50.54(f) Section 2.1 Seismic –
Black & Veatch *Seismic Hazard and Screening Report Cooper Nuclear Station* Acceptance

Engineering Report Type:

New ☒ Revision ☐ Cancelled ☐ Superseded ☐
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Prepared by: Black & Veatch Date: ______
Responsible Engineer (Print Name/Sign)

Design Verified: N/A Date: ______
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Reviewed by: Mitchell Marotz / Michael Pettini [signatures] Date: 3/20/2014
Reviewer (Print Name/Sign)

Approved by: Marshall Van Winkle [signature] Date: 3-20-14
Supervisor / Manager (Print Name/Sign)

1. Scope and Objective

In responding to the Fukushima Near-Term Task Force Recommendation 2.1 Seismic; Cooper Nuclear Station (CNS) contracted Black & Veatch Corporation as a subject matter expert to develop the Seismic Hazard and Screening Report in accordance with EPRI Report *Screening, Prioritization and Implementation Details* (SPID) [Reference 2].

The information within this report is intended for use in responding to the Fukushima Near-Term Task Force Recommendation 2.1: Seismic.

This Engineering Report accepts the Seismic Hazard and Screening Report which was developed by Black & Veatch for CNS.

2. Design Inputs

The design inputs are as listed:

1. CNS Letter NLS2013085, "*Nebraska Public Power District's Response to Nuclear Regulatory Commission Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Seismic Aspects of Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident- 1.5 Year Response for CEUS Sites Cooper Nuclear Station*", NRC Docket No. 50-298, License No. DPR-46.

3. Assumptions

No assumptions were made by CNS in the development of this Engineering Report.

4. Detailed Discussion

Following the accident at the Fukushima Daiichi nuclear power plant resulting from the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami, the Nuclear Regulatory Commission (NRC) established a Near Term Task Force (NTTF) to conduct a systematic review of NRC processes and regulations and to determine if the agency should make additional improvements to its regulatory system. The NTTF developed a set of recommendations intended to clarify and strengthen the regulatory framework for protection against natural phenomena. NTTF Recommendation 2.1 for seismic hazards, as amended by the SRMs associated with SECY-11-0124 and SECY-11-0137, instructed the NRC staff to issue requests for information to licensees pursuant to Sections 161.c, 103.b, and 182.a of the Atomic Energy Act of 1954, as amended, and 10 CFR 50.54(f). This information request was for licensees under 10 CFR 50 to reevaluate the seismic hazards at their sites against present-day NRC requirements and guidance. Based upon this information, the NRC staff will determine whether additional regulatory actions are necessary (e.g., update the design basis and SSCs important to safety) to protect against the updated hazards. In developing Recommendation 2.1, the NTTF recognized that the state of knowledge of seismic hazard within the United States (U.S.) has evolved and the level of conservatism in the determination of the original seismic design bases should be reexamined.

The Electric Power Research Institute (EPRI) took the responsibility of developing new Ground Motion Response Spectra (GMRS) for each site in the industry. The new GMRS that was generated utilizes newly developed methodology.

EPRI, in conjunction with the Nuclear Energy Institute (NEI), developed the Seismic Evaluation Guidance (SPID) [Reference 2] for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic and the Template for the Seismic Hazard and Screening Reports for Central and Eastern United States (CEUS) Plants (Attachment 2).

The final Black & Veatch *Seismic Hazard and Screening* Report, as it is accepted at CNS, is included as Attachment A to this Report. All comments have been resolved and no further changes are necessary.

5. Summary of Results

The results presented by Black and Veatch in *CNS Seismic Hazard and Screening Report* can be found in Attachment A. Discussion of the methodology used in the development of the Seismic Hazard and Screening Report is specifically addressed within EPRI Report 1025287 and will not be discussed in this report.

Review of Seismic Hazard and Screening Report resulted in comments that were resolved accordingly. No further review is necessary.

6. Conclusions and Recommendations

1. The final Black & Veatch Seismic Hazard and Screening Report Cooper Nuclear Station Report (Attachment A) is acceptable for adoption at CNS.

7. References

1. CNS Engineering Report 14-002, "LCI GMRS Report Acceptance"
2. EPRI Report 1025287 "Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic" Dated February 2013

8. Attachments

A. Black & Veatch "Seismic Hazard and Screening Report Cooper Nuclear Station – Final" March 19, 2014

B. EPRI Final Template for "Seismic Hazard and Screening Report (Example Submittal for CEUS Site)" February 25, 2014

ENGINEERING REPORT ER 2014-003

Attachment A

Black & Veatch

"Seismic Hazard and Screening Report Cooper Nuclear Station – Final"
March 19, 2014

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REVIEW AND APPROVAL RECORD

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Project Cooper Nuclear Station File No. 180333.19.9260

Subject Seismic Hazard and Screening Report Date March 19, 2014

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Reason for Revision (include a complete summary and reference applicable engineering records such as an Engineering Change Notice): Corrected reference numbers to tables and figures.

APPROVAL

Title	Print/Sign	Date
Preparer:	Stephen E. Sawtelle [signature]	3/19/2014
Approver:	A. D. BOCKELMAN [signature]	3/19/2014

Nebraska Public Power District

Cooper Nuclear Station

Contract No. TA4700001660

Seismic Hazard and Screening Report

CLIENT APP.: NA

BLACK & VEATCH

Overland Park, KS

NO.	DATE	DESCRIPTION	DWN	DGN	CHK	APP
1	03/19/2014	Minor Revisions (RAR-0002)	SES	SES	DVR-0003	ADB
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THIS DOCUMENT CONTAINS SEISMIC CATEGORY I ITEMS ☐ YES ☒ NO

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Seismic Hazard and Screening Report
Cooper Nuclear Station

Final
March 31, 2014

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Acronym List

CEUS SSC	Central and Eastern United States Seismic Source Characterization
CNS	Cooper Nuclear Station
CFR	Code of Federal Regulations
EPRI	Electric Power Research Institute
GMM	Ground Motion Model
GMRS	Ground Motion Response Spectra
IPEEE	Individual Plant Examination of External Events
MM	Modified Mercalli
MSL	Mean Sea Level
NRC	Nuclear Regulatory Commission
NTTF	Near Term Task Force
PGA	Peak Ground Acceleration
PSHA	Probabilistic Seismic Hazard Analysis
RG	Regulatory Guide
RLE	Review Level Earthquake
RLME	Repeated Large Magnitude Earthquake
RVT	Random Vibration Theory
SMA	Seismic Margin Assessment
SPID	Screening, Prioritization, and Implementation Details
SPRA	Seismic Probabilistic Risk Assessment
SSC	Structures, Systems, and Components
SSE	Safe Shutdown Earthquake
SSI	Soil-Structure Interaction
UHRS	Uniform Hazard Response Spectra
USAR	Updated Safety Analysis Report

1.0 Introduction

Following the accident at the Fukushima Daiichi nuclear power plant resulting from the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami, the Nuclear Regulatory Commission (NRC) established a Near Term Task Force (NTTF) to conduct a systematic review of NRC processes and regulations. The NTTF was also tasked with determining whether the NRC 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(1) that requests information to assure these recommendations are addressed by all U.S. nuclear plants. The 50.54(f) letter(1) requests that licensees and holders of construction permits under Title 10 Code of Federal Regulations (CFR) Part 50 reevaluate the seismic hazards at their sites against present-day NRC requirements and guidance. 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 that are acceptable to the staff include a seismic probabilistic risk assessment (SPRA), or a seismic margin assessment (SMA). Based upon the risk assessment results, the NRC staff will determine whether additional regulatory actions are necessary.

This report provides the information requested in items (1) through (7) of the "Requested Information" section and Attachment 1 of the 50.54(f) letter(1) pertaining to NTTF Recommendation 2.1 for the Cooper Nuclear Station (CNS), located in Nemaha County, Nebraska. In providing this information, CNS 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*(3). The Augmented Approach, Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic(17), has been developed as the process for evaluating critical plant equipment as an interim action to demonstrate additional plant safety margin, prior to performing the complete plant seismic risk evaluations.

The original geologic and seismic siting investigations for CNS were performed in accordance with Appendix A to 10 CFR Part 100 as it existed prior to the construction permits. To the extent discussed in the USAR, CNS meets the General Design Criterion 2 in Appendix A to 10 CFR Part 50 which was not part of the original licensing basis. The Safe Shutdown Earthquake Ground Motion (SSE) was subsequently evaluated against criteria in Appendix A to 10 CFR Part 100 and found to be acceptable. This SSE was used for the design of seismic Category I systems, structures and components.

In response to the 50.54(f) letter(1) and following the guidance provided in the (SPID)(3), a seismic hazard reevaluation was performed. For screening purposes a Ground Motion Response Spectrum (GMRS) was developed.

Based on the results of the screening evaluation, no further evaluations will be performed.

2.0 Seismic Hazard Reevaluation

Section II-5 of the CNS USAR[4] contains the following description of the site:

> "Cooper Nuclear Station (CNS) is located in Nemaha County, Southeastern Nebraska, on the west bank of the Missouri River. It is situated on the first bottomland of the broad, nearly level, flood plain which is approximately six miles wide at the site. The natural relief is about ten feet."

Section II-5 of the CNS USAR[4] contains the following description of seismicity:

> "The earthquakes most significant for the evaluation of the seismicity of the site are the New Madrid earthquakes of 1811 and 1812; the Lincoln, Nebraska, earthquake of 1877; the Tecumseh, Nebraska, earthquake of 1935; and the El Reno, Oklahoma, earthquake of 1952. On the basis of the historical earthquake records, it is concluded that:
>
> - There is a reasonable chance that during the life of the nuclear power station, earthquakes would affect the site with an intensity Modified Mercalli (MM) VII.
> - The hypothetical maximum possible intensity of ground motion at the site would result from a local earthquake smaller than the New Madrid earthquakes of 1811 and 1812.
>
> "Small slips appear to occur along the Humboldt Fault and many of the regional earthquakes had epicenters in the vicinity of the Nemaha Anticline and Humboldt Fault. However, important displacements of the Humboldt Fault have not occurred for 200 million years and it is improbable that future earthquakes with epicenters located in the vicinity of the Humboldt Fault will have epicentral intensities greater than MM VII.
>
> "There is no evidence at the site of either a fault or other bedrock discontinuity which would tend to increase the seismicity of the site as compared to nearby sites."

2.1 Regional and Local Geology

2.1.1 Regional Geology

Section II-5 of the CNS USAR[4] contains the following description of the regional geology:

> "The principal geologic strata in the region in order of increasing depth are soil deposits, sedimentary rocks, and deep basement igneous rocks. The soil deposits consist of loess and till in the uplands, and either stratified or heterogeneous alluvium in the flood plains. Thickness of deposits varies from a few feet to about 100 feet for loess, none to several feet for till, and less than 10 feet to more than 100 feet for alluvium. The rock strata are gently dipping sedimentary rocks mainly Paleozoic in age. Alternating beds of shale, limestone, sandstone, and occasional thin beds of coal are present. The total thickness varies from over 3,500 feet near the site to about 500 feet, 30 miles west. The deep basement igneous rocks are Precambrian in origin, chiefly primary granite or granitoid rocks.
>
> "The major geologic structures in the region are the Nemaha Anticline, Forest City Basin, Humboldt Fault, and Thurman-Wilson Fault. Except for the Forest City Basin, none of these structures is in the immediate vicinity of the site. The closest one, 20 miles to the west, is the Nemaha Anticline and its associated Humboldt Fault.

"The Nemaha Anticline is a major structural feature of the midcontinent which separates two depositional basins, the Forest City Basin on its east flank and the northern extension of the Salina Basin on the west. It is a sharp uplift of Precambrian granite. The anticline is believed to have first come into existence by folding and faulting at the close of the Proterozoic. Its development of near orogenic proportions occurred near the end of the Mississippian and continued through Pennsylvanian into early Permian. By early Permian, major tectonic movements appear to have ceased. The anticline trends southward from Omaha, through Nebraska, across Kansas, and into northern Oklahoma. The crest of the buried mountain range is irregular; its depth below ground surface varies from 400 feet at the Nebraska-Kansas line to 3,000 feet at the Kansas-Oklahoma line. The anticline has a very steep eastern front which is faulted in several areas. The most notable fault is the Humboldt Fault, principally a normal fault striking in a general north-south direction. Vertical displacement of 1,000 to 1,500 feet in Nebraska and in the vicinity of Nebraska City, Nebraska, are reported.

"The Forest City Basin underlies the site. Its basinal axis in Nebraska lies close to and roughly parallels the Nemaha Anticline on the east. Its west flank shares a common front with the steep eastern flank of the Nemaha Anticline.

"The Thurman-Wilson Fault is associated with the Redfield Anticline which strikes southwest from approximately Des Moines, Iowa, toward Lincoln, Nebraska. The fault is about 40 miles north of the site and is located south of the crest of the anticlinal axis. The fault has a southward displacement of about ten feet."

2.1.2 Local Geology

Section II-5 of the CNS USAR(4) contains the following description of the local geology:

"Locally, the stratigraphy is best represented by a section through the bluffs along the western boundary of the site. It shows Peorian loess, Kansas till, limestone and shale of the Permian system, and limestone, shale, sandstone, and occasional thin beds of coal of the Pennsylvanian system. The contact between the two systems is unconformable and occurs in the bluff at approximately elevation 930 feet mean sea level (MSL).

"Detailed classification of rock cores obtained in borings at the site show excellent correlation with published regional stratigraphic columns in both sequence and thickness.

"The geologic structures occurring within the rocks at the site are minor. Field observations suggest the possibility of minor plains-type folding resulting from differential compaction of underlying sediments. No faults have been found at the site or in the local area, nor are any known of or suspected.

"Locally, three principal types of soils are found, each of different geologic origin; loess and till in the bluffs and alluvial and glacial deposits in the flood plains.

"The loess are wind-blown silts. The topography of the loess reflects the surface configuration of the underlying till or rock. Its ability to maintain steep faces is responsible for the near vertical slopes in the upper portion of the bluffs.

"The Kansan till underlies the loess. It is a heterogeneous mixture of clay, silt, sand, gravel, cobble, and boulder, and is five to ten feet thick. In an unleached and unoxidized condition, it is commonly a dark gray silty clay which contains erratics and locally derived cobbles and boulders. Sand lenses are distributed throughout the deposit. Complete removal of calcareous minerals in the upper limits of the till produces the highly tenacious gumbotil.

"The alluvial deposits in the flood plain at the site vary in thickness from 62 to 71 feet. Two major subtypes of different geologic origin are present; the surficial fine-grained soils and the underlying sands.

"The surficial fine-grained soils are recent alluvial deposits derived from the meandering Missouri River. Evidences of the meander were analyzed by a stereoscopic study of aerial photographs. The surficial soils consist of meander-belt and back-swamp deposits, ranging in thickness from 10 to 25 feet. For the most part, these deposits are silty sand, sandy silt, silty clay, and clay, and may be encountered in localized pockets or in complex combinations.

"The underlying sands appear to be either fluvial or glacial outwash deposits or both. The amount of silt and clay size particles is generally small. They grade from fine to coarse with increasing depth. Lenses of clay, coarse sand, and fine gravel are distributed irregularly throughout the deposit."

2.2 Probabilistic Seismic Hazard Analysis

2.2.1 Probabilistic Seismic Hazard Analysis Results

In accordance with the 50.54(f) letter(1) and following the guidance in the SPID(3), a probabilistic seismic hazard analysis (PSHA) was completed using the recently developed Central and Eastern United States Seismic Source Characterization (CEUS SSC) for Nuclear Facilities(5) together with the updated Electric Power Research Institute (EPRI) Ground Motion Model (GMM) for the CEUS(6). For the PSHA, a lower-bound moment magnitude of 5.0 was used, as specified in the 50.54(f) letter(1).

For the PSHA, the CEUS SSC background seismic sources out to a distance of 400 miles (640 km) around CNS were included. This distance exceeds the 200 mile (320 km) recommendation contained in USNRC Reg Guide 1.208(7) and was chosen for completeness. Background sources included in this site analysis are the following:

1. Extended Continental Crust-Gulf Coast (ECC_GC)
2. Illinois Basin Extended Basement (IBEB)
3. Mesozoic and younger extended prior – narrow (MESE-N)
4. Mesozoic and younger extended prior – wide (MESE-W)
5. Midcontinent-Craton alternative A (MIDC_A)
6. Midcontinent-Craton alternative B (MIDC_B)
7. Midcontinent-Craton alternative C (MIDC_C)
8. Midcontinent-Craton alternative D (MIDC_D)
9. Non-Mesozoic and younger extended prior – narrow (NMESE-N)
10. Non-Mesozoic and younger extended prior – wide (NMESE-W)
11. Oklahoma Aulacogen (OKA)

12. Reelfoot Rift (RR)
13. Reelfoot Rift including the Rough Creek Graben (RR-RCG)
14. Study region (STUDY_R)

For sources of large magnitude earthquakes, designated repeated large magnitude earthquake (RLME) sources in CEUS SSC[5], the following sources lie within 1,000 km of the site and were included in the analysis:

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

For each of the above background and RLME sources, the mid-continent version of the updated CEUS EPRI GMM[6] was used.

2.2.2 Base Rock Seismic Hazard Curves

Consistent with the SPID[3] Subsection 2.5.3, base rock seismic hazard curves are not provided, because the site amplification approach referred to as Method 3 has been used. Seismic hazard curves are shown in Section 3.0 at the SSE control point elevation (869.5'), which is the base of the Control Building.

2.3 Site Response Evaluation

Following the guidance contained in Seismic Enclosure 1 of the March 12, 2012, 50.54(f) Request for Information[1] and in the SPID[3] for nuclear power plant sites that are not sited on hard rock (defined as shear wave velocity of 9,300 feet per second [ft/s] [2.83 km/sec]), a site response analysis was performed for CNS[15].

2.3.1 Description of Subsurface Material

The CNS is located in Nemaha County, Southeastern Nebraska on the west bank of the Missouri River. It is situated on the first bottomland of the broad, nearly level, flood plain which is about 6 miles (20 km) wide at the site. The basic information used to create the site geologic profile at CNS is shown in Table 2.3.1-1a (for shallow stratigraphy) and Table 2.3.1-1b (for deep stratigraphy). This profile was developed using information documented in utility communications and CNS Engineering Report ER 14-002[15]. As indicated in utility communications, the SSE Control Point is defined at elevation 869.5 feet, and the profile was modeled up to this elevation. The profile consists of about 49.5 feet (15m) of fill and compacted alluvium overlying about 3,450 feet (1,052m) of firm sedimentary rock. Precambrian basement rock is estimated to be at a depth of about 3,500 feet (1,067m).

Table 2.3.1-1b provides elevations for the four deepest bedrock stratigraphic units - Silurian, Ordovician, Cambrian, and Precambrian. The Precambrian basement rock in Table 2.3.1-1b is estimated to be approximately 700 feet higher than the elevation provided previously in a letter to the NRC[12]. This difference is due to variations in the interpretation of the regional geology near the site. However, a Precambrian basement rock depth of about 3,500 feet (1,067m) is consistent with the thickness of Paleozoic sedimentary rocks reported in USAR Section II-5.1[4] and by utility communications and CNS Engineering Report ER 2014-02[15]. There are no differences between Tables 2.3.1-1a or the three shear wave velocity profiles (Table 2.3.2-2 and Figure 2.3.2-1) and the corresponding tables and figure presented previously in the letter to the NRC.[12]

Table 2.3.1-1a Geologic Profile for Estimated Layer Thickness for CNS[8]* - Shallow Profile

Depth Range (feet)	Elevation (feet above MSL)	Soil/Rock Description	Density (pcf)	Shear Wave Velocity (fps)	Compressional Wave Velocity (fps)	Poisson's Ratio
0-5	902/903-898	Type I or Type II Fill	134	600	1600	0.27
5-8	898-895	Type I or Type II Fill	134	750	1600	0.27
8-13	895-890	Type I or Type II Fill	134	750	1600	0.27
13-23	890-880	Type I Fill/In-Situ Compacted Alluvium	134	850	1600	0.27
23-30	880-873	Type I Fill/In-Situ Compacted Alluvium	134	920	3295	0.42
30-33	873-870	Type I Fill/In-Situ Compacted Alluvium	133	920	5505	0.48
33-48	870-855	Type I Fill/In-Situ Compacted Alluvium	133	1020	5505	0.48
48-58	855-845	Type I Fill/In-Situ Compacted Alluvium	133	1030	5505	0.48
58-68	845-835	Type I Fill/In-Situ Compacted Alluvium	133	1040	5505	0.48
68-74	835-829	Type I Fill/In-Situ Compacted Alluvium	132	1040	2535	0.38
74-83	829-820	Type I Fill/In-Situ Compacted Alluvium	132	1120	6100	0.48
83-93	820-810	Soft Bedrock	140	1620	6420	0.47
93-118	810-785	Soft Bedrock	140	1760	6600	0.47
118-128	785-775	Harder Bedrock	160	2750	9970	0.45
>128	<775	Per Table B.5 NEDC 13-019	---	---	---	---

*From Table B.1, Soil Profile 1-Recommended Dynamic Soil and Rock Profiles Lower Bound, Best Fit, and Upper Bound [page 39 of NEDC (13-019)][9]

Table 2.3.1-1b Geologic Profile for Estimated Layer Thickness CNS - Deep Bedrock Stratigraphy[4][8]

Elevation of Bottom of Unit (feet, MSL)	System	Series	Group(s)	Rock Types
600	Pennsylvanian	Virgil	Wabaunsee	Shale, Limestone, Sandstone, Coal
300	Pennsylvanian	Virgil	Shawnee	Limestone, Shale
150	Pennsylvanian	Virgil	Douglas	Shale, Sandstone, Limestone
100	Pennsylvanian	Missouri	Lansing	Limestone, Shale
-100	Pennsylvanian	Missouri	Kansas City	Shale, Limestone
-150	Pennsylvanian	Missouri	Pleasanton	Limestone, Shale
-350	Pennsylvanian	Missouri, Des Moines	Marmaton	Shale, Limestone, Coal
-1050	Pennsylvanian, Mississippian	Des Moines	Cherokee	Shale, Coal, Sandstone
-1350	Mississippian	--	Meramec, Osage, Kinderhook	Limestone, Chert, Shale
-1750	Devonian	-	-	Shale, Limestone
-2150	Silurian	-	-	Dolomite
unknown	Ordovician	-	Maquoketa, Galena (Viola), Decorah-Platteville, St. Peter, Oneoto (Up. Arbuckle)	Shale, Dolomite, Limestone, Sandstone
-2600 *(3500 ft deep)*	Cambrian	-	Bonneterre (Lr. Arbuckle), La Motte	Sandstone, Shale, Glauconite, Granite
Unknown	Precambrian	-	-	Metamorphic, Granite

Notes:

1. Elevations, systems, series, and groups were interpreted from USAR Figure II-5-3[4].
2. Elevations are in feet and were rounded to the nearest 50 feet.
3. Rock types are from Condra (1935)[11].

2.3.2 Development of Base Case Profiles and Nonlinear Material Properties

Table 2.3.1-1a shows the recommended shear wave velocities and unit weights along with elevations and corresponding stratigraphy. As indicated in utility communications and CNS Engineering Report ER 2014-002[15], the SSE control point is at elevation 869.5 feet (2655 m) within Type I fill/in-situ compacted alluvium.

Shear wave velocity estimates shown in Table 2.3.1-1a considered recent measurements made using a suspension logging system and downhole seismic measurements presented in NEDC (13-019)[9]. For the firm rock below a depth of 128 feet (39m), 97 feet (30m) below the SSE, a shear wave velocity of 7,292 ft/s (2,222 m/s) was considered reasonable for the highest elevation of the firm rock units, based on the geologic description (Table 2.3.1-1b). The mean base case profile (P1) was based on the recommended densities and shear wave velocities listed in Table 2.3.1-1a along with a shear wave velocity of 7,292 ft/s (2,222m/s) for the underlying firm rock. Lower- and upper-range profiles were developed with scale factors of 1.25 for the top 49.5 feet (15m) and 1.57 below to reflect increased epistemic uncertainty for assumed shear wave velocities. The scale factors of 1.25 and 1.57 reflect a $\sigma_{\mu ln}$ of about 0.2 and 0.35, respectively, based on the SPID[3] 10th and 90th fractiles, which implies a scale factor of 1.28 on $\sigma_{\mu ln}$. Depth to Precambrian basement was taken at 3,500 feet (1,067m) randomized ± 1,050 feet (320m). Profile P3, the stiffest profile, encountered hard rock shear wave velocities (9,285 ft/s, 2,890 m/s) at a depth below the SSE of about 97 feet (30m). The three shear wave velocity profiles are shown on Figure 2.3.2-1 and listed in Table 2.3.2-2.

Table 2.3.2-2 Geologic Profile and Estimated Layer Thickness for CNS

Profile 1			Profile 2			Profile 3		
Thickness (ft)	Depth (ft)	Vs (ft/s)	Thickness (ft)	Depth (ft)	Vs (ft/s)	Thickness (ft)	Depth (ft)	Vs (ft/s)
	0	1020		0	816		0	1275
10.0	10.0	1020	10.0	10.0	816	10.0	10.0	1275
4.5	14.5	1020	4.5	14.5	816	4.5	14.5	1275
10.0	24.5	1030	10.0	24.5	824	10.0	24.5	1288
10.0	34.5	1040	10.0	34.5	832	10.0	34.5	1300
6.0	40.5	1040	6.0	40.5	832	6.0	40.5	1300
9.0	49.5	1120	9.0	49.5	896	9.0	49.5	1400
10.0	59.5	1620	10.0	59.5	1032	10.0	59.5	2543
10.0	69.5	1760	10.0	69.5	1121	10.0	69.5	2763
10.0	79.5	1760	10.0	79.5	1121	10.0	79.5	2763
5.0	84.5	1760	5.0	84.5	1121	5.0	84.5	2763
10.0	94.5	2750	10.0	94.5	1752	10.0	94.5	4318
2.5	97.0	7292	2.5	97.0	4645	2.5	97.0	9285
10.0	107.0	7294	10.0	107.0	4647	10.0	107.0	9285
10.0	117.0	7299	10.0	117.0	4650	10.0	117.0	9285
10.0	127.0	7304	10.0	127.0	4653	10.0	127.0	9285
10.0	137.0	7309	10.0	137.0	4656	10.0	137.0	9285
10.0	147.0	7314	10.0	147.0	4659	10.0	147.0	9285
10.0	157.0	7319	10.0	157.0	4662	10.0	157.0	9285
10.0	167.0	7324	10.0	167.0	4666	10.0	167.0	9285
10.0	177.0	7329	10.0	177.0	4669	10.0	177.0	9285
10.0	187.0	7334	10.0	187.0	4672	10.0	187.0	9285
10.0	197.0	7339	10.0	197.0	4675	10.0	197.0	9285
10.0	207.0	7344	10.0	207.0	4678	10.0	207.0	9285
10.0	217.0	7349	10.0	217.0	4682	10.0	217.0	9285
10.0	227.0	7354	10.0	227.0	4685	10.0	227.0	9285
10.0	237.0	7359	10.0	237.0	4688	10.0	237.0	9285
10.0	247.0	7364	10.0	247.0	4691	10.0	247.0	9285
10.0	257.0	7369	10.0	257.0	4694	10.0	257.0	9285
10.0	267.0	7374	10.0	267.0	4698	10.0	267.0	9285
10.0	277.0	7379	10.0	277.0	4701	10.0	277.0	9285
10.0	287.0	7384	10.0	287.0	4704	10.0	287.0	9285
10.0	297.0	7389	10.0	297.0	4707	10.0	297.0	9285
10.0	307.0	7394	10.0	307.0	4710	10.0	307.0	9285
10.0	317.0	7399	10.0	317.0	4713	10.0	317.0	9285
10.0	327.0	7404	10.0	327.0	4717	10.0	327.0	9285
10.0	337.0	7409	10.0	337.0	4720	10.0	337.0	9285
10.0	347.0	7414	10.0	347.0	4723	10.0	347.0	9285
10.0	357.0	7419	10.0	357.0	4726	10.0	357.0	9285

Profile 1			Profile 2			Profile 3		
Thickness (ft)	Depth (ft)	Vs (ft/s)	Thickness (ft)	Depth (ft)	Vs (ft/s)	Thickness (ft)	Depth (ft)	Vs (ft/s)
10.0	367.0	7424	10.0	367.0	4729	10.0	367.0	9285
10.0	377.0	7429	10.0	377.0	4733	10.0	377.0	9285
10.0	387.0	7434	10.0	387.0	4736	10.0	387.0	9285
10.0	397.0	7439	10.0	397.0	4739	10.0	397.0	9285
10.0	407.0	7444	10.0	407.0	4742	10.0	407.0	9285
10.0	417.0	7449	10.0	417.0	4745	10.0	417.0	9285
10.0	427.0	7454	10.0	427.0	4748	10.0	427.0	9285
10.0	437.0	7459	10.0	437.0	4752	10.0	437.0	9285
10.0	447.0	7464	10.0	447.0	4755	10.0	447.0	9285
10.0	457.0	7469	10.0	457.0	4758	10.0	457.0	9285
10.0	467.0	7474	10.0	467.0	4761	10.0	467.0	9285
10.0	477.0	7479	10.0	477.0	4764	10.0	477.0	9285
10.0	487.0	7484	10.0	487.0	4768	10.0	487.0	9285
10.0	497.0	7489	10.0	497.0	4771	10.0	497.0	9285
10.0	507.0	7494	10.0	507.0	4774	10.0	507.0	9285
10.0	517.0	7499	10.0	517.0	4777	10.0	517.0	9285
10.0	527.0	7504	10.0	527.0	4780	10.0	527.0	9285
10.0	537.0	7509	10.0	537.0	4784	10.0	537.0	9285
10.0	547.0	7514	10.0	547.0	4787	10.0	547.0	9285
10.0	557.0	7519	10.0	557.0	4790	10.0	557.0	9285
10.0	567.0	7524	10.0	567.0	4793	10.0	567.0	9285
100.0	667.0	7549	100.0	667.0	4809	100.0	667.0	9285
100.0	767.0	7599	100.0	767.0	4841	100.0	767.0	9285
100.0	867.0	7649	100.0	867.0	4873	100.0	867.0	9285
100.0	967.0	7699	100.0	967.0	4905	100.0	967.0	9285
100.0	1067.0	7749	100.0	1067.0	4936	100.0	1067.0	9285
100.0	1167.0	7799	100.0	1167.0	4968	100.0	1167.0	9285
100.0	1266.9	7849	100.0	1266.9	5000	100.0	1266.9	9285
100.0	1366.9	7899	100.0	1366.9	5032	100.0	1366.9	9285
100.0	1466.9	7949	100.0	1466.9	5064	100.0	1466.9	9285
100.0	1566.9	7999	100.0	1566.9	5096	100.0	1566.9	9285
100.0	1666.9	8049	100.0	1666.9	5127	100.0	1666.9	9285
100.0	1766.9	8099	100.0	1766.9	5159	100.0	1766.9	9285
100.0	1866.9	8149	100.0	1866.9	5191	100.0	1866.9	9285
100.0	1966.9	8199	100.0	1966.9	5223	100.0	1966.9	9285
100.0	2066.9	8249	100.0	2066.9	5255	100.0	2066.9	9285
100.0	2166.9	8299	100.0	2166.9	5287	100.0	2166.9	9285
100.0	2266.9	8349	100.0	2266.9	5319	100.0	2266.9	9285
100.0	2366.9	8399	100.0	2366.9	5350	100.0	2366.9	9285
100.0	2466.9	8449	100.0	2466.9	5382	100.0	2466.9	9285
100.0	2566.9	8499	100.0	2566.9	5414	100.0	2566.9	9285

Profile 1			Profile 2			Profile 3		
Thickness (ft)	Depth (ft)	Vs (ft/s)	Thickness (ft)	Depth (ft)	Vs (ft/s)	Thickness (ft)	Depth (ft)	Vs (ft/s)
100.0	2666.9	8549	100.0	2666.9	5446	100.0	2666.9	9285
100.0	2766.9	8599	100.0	2766.9	5478	100.0	2766.9	9285
100.0	2866.9	8649	100.0	2866.9	5510	100.0	2866.9	9285
100.0	2966.9	8699	100.0	2966.9	5541	100.0	2966.9	9285
100.0	3066.9	8749	100.0	3066.9	5573	100.0	3066.9	9285
100.0	3166.9	8799	100.0	3166.9	5605	100.0	3166.9	9285
100.0	3266.8	8849	100.0	3266.8	5637	100.0	3266.8	9285
100.0	3366.8	8899	100.0	3366.8	5669	100.0	3366.8	9285
100.0	3466.8	8949	100.0	3466.8	5701	100.0	3466.8	9285
80.2	3547.1	8999	80.2	3547.1	5733	80.2	3547.1	9285
3280.8	6827.9	9285	3280.8	6827.9	9285	3280.8	6827.9	9285

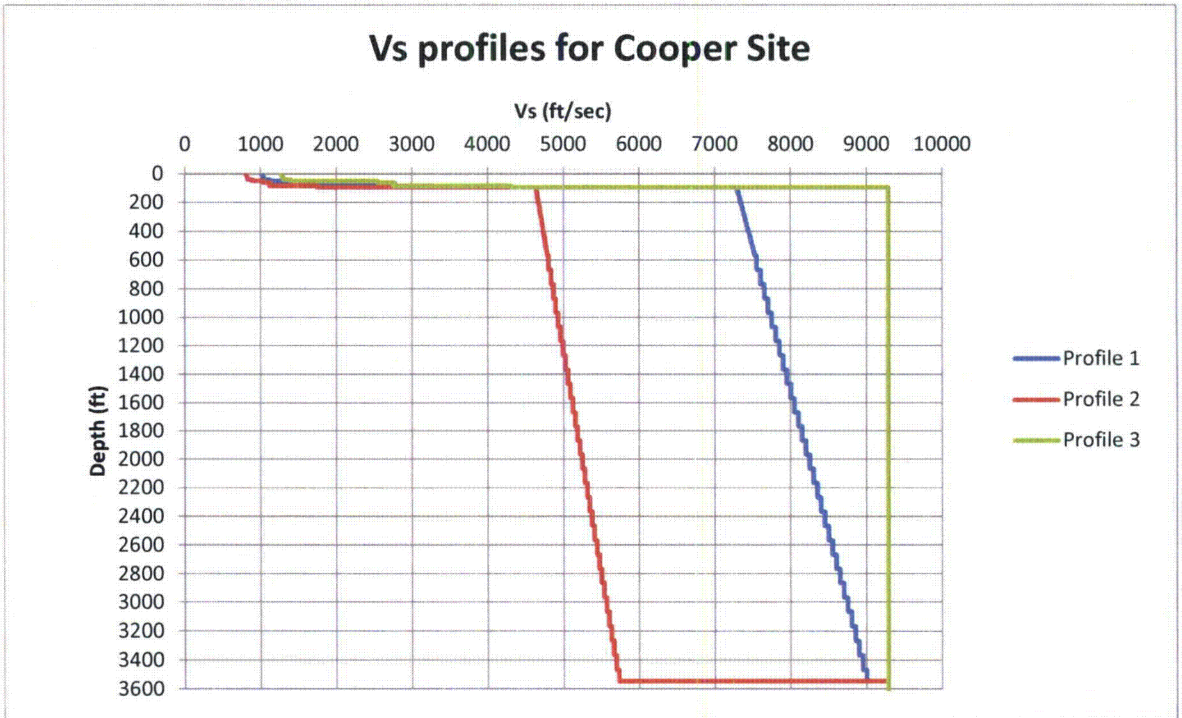

Figure 2.3.2-1 Shear Wave Velocity Profile Used in Site Response Calculations for Cooper Nuclear Station

2.3.2.1 Shear Modulus and Damping Curves

Recent nonlinear dynamic material properties were not available for the CNS soils and sedimentary rocks. To accommodate epistemic uncertainty in nonlinear dynamic material properties for the soils, two sets of shear modulus reduction and hysteretic damping curves were used. The rock material over the upper 500 feet (150 m) was assumed to have behavior that could be modeled as either linear or nonlinear. To represent this potential for either case in the upper 500 feet of sedimentary rock at the CNS site, two sets of shear modulus reduction and hysteretic damping curves were used. Consistent with the SPID[3], the EPRI soil and rock curves (model M1) were considered to be appropriate to represent the upper range nonlinearity likely in the materials at this site and linear analyses for firm rock along with Peninsular Range curves for soils (model M2) was assumed to represent an equally plausible alternative soil and firm rock response across loading level. For the linear analyses, the low strain damping from the EPRI rock curves were used as the constant damping values in the upper 500 feet.

2.3.2.2 Kappa

Base case kappa estimates were determined using Section B-5.1.3.1 of the SPID[3] for a firm CEUS rock site. Kappa for a firm rock site with at least 3,000 feet (1 km) of sedimentary rock may be estimated from the average S-wave velocity over the upper 100 feet (V_{s100}) of the subsurface profile while for a site with less than 3,000 feet (1 km) of firm rock, kappa may be estimated with a Q_s of 40 below 500 feet combined with the low strain damping from the EPRI rock curves and an additional kappa of 0.006s for the underlying hard rock. For the CNS site, with about 50 feet of soils overlying about 3,450 feet (1,052m) of firm rock, kappa was estimated with the low strain damping over the top 500 feet (152m) combined with a Q_S of 40 below and 0.006s for the underlying hard rock. The resulting kappa values were 0.021s, 0.030s, and 0.008s for base case profiles P1, P2, and P3, respectively. Refer to Table 2.3.2-3.

Table 2.3.2-3 Kappa Values Used for Site Response Analyses

Velocity Profile	Kappa(s)
P1	0.021
P2	0.030
P3	0.008
	Weights
P1	0.4
P2	0.3
P3	0.3
G/G_{max} and Hysteretic Damping Curves	
M1	0.5
M2	0.5

2.3.3 Randomization of Base Case Profiles

To account for the aleatory variability in dynamic material properties that is expected to occur across a site at the scale of a typical nuclear facility, variability in the assumed shear wave velocity profiles has been incorporated in the site response calculations. For the CNS site, randomized shear wave velocity profiles were developed from the base case profiles shown on Figure 2.3.2-1. Consistent with the discussion in Appendix B of the SPID[3], the velocity randomization procedure made use of random field models that describe the statistical correlation between layering and shear wave velocity. The default randomization parameters developed in Toro (1997)[10] for USGS "A" site conditions were used for this site. Thirty random velocity profiles were generated for each base case profile. These random velocity profiles were generated using a natural log standard deviation of 0.25 over the upper 50 feet and 0.15 below that depth. As specified in the SPID[3], correlation of shear wave velocity between layers was modeled using the footprint correlation model. In the correlation model, a limit of ±2 standard deviations about the median value in each layer was assumed for the limits on random velocity fluctuations. All random velocities were limited to be less than or equal to 9830 ft/sec.

2.3.4 Input Spectra

Consistent with the guidance in Appendix B of the SPID[3], input Fourier amplitude spectra were defined for a single representative earthquake magnitude (**M** 6.5) using two different assumptions regarding the shape of the seismic source spectrum (single-corner and double-corner). A range of 11 different input amplitudes (peak ground acceleration [PGA] ranging from 0.01 to 1.5 g) were used in the site response analyses. The characteristics of the seismic source and upper crustal attenuation properties assumed for the analysis of the CNS site were the same as those identified in Tables B-4, B-5, B-6 and B-7 of the SPID[3] as appropriate for typical CEUS sites.

2.3.5 Methodology

To perform the site response analyses for the CNS site, a random vibration theory (RVT) approach was employed. This process utilizes a simple, efficient approach for computing site-specific amplification functions and is consistent with existing NRC guidance and the SPID[3]. The guidance contained in Appendix B of the SPID[3] on incorporating epistemic uncertainty in shear wave velocities, kappa, nonlinear dynamic properties and source spectra for plants with limited at-site information was followed for the CNS site.

2.3.6 Amplification Functions

The results of the site response analysis consist of amplification factors (5 percent damped pseudo absolute response spectra) that describe the amplification (or de-amplification) of hard reference rock motion as a function of frequency and input reference rock amplitude. The amplification factors are represented in terms of a median amplification value and an associated standard deviation (sigma) for each oscillator frequency and input rock amplitude. Consistent with the SPID[3], a minimum median amplification value of 0.5 was employed in the present analysis. Figure 2.3.6-1 illustrates the median and ±1 standard deviation in the predicted amplification factors developed for the eleven loading levels parameterized by the median reference (hard rock) peak acceleration (0.01g to 1.50g) for profile P1 and EPRI[8] rock G/G_{max} and hysteretic damping curves. The variability in the amplification factors results from variability in shear wave velocity, depth to hard rock, and modulus reduction and hysteretic damping curves. To illustrate the effects of nonlinearity at the CNS firm rock site, Figure 2.3.6-2 shows the corresponding amplification factors developed with linear site response analyses (model M2). Tabulated values of the amplification factors are provided in Appendix A.

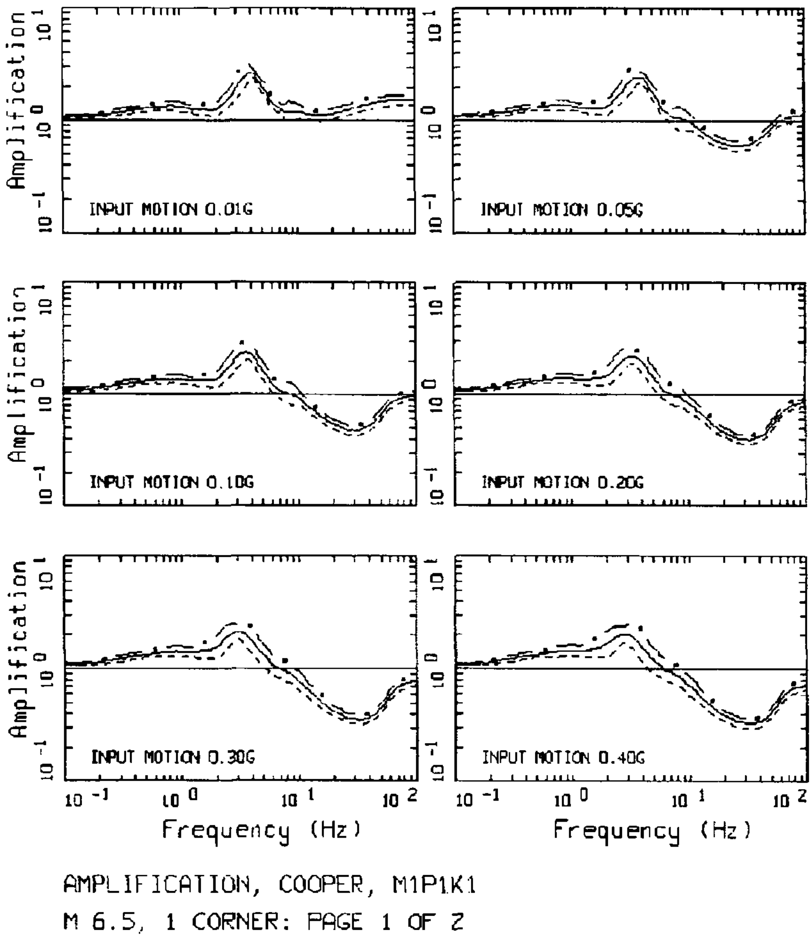

Figure 2.3.6-1 Example Suite of Amplification Factors (5 percent damping pseudo absolute acceleration spectra) developed for the mean base case profile (P1), EPRI rock modulus reduction and hysteretic damping curves (model M1), and base-case kappa (K1) at 11 loading levels of hard rock median peak acceleration values from 0.01g to 1.50g. M 6.5 and single-corner source model (SPID[3]).

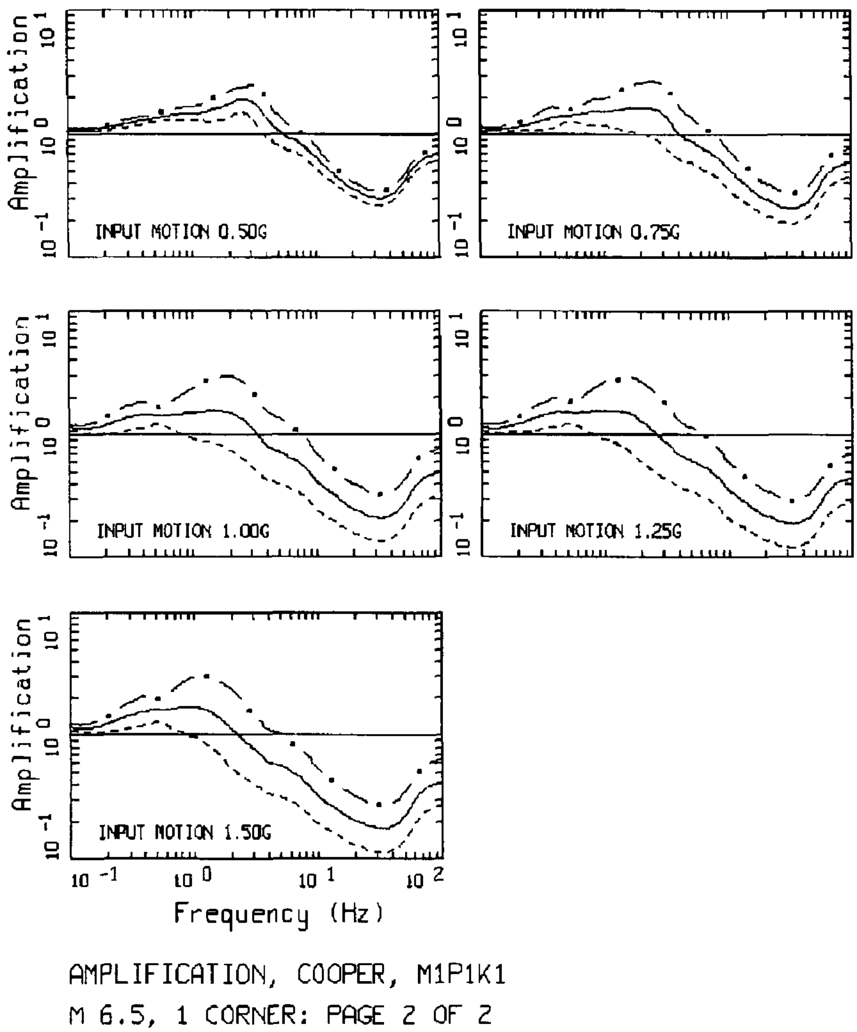

Figure 2.3.6-1. (continued)

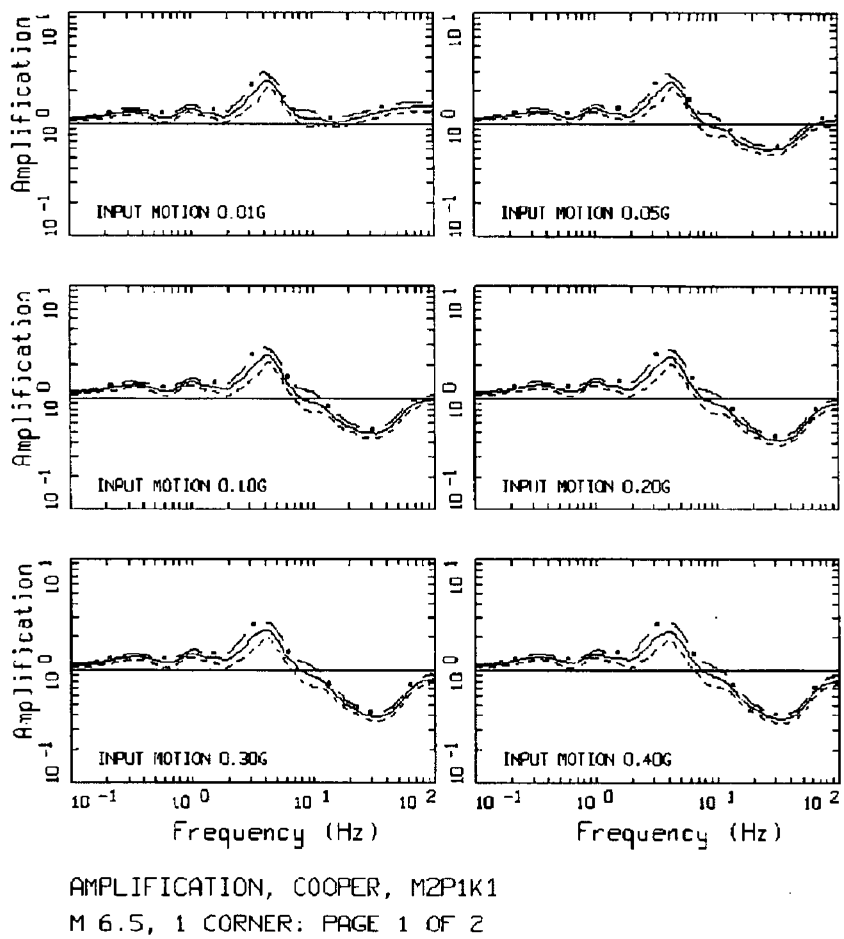

Figure 2.3.6-2 Example Suite of Amplification Factors (5 percent damping pseudo absolute acceleration spectra) developed for the mean base case profile (P1), linear site response (model M2), and base case kappa (K1) at 11 loading levels of hard rock median peak acceleration values from 0.01g to 1.50g. M 6.5 and single-corner source model (SPID[3]).

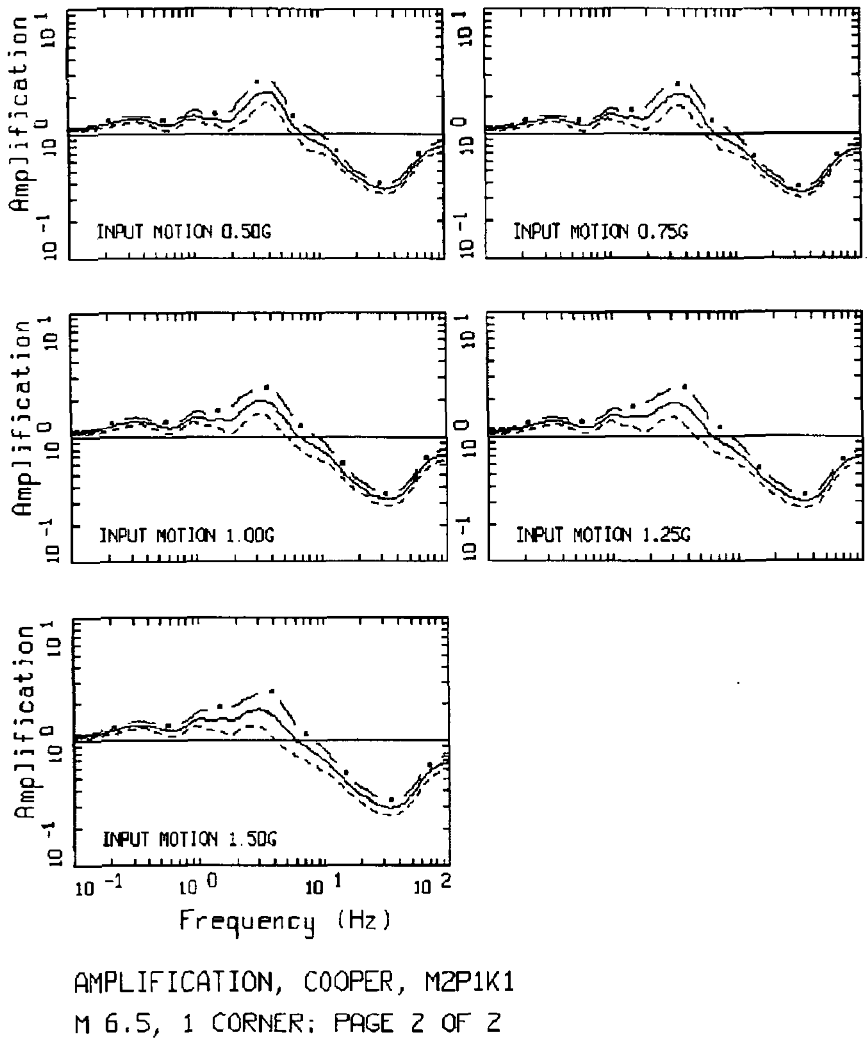

Figure 2.3.6-2. (continued)

2.3.7 Control Point Seismic Hazard Curves

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

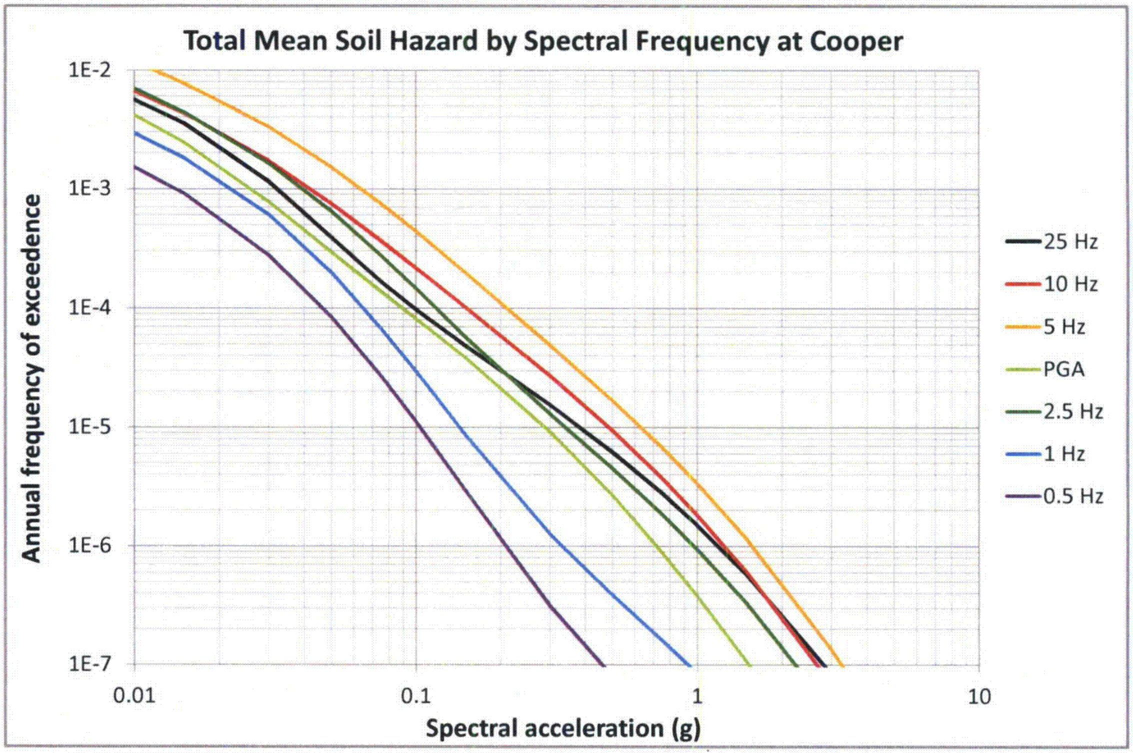

Figure 2.3.7-1 Control Point Mean Hazard Curves for Spectral Frequencies of 0.5, 1, 2.5, 5, 10, 25 and 100 Hz at CNS

2.4 Control Point Response Spectra

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

The 1E-4 and 1E-5 UHRS, along with the design factor (DF) are used to compute the GMRS at the control point using the criteria in Regulatory Guide 1.208[7]. Table 2.4-1 shows the UHRS and GMRS spectral accelerations.

Table 2.4-1 shows the UHRS and GMRS accelerations for a range of spectral frequencies.

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

Table 2.4-1 UHRS for 10^{-4} and 10^{-5} and GMRS at Control Point for CNS

Freq. (Hz)	10^{-4} UHRS (g)	10^{-5} UHRS (g)	GMRS (g)
100	8.94E-02	2.88E-01	1.37E-01
90	8.93E-02	2.91E-01	1.38E-01
80	8.93E-02	2.96E-01	1.40E-01
70	8.92E-02	3.02E-01	1.42E-01
60	8.93E-02	3.08E-01	1.44E-01
50	8.95E-02	3.17E-01	1.48E-01
40	9.06E-02	3.31E-01	1.53E-01
35	9.17E-02	3.42E-01	1.58E-01
30	9.39E-02	3.57E-01	1.64E-01
25	9.83E-02	3.83E-01	1.75E-01
20	1.06E-01	3.98E-01	1.83E-01
15	1.26E-01	4.38E-01	2.05E-01
12.5	1.40E-01	4.79E-01	2.25E-01
10	1.52E-01	4.88E-01	2.32E-01
9	1.55E-01	4.96E-01	2.36E-01
8	1.58E-01	5.05E-01	2.40E-01
7	1.65E-01	5.26E-01	2.50E-01
6	1.83E-01	5.69E-01	2.72E-01
5	2.11E-01	6.31E-01	3.04E-01
4	2.09E-01	5.89E-01	2.87E-01
3.5	1.94E-01	5.35E-01	2.62E-01
3	1.63E-01	4.51E-01	2.21E-01
2.5	1.18E-01	3.40E-01	1.65E-01
2	9.57E-02	2.75E-01	1.34E-01
1.5	7.69E-02	2.01E-01	9.95E-02
1.25	6.93E-02	1.67E-01	8.42E-02
1	6.48E-02	1.43E-01	7.31E-02
0.9	6.08E-02	1.34E-01	6.86E-02
0.8	5.62E-02	1.24E-01	6.35E-02
0.7	5.28E-02	1.17E-01	5.97E-02
0.6	5.02E-02	1.11E-01	5.69E-02
0.5	4.65E-02	1.04E-01	5.29E-02
0.4	3.72E-02	8.28E-02	4.23E-02
0.35	3.25E-02	7.25E-02	3.70E-02
0.3	2.79E-02	6.21E-02	3.17E-02
0.25	2.32E-02	5.18E-02	2.65E-02
0.2	1.86E-02	4.14E-02	2.12E-02
0.15	1.39E-02	3.11E-02	1.59E-02
0.125	1.16E-02	2.59E-02	1.32E-02
0.1	9.29E-03	2.07E-02	1.06E-02

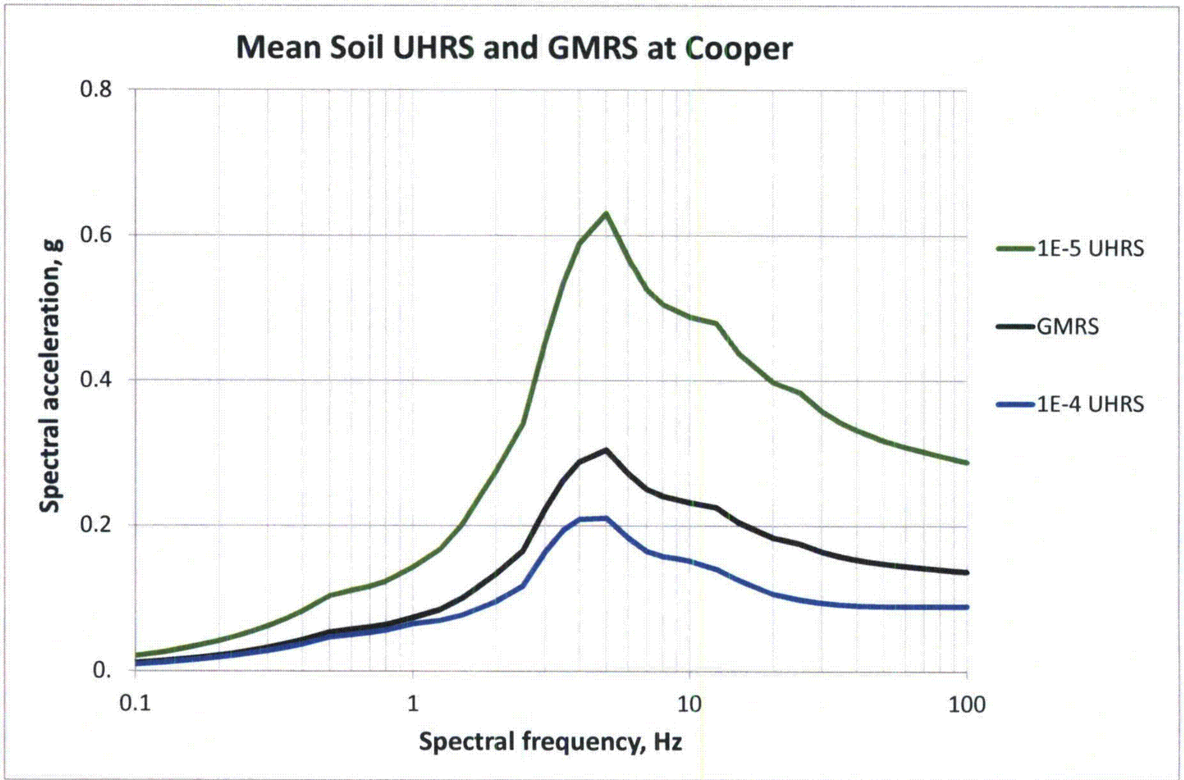

Figure 2.4-1 UHRS for 1E-4 and 1E-5 and GMRS at Control Point for CNS

3.0 Plant Design Basis

The design basis for CNS is identified in the USAR[4].

3.1 SSE Description of Spectral Shape

The SSE was developed in accordance with 10 CFR Part 100, Appendix A that existed at the time of the construction permit through an evaluation of the maximum earthquake potential for the region surrounding the site. The SSE for CNS was developed based on the U.S. Coast & Geodetic Survey (USC&GS) Seismic-Probability Map, the records of historical earthquakes, and the regional and local geologic structural features according to CNS USAR, Section II-5.2[4]. Considering the historical seismicity of the site region, CNS determined that an earthquake with an intensity of VII on the Modified Mercalli Scale (MM) would affect the site during the life of the nuclear power station. The hypothetical maximum possible intensity of ground motion at the site would likely result from a local earthquake smaller than the New Madrid earthquakes of 1811 and 1812. CNS USAR, Section II-5.2[4], considered it improbable that future local earthquakes (e.g., the Humboldt Fault) would have epicentral intensities greater than MM VII.

Considering the regional and local geology and seismology at the CNS as stated the CNS USAR, Chapter II[4], a hypothetical maximum possible design earthquake, i.e., SSE of 0.2g, was selected for structural analysis. The 0.2g value was chosen for the horizontal component of the acceleration at both the rock surface, approximate elevation of 820 feet MSL, and the base of the structures. The application of the SSE at the base of each Class I structure is based on the assumption that the structures are founded on a dense structural fill.

Also from the USAR[4], the SSE response spectrum was developed using the accelerogram of the N69W component of the July 21, 1952, Kern County earthquake recorded at Taft, California. This accelerogram was selected for reasons of geology, geometry, seismology, and comparison with other spectra. The SSE response spectrum developed for the CNS is shown on Table 3.1-1 and is similar to the average spectrum recommended by the US Atomic Energy Commission TID-7024[13]. The SSE response spectrum is provided in the following table.

Table 3.1-1 SSE for CNS (5 Percent Damping)

Frequency (Hz)	100/PGA	33	25	9	5	3	2.5	1.8	1	0.5
Spectral Acc. (g)	0.20	0.20	0.26	0.34	0.42	0.53	0.50	0.41	0.19	0.13

3.2 Control Point Elevation(s)

A single SSE control point is defined at elevation 869.5 of the Control Building.[8]

The CNS SSE has multiple control points described in the CNS USAR[4]. For the original CNS Individual Plant Examination of External Events (IPEEE) evaluation, a soil-structure interaction (SSI) analysis was performed for both the Reactor Building and Control Building[14]. For the comparison of the GMRS and SSE, the Control Building control point elevation (869.5') is used since it is at a higher elevation than the Reactor Building foundation elevation. This is consistent with the SPID[3] guidance.

4.0 Screening Evaluation

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

4.1 Risk Evaluation (1 to 10 Hz)

In the 1 to 10 Hz part of the response spectrum, the SSE exceeds the GMRS. Therefore, a risk evaluation will not be performed.

4.2 High Frequency Screening (> 10Hz)

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

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

In the 1 to 10 Hz part of the response spectrum, the SSE exceeds the GMRS. Therefore, a spent fuel pool evaluation will not be performed.

5.0 Interim Actions

Based on the screening evaluation, the expedited seismic evaluation described in EPRI 3002000704[17] will not be performed. CNS screens from this activity since its GMRS is less than the SSE between 1 and 10 Hz.

Consistent with NRC letter[18] dated February 20, 2014, [ML14030A046] the seismic hazard reevaluations presented herein are distinct from the current design and licensing bases of CNS. 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[19] to the NRC dated March 12, 2014, provides seismic core damage risk estimates using the updated seismic hazards for the operating nuclear plants in the Central and Eastern United States. These risk estimates continue to support the following conclusions of the NRC GI-199 Safety/Risk Assessment:

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

CNS is included in the March 12, 2014 risk estimates[19]. Using the methodology described in the NEI letter[19], all plants were shown to be below 10^{-4}/year; thus, the above conclusions apply.

5.1 NTTF 2.3 – Seismic Walkdowns

CNS performed seismic walkdowns to meet Near-Term Task Force Recommendation 2.3. As part of this program a total of 104 seismic walkdowns and 60 area walk-bys were conducted resulting in 53 Condition Reports (CR). A summary of these CR's is available in the Cooper Nuclear Station Seismic Walkdown Report for Resolution of Fukushima Near-Term Task Force Recommendation 2.3: Seismic[16]. These CR's are documented in a table in the seismic walkdown report along with the categorization of the action to have them resolved.

Also as part of the 2.3 walkdown, IPEEE vulnerabilities were reviewed and evaluated. This evaluation concluded that there are no IPEEE vulnerabilities at CNS. Details of these evaluations are available for review in Seismic Walkdown Report[16].

The Seismic Walkdown project is open pending three additional walkdowns that will be performed in accordance with commitments identified in a letter to the NRC (NLS2012125)[20].

6.0 Conclusions

In accordance with the 50.54(f) request for information letter a seismic hazard and screening evaluation was performed for CNS. A GMRS was developed solely for the purpose of screening for additional evaluation in accordance with the SPID.

Based on the results of the screening evaluation, no further evaluations will be performed.

7.0 References

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14. NEDC (87-162), Attachment K, Generation of Conservtaive Design and Median-Centered In-Structure Response Spectra for the Cooper Nuclear Plant Control and Reactor Buildings, July 1994.

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Appendix A
PGA Seismic Hazard Curves at CNS

Table A-1a. Mean and Fractiles for PGA Hazard at CNS

PGA (g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	4.46E-02	1.79E-02	3.33E-02	4.50E-02	5.75E-02	6.36E-02
0.001	3.12E-02	1.11E-02	2.13E-02	3.05E-02	4.19E-02	4.98E-02
0.005	8.46E-03	2.60E-03	4.90E-03	7.77E-03	1.18E-02	1.72E-02
0.01	4.14E-03	1.18E-03	2.01E-03	3.52E-03	6.00E-03	9.79E-03
0.015	2.44E-03	6.83E-04	1.05E-03	1.95E-03	3.52E-03	6.54E-03
0.03	7.73E-04	1.87E-04	2.88E-04	5.42E-04	1.05E-03	2.42E-03
0.05	2.94E-04	5.75E-05	9.65E-05	1.92E-04	4.25E-04	1.01E-03
0.075	1.38E-04	2.29E-05	4.25E-05	8.72E-05	2.10E-04	4.70E-04
0.1	8.15E-05	1.27E-05	2.49E-05	5.20E-05	1.25E-04	2.68E-04
0.15	3.83E-05	5.50E-06	1.18E-05	2.53E-05	5.83E-05	1.21E-04
0.3	9.16E-06	1.05E-06	2.57E-06	6.26E-06	1.42E-05	2.68E-05
0.5	2.67E-06	2.04E-07	5.83E-07	1.74E-06	4.37E-06	8.12E-06
0.75	8.85E-07	3.84E-08	1.38E-07	5.27E-07	1.49E-06	2.92E-06
1.	3.79E-07	9.93E-09	4.31E-08	2.01E-07	6.54E-07	1.34E-06
1.5	1.05E-07	1.18E-09	6.54E-09	4.37E-08	1.77E-07	4.19E-07
3.	8.99E-09	1.62E-10	2.53E-10	2.10E-09	1.32E-08	4.37E-08
5.	1.13E-09	1.32E-10	1.62E-10	2.60E-10	1.42E-09	6.17E-09
7.5	1.78E-10	1.21E-10	1.32E-10	1.62E-10	2.92E-10	1.11E-09
10.	4.27E-11	1.21E-10	1.32E-10	1.62E-10	1.72E-10	3.68E-10

Table A-1b. 0.5 Hz Seismic Hazard Curves at CNS

PGA (g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	1.78E-02	8.00E-03	1.16E-02	1.72E-02	2.39E-02	2.92E-02
0.001	1.07E-02	4.37E-03	6.45E-03	1.01E-02	1.46E-02	1.87E-02
0.005	3.00E-03	4.90E-04	1.05E-03	2.64E-03	4.90E-03	6.73E-03
0.01	1.52E-03	1.05E-04	2.88E-04	1.10E-03	2.80E-03	4.31E-03
0.015	9.12E-04	3.63E-05	1.11E-04	5.27E-04	1.77E-03	3.01E-03
0.03	2.76E-04	4.70E-06	1.57E-05	9.93E-05	5.20E-04	1.13E-03
0.05	8.43E-05	9.37E-07	3.14E-06	2.13E-05	1.36E-04	3.79E-04
0.075	2.72E-05	2.39E-07	8.23E-07	5.66E-06	3.84E-05	1.23E-04
0.1	1.12E-05	8.35E-08	3.14E-07	2.10E-06	1.44E-05	4.90E-05
0.15	2.94E-06	1.64E-08	7.55E-08	5.35E-07	3.63E-06	1.29E-05
0.3	3.14E-07	8.47E-10	5.20E-09	5.12E-08	3.90E-07	1.46E-06
0.5	8.04E-08	1.92E-10	6.64E-10	8.47E-09	8.60E-08	3.84E-07
0.75	3.09E-08	1.62E-10	2.13E-10	1.98E-09	2.64E-08	1.42E-07
1.	1.59E-08	1.62E-10	1.62E-10	7.13E-10	1.15E-08	7.03E-08
1.5	6.04E-09	1.32E-10	1.62E-10	2.35E-10	3.19E-09	2.46E-08
3.	9.74E-10	1.21E-10	1.32E-10	1.62E-10	3.84E-10	3.19E-09
5.	2.09E-10	1.21E-10	1.32E-10	1.62E-10	1.69E-10	6.26E-10
7.5	5.35E-11	1.21E-10	1.32E-10	1.62E-10	1.62E-10	2.35E-10
10.	1.88E-11	1.21E-10	1.32E-10	1.62E-10	1.62E-10	1.69E-10

Table A-1c. 1 Hz Seismic Hazard Curves at CNS

PGA (g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	3.54E-02	1.64E-02	2.35E-02	3.52E-02	4.70E-02	5.42E-02
0.001	2.30E-02	9.37E-03	1.42E-02	2.22E-02	3.19E-02	3.84E-02
0.005	5.86E-03	1.79E-03	3.01E-03	5.50E-03	8.72E-03	1.11E-02
0.01	2.93E-03	5.42E-04	1.08E-03	2.57E-03	4.77E-03	6.54E-03
0.015	1.81E-03	2.29E-04	4.98E-04	1.42E-03	3.19E-03	4.70E-03
0.03	6.02E-04	4.07E-05	9.79E-05	3.47E-04	1.13E-03	2.01E-03
0.05	1.98E-04	9.93E-06	2.42E-05	8.98E-05	3.42E-04	7.45E-04
0.075	6.79E-05	3.05E-06	7.45E-06	2.84E-05	1.08E-04	2.60E-04
0.1	2.94E-05	1.27E-06	3.14E-06	1.20E-05	4.50E-05	1.15E-04
0.15	8.59E-06	3.42E-07	9.51E-07	3.63E-06	1.32E-05	3.28E-05
0.3	1.25E-06	2.84E-08	1.07E-07	5.20E-07	2.07E-06	4.98E-06
0.5	3.86E-07	3.52E-09	1.84E-08	1.32E-07	6.26E-07	1.62E-06
0.75	1.60E-07	6.83E-10	4.07E-09	4.31E-08	2.49E-07	7.13E-07
1.	8.50E-08	2.84E-10	1.36E-09	1.84E-08	1.27E-07	3.84E-07
1.5	3.33E-08	1.64E-10	3.47E-10	5.20E-09	4.56E-08	1.55E-07
3.	5.57E-09	1.44E-10	1.62E-10	5.35E-10	6.17E-09	2.60E-08
5.	1.23E-09	1.32E-10	1.62E-10	1.84E-10	1.18E-09	5.50E-09
7.5	3.25E-10	1.21E-10	1.32E-10	1.62E-10	3.52E-10	1.42E-09
10.	1.17E-10	1.21E-10	1.32E-10	1.62E-10	2.01E-10	5.58E-10

Table A-1d. 2.5 Hz Seismic Hazard Curves at CNS

PGA (g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	5.33E-02	3.52E-02	4.25E-02	5.35E-02	6.45E-02	7.03E-02
0.001	4.26E-02	2.32E-02	2.96E-02	4.25E-02	5.50E-02	6.36E-02
0.005	1.42E-02	5.27E-03	7.66E-03	1.31E-02	2.10E-02	2.68E-02
0.01	7.02E-03	2.07E-03	3.33E-03	6.36E-03	1.08E-02	1.40E-02
0.015	4.37E-03	1.04E-03	1.79E-03	3.84E-03	7.03E-03	9.37E-03
0.03	1.63E-03	2.49E-04	4.63E-04	1.23E-03	2.84E-03	4.31E-03
0.05	6.46E-04	7.77E-05	1.51E-04	4.19E-04	1.11E-03	1.98E-03
0.075	2.75E-04	2.96E-05	5.91E-05	1.69E-04	4.56E-04	8.85E-04
0.1	1.44E-04	1.51E-05	3.01E-05	8.85E-05	2.35E-04	4.56E-04
0.15	5.75E-05	5.75E-06	1.23E-05	3.57E-05	9.51E-05	1.79E-04
0.3	1.30E-05	1.11E-06	2.72E-06	8.23E-06	2.22E-05	4.07E-05
0.5	4.50E-06	2.92E-07	8.35E-07	2.80E-06	7.77E-06	1.44E-05
0.75	1.85E-06	9.37E-08	2.96E-07	1.10E-06	3.23E-06	6.09E-06
1.	9.36E-07	3.73E-08	1.31E-07	5.27E-07	1.64E-06	3.19E-06
1.5	3.26E-07	9.24E-09	3.57E-08	1.64E-07	5.75E-07	1.18E-06
3.	4.09E-08	6.64E-10	2.53E-09	1.49E-08	6.93E-08	1.67E-07
5.	7.35E-09	1.87E-10	3.47E-10	1.74E-09	1.11E-08	3.28E-08
7.5	1.72E-09	1.55E-10	1.67E-10	3.57E-10	2.25E-09	8.00E-09
10.	5.85E-10	1.32E-10	1.62E-10	1.87E-10	7.34E-10	2.76E-09

Table A-1e. 5Hz Seismic Hazard Curves at CNS

PGA(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	5.89E-02	4.43E-02	4.90E-02	5.83E-02	6.83E-02	7.34E-02
0.001	5.17E-02	3.37E-02	4.07E-02	5.20E-02	6.26E-02	6.93E-02
0.005	2.19E-02	9.79E-03	1.36E-02	2.10E-02	3.05E-02	3.68E-02
0.01	1.18E-02	4.70E-03	6.83E-03	1.11E-02	1.69E-02	2.10E-02
0.015	7.77E-03	2.76E-03	4.25E-03	7.23E-03	1.13E-02	1.44E-02
0.03	3.32E-03	9.37E-04	1.51E-03	2.92E-03	5.20E-03	7.13E-03
0.05	1.53E-03	3.79E-04	6.09E-04	1.21E-03	2.42E-03	3.73E-03
0.075	7.53E-04	1.67E-04	2.76E-04	5.66E-04	1.16E-03	1.98E-03
0.1	4.39E-04	8.98E-05	1.51E-04	3.23E-04	6.73E-04	1.16E-03
0.15	1.99E-04	3.52E-05	6.36E-05	1.44E-04	3.05E-04	5.35E-04
0.3	4.91E-05	6.73E-06	1.36E-05	3.52E-05	8.00E-05	1.36E-04
0.5	1.69E-05	1.69E-06	3.90E-06	1.16E-05	2.88E-05	4.90E-05
0.75	6.79E-06	4.56E-07	1.21E-06	4.43E-06	1.21E-05	2.10E-05
1.	3.38E-06	1.55E-07	4.77E-07	2.04E-06	6.17E-06	1.10E-05
1.5	1.14E-06	2.72E-08	1.07E-07	6.09E-07	2.16E-06	4.01E-06
3.	1.34E-07	8.60E-10	5.83E-09	4.90E-08	2.49E-07	5.42E-07
5.	2.19E-08	1.72E-10	5.66E-10	5.50E-09	3.73E-08	9.65E-08
7.5	4.73E-09	1.62E-10	1.82E-10	8.85E-10	7.03E-09	2.16E-08
10.	1.53E-09	1.32E-10	1.62E-10	2.96E-10	2.04E-09	7.03E-09

Table A-1f. 10 Hz Seismic Hazard Curves at CNS

PGA (g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	5.25E-02	3.57E-02	4.25E-02	5.27E-02	6.26E-02	6.83E-02
0.001	4.06E-02	2.35E-02	3.14E-02	4.07E-02	4.98E-02	5.66E-02
0.005	1.29E-02	5.91E-03	8.35E-03	1.23E-02	1.72E-02	2.25E-02
0.01	6.71E-03	2.60E-03	3.84E-03	6.17E-03	9.37E-03	1.29E-02
0.015	4.31E-03	1.53E-03	2.25E-03	3.84E-03	6.26E-03	8.98E-03
0.03	1.72E-03	5.50E-04	8.00E-04	1.40E-03	2.49E-03	4.13E-03
0.05	7.56E-04	2.22E-04	3.33E-04	5.91E-04	1.07E-03	1.92E-03
0.075	3.68E-04	9.93E-05	1.55E-04	2.84E-04	5.20E-04	9.65E-04
0.1	2.17E-04	5.35E-05	8.85E-05	1.67E-04	3.19E-04	5.75E-04
0.15	1.02E-04	2.19E-05	3.95E-05	7.89E-05	1.57E-04	2.64E-04
0.3	2.74E-05	4.77E-06	9.93E-06	2.16E-05	4.37E-05	7.03E-05
0.5	9.52E-06	1.34E-06	3.09E-06	7.34E-06	1.55E-05	2.49E-05
0.75	3.75E-06	4.07E-07	1.04E-06	2.76E-06	6.26E-06	1.04E-05
1.	1.83E-06	1.51E-07	4.25E-07	1.27E-06	3.14E-06	5.35E-06
1.5	6.05E-07	3.09E-08	1.07E-07	3.68E-07	1.07E-06	1.92E-06
3.	6.91E-08	1.34E-09	6.00E-09	3.09E-08	1.27E-07	2.53E-07
5.	1.11E-08	2.04E-10	5.42E-10	3.63E-09	1.95E-08	4.63E-08
7.5	2.29E-09	1.62E-10	1.77E-10	6.36E-10	3.73E-09	1.05E-08
10.	6.96E-10	1.32E-10	1.62E-10	2.49E-10	1.11E-09	3.42E-09

Table A-1g. 25 Hz Seismic Hazard Curves at CNS

PGA (g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	4.64E-02	2.19E-02	3.68E-02	4.63E-02	5.75E-02	6.45E-02
0.001	3.36E-02	1.42E-02	2.49E-02	3.28E-02	4.31E-02	5.27E-02
0.005	1.04E-02	3.79E-03	6.17E-03	9.51E-03	1.40E-02	2.16E-02
0.01	5.60E-03	1.84E-03	2.92E-03	4.90E-03	7.89E-03	1.27E-02
0.015	3.54E-03	1.13E-03	1.74E-03	2.92E-03	5.12E-03	8.60E-03
0.03	1.15E-03	3.37E-04	4.98E-04	8.85E-04	1.57E-03	3.23E-03
0.05	3.89E-04	9.65E-05	1.55E-04	2.88E-04	5.50E-04	1.13E-03
0.075	1.66E-04	3.52E-05	6.26E-05	1.23E-04	2.53E-04	4.70E-04
0.1	9.69E-05	1.90E-05	3.57E-05	7.34E-05	1.49E-04	2.64E-04
0.15	4.85E-05	9.11E-06	1.84E-05	3.79E-05	7.45E-05	1.27E-04
0.3	1.55E-05	2.72E-06	6.09E-06	1.27E-05	2.39E-05	3.84E-05
0.5	6.24E-06	9.93E-07	2.32E-06	5.12E-06	9.65E-06	1.51E-05
0.75	2.80E-06	3.95E-07	9.65E-07	2.29E-06	4.43E-06	7.13E-06
1.	1.50E-06	1.87E-07	4.70E-07	1.20E-06	2.39E-06	4.01E-06
1.5	5.72E-07	5.35E-08	1.51E-07	4.31E-07	9.37E-07	1.67E-06
3.	8.30E-08	3.95E-09	1.36E-08	5.27E-08	1.40E-07	2.88E-07
5.	1.55E-08	4.98E-10	1.64E-09	8.00E-09	2.64E-08	6.09E-08
7.5	3.47E-09	1.84E-10	3.42E-10	1.49E-09	5.91E-09	1.51E-08
10.	1.09E-09	1.62E-10	1.84E-10	4.77E-10	1.87E-09	5.05E-09

Table A-2a. Medians and Logarithmic Sigmas of Amplification Factors for CNS

PGA	Median AF	Sigma ln(AF)	25 Hz	Median AF	Sigma ln(AF)	10 Hz	Median AF	Sigma ln(AF)	5 Hz	Median AF	Sigma ln(AF)
1.00E-02	1.52E+00	1.04E-01	1.30E-02	1.18E+00	1.03E-01	1.90E-02	1.14E+00	1.44E-01	2.09E-02	2.07E+00	1.44E-01
4.95E-02	1.11E+00	9.99E-02	1.02E-01	5.89E-01	9.78E-02	9.99E-02	9.64E-01	1.72E-01	8.24E-02	1.95E+00	1.50E-01
9.64E-02	9.73E-01	9.80E-02	2.13E-01	5.00E-01	9.56E-02	1.85E-01	9.13E-01	1.75E-01	1.44E-01	1.86E+00	1.56E-01
1.94E-01	8.61E-01	9.34E-02	4.43E-01	5.00E-01	9.17E-02	3.56E-01	8.53E-01	1.70E-01	2.65E-01	1.75E+00	1.75E-01
2.92E-01	8.02E-01	9.23E-02	6.76E-01	5.00E-01	9.21E-02	5.23E-01	8.12E-01	1.72E-01	3.84E-01	1.65E+00	1.92E-01
3.91E-01	7.60E-01	9.40E-02	9.09E-01	5.00E-01	9.51E-02	6.90E-01	7.80E-01	1.75E-01	5.02E-01	1.57E+00	2.07E-01
4.93E-01	7.28E-01	9.84E-02	1.15E+00	5.00E-01	1.00E-01	8.61E-01	7.51E-01	1.80E-01	6.22E-01	1.50E+00	2.24E-01
7.41E-01	6.63E-01	1.52E-01	1.73E+00	5.00E-01	1.51E-01	1.27E+00	6.89E-01	2.14E-01	9.13E-01	1.35E+00	2.77E-01
1.01E+00	6.13E-01	1.85E-01	2.36E+00	5.00E-01	1.85E-01	1.72E+00	6.34E-01	2.41E-01	1.22E+00	1.22E+00	3.21E-01
1.28E+00	5.74E-01	1.91E-01	3.01E+00	5.00E-01	1.92E-01	2.17E+00	5.86E-01	2.50E-01	1.54E+00	1.11E+00	3.45E-01
1.55E+00	5.43E-01	2.04E-01	3.63E+00	5.00E-01	2.05E-01	2.61E+00	5.47E-01	2.60E-01	1.85E+00	1.03E+00	3.67E-01

2.5 Hz	Median AF	Sigma ln(AF)	1 Hz	Median AF	Sigma ln(AF)	0.5 Hz	Median AF	Sigma ln(AF)			
2.18E-02	1.56E+00	1.92E-01	1.27E-02	1.41E+00	1.11E-01	8.25E-03	1.35E+00	1.05E-01			
7.05E-02	1.63E+00	2.06E-01	3.43E-02	1.43E+00	1.09E-01	1.96E-02	1.36E+00	1.03E-01			
1.18E-01	1.68E+00	2.12E-01	5.51E-02	1.44E+00	1.10E-01	3.02E-02	1.36E+00	1.03E-01			
2.12E-01	1.73E+00	2.11E-01	9.63E-02	1.47E+00	1.12E-01	5.11E-02	1.38E+00	1.03E-01			
3.04E-01	1.74E+00	2.08E-01	1.36E-01	1.50E+00	1.18E-01	7.10E-02	1.39E+00	1.04E-01			
3.94E-01	1.72E+00	2.07E-01	1.75E-01	1.53E+00	1.28E-01	9.06E-02	1.40E+00	1.06E-01			
4.86E-01	1.69E+00	2.26E-01	2.14E-01	1.57E+00	1.44E-01	1.10E-01	1.41E+00	1.07E-01			
7.09E-01	1.59E+00	3.28E-01	3.10E-01	1.60E+00	2.61E-01	1.58E-01	1.42E+00	1.26E-01			
9.47E-01	1.50E+00	3.92E-01	4.12E-01	1.61E+00	3.20E-01	2.09E-01	1.44E+00	1.56E-01			
1.19E+00	1.42E+00	3.97E-01	5.18E-01	1.61E+00	3.40E-01	2.62E-01	1.46E+00	2.03E-01			
1.43E+00	1.39E+00	3.82E-01	6.19E-01	1.63E+00	3.53E-01	3.12E-01	1.47E+00	2.60E-01			

Appendix A (Continued)

Median Amplification Factors and Uncertainties

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

Table A2-b1. Median AFs and Sigmas for Model 1, 2 PGA Levels

M1P1K1		Rock PGA=0.0964		M1P1K1		PGA=0.391	
Freq. (Hz)	PGA Soil_SA	Med. AF	Sigma ln(AF)	Freq. (Hz)	PGA Soil_SA	Med. AF	Sigma ln(AF)
100.0	0.095	0.982	0.102	100.0	0.286	0.732	0.105
87.1	0.095	0.963	0.102	87.1	0.287	0.711	0.105
75.9	0.095	0.931	0.102	75.9	0.287	0.676	0.105
66.1	0.095	0.871	0.102	66.1	0.287	0.612	0.105
57.5	0.095	0.769	0.102	57.5	0.288	0.514	0.105
50.1	0.096	0.654	0.102	50.1	0.289	0.425	0.106
43.7	0.096	0.560	0.102	43.7	0.290	0.361	0.106
38.0	0.097	0.508	0.102	38.0	0.292	0.333	0.107
33.1	0.098	0.480	0.102	33.1	0.295	0.321	0.108
28.8	0.100	0.482	0.102	28.8	0.300	0.329	0.110
25.1	0.103	0.484	0.103	25.1	0.307	0.338	0.112
21.9	0.107	0.519	0.101	21.9	0.316	0.368	0.114
19.1	0.113	0.549	0.102	19.1	0.330	0.393	0.117
16.6	0.121	0.602	0.117	16.6	0.350	0.439	0.132
14.5	0.131	0.676	0.121	14.5	0.373	0.492	0.146
12.6	0.146	0.764	0.132	12.6	0.408	0.558	0.159
11.0	0.163	0.864	0.136	11.0	0.458	0.646	0.182
9.5	0.175	0.967	0.196	9.5	0.498	0.739	0.200
8.3	0.171	1.011	0.223	8.3	0.517	0.837	0.198
7.2	0.168	1.053	0.180	7.2	0.526	0.913	0.200
6.3	0.176	1.163	0.146	6.3	0.524	0.973	0.214
5.5	0.206	1.414	0.175	5.5	0.548	1.071	0.225
4.8	0.252	1.759	0.187	4.8	0.607	1.216	0.261
4.2	0.305	2.180	0.172	4.2	0.690	1.431	0.310
3.6	0.323	2.362	0.153	3.6	0.802	1.717	0.309
3.2	0.294	2.269	0.232	3.2	0.857	1.953	0.239
2.8	0.236	1.913	0.241	2.8	0.827	1.993	0.177
2.4	0.185	1.615	0.209	2.4	0.736	1.929	0.222
2.1	0.146	1.399	0.175	2.1	0.602	1.738	0.260
1.8	0.124	1.324	0.141	1.8	0.491	1.592	0.235
1.6	0.108	1.322	0.128	1.6	0.406	1.523	0.197
1.4	0.093	1.320	0.119	1.4	0.337	1.470	0.163
1.2	0.083	1.320	0.083	1.2	0.288	1.431	0.117
1.0	0.077	1.349	0.093	1.0	0.259	1.431	0.115
0.91	0.071	1.373	0.099	0.91	0.235	1.436	0.113
0.79	0.065	1.375	0.101	0.79	0.210	1.425	0.109
0.69	0.058	1.360	0.091	0.69	0.183	1.401	0.097
0.60	0.050	1.340	0.074	0.60	0.156	1.374	0.078
0.52	0.042	1.318	0.061	0.52	0.129	1.347	0.063
0.46	0.035	1.294	0.060	0.46	0.105	1.319	0.061
0.10	0.001	1.100	0.024	0.10	0.004	1.104	0.026

Table A2-b2. Median AFs and Sigmas for Model 2, 2 PGA Levels

M2P1K1		PGA=0.0964		M2P1K1		PGA=0.391	
Freq. (Hz)	PGA Soil_SA	Med. AF	Sigma ln(AF)	Freq. (Hz)	PGA Soil_SA	Med. AF	Sigma ln(AF)
100.0	0.095	0.981	0.093	100.0	0.322	0.824	0.092
87.1	0.095	0.962	0.093	87.1	0.323	0.801	0.092
75.9	0.095	0.930	0.092	75.9	0.323	0.761	0.092
66.1	0.095	0.871	0.092	66.1	0.324	0.690	0.092
57.5	0.095	0.768	0.092	57.5	0.325	0.580	0.092
50.1	0.096	0.655	0.092	50.1	0.326	0.480	0.092
43.7	0.096	0.561	0.092	43.7	0.329	0.409	0.091
38.0	0.097	0.509	0.092	38.0	0.332	0.379	0.091
33.1	0.099	0.482	0.091	33.1	0.338	0.368	0.090
28.8	0.101	0.486	0.091	28.8	0.346	0.380	0.091
25.1	0.104	0.490	0.093	25.1	0.358	0.394	0.093
21.9	0.109	0.531	0.085	21.9	0.375	0.437	0.088
19.1	0.116	0.562	0.086	19.1	0.398	0.475	0.084
16.6	0.124	0.619	0.117	16.6	0.426	0.534	0.108
14.5	0.134	0.689	0.099	14.5	0.468	0.618	0.112
12.6	0.154	0.807	0.127	12.6	0.533	0.729	0.122
11.0	0.167	0.887	0.158	11.0	0.584	0.823	0.165
9.5	0.169	0.930	0.205	9.5	0.593	0.880	0.200
8.3	0.166	0.983	0.202	8.3	0.575	0.931	0.213
7.2	0.175	1.094	0.139	7.2	0.591	1.027	0.171
6.3	0.198	1.311	0.131	6.3	0.646	1.200	0.166
5.5	0.248	1.708	0.156	5.5	0.779	1.521	0.200
4.8	0.307	2.143	0.151	4.8	0.947	1.899	0.219
4.2	0.334	2.392	0.134	4.2	1.057	2.194	0.186
3.6	0.298	2.177	0.241	3.6	1.011	2.163	0.201
3.2	0.247	1.906	0.251	3.2	0.885	2.016	0.251
2.8	0.195	1.579	0.197	2.8	0.714	1.719	0.255
2.4	0.158	1.381	0.155	2.4	0.567	1.484	0.210
2.1	0.129	1.235	0.122	2.1	0.452	1.306	0.167
1.8	0.112	1.188	0.118	1.8	0.382	1.238	0.149
1.6	0.102	1.251	0.104	1.6	0.344	1.290	0.124
1.4	0.090	1.274	0.089	1.4	0.299	1.304	0.096
1.2	0.082	1.306	0.078	1.2	0.267	1.330	0.085
1.0	0.078	1.381	0.084	1.0	0.253	1.400	0.090
0.91	0.071	1.361	0.060	0.91	0.226	1.378	0.065
0.79	0.059	1.249	0.068	0.79	0.186	1.264	0.069
0.69	0.049	1.166	0.088	0.69	0.154	1.180	0.088
0.60	0.043	1.150	0.095	0.60	0.132	1.163	0.095
0.52	0.038	1.185	0.084	0.52	0.115	1.197	0.085
0.46	0.033	1.240	0.062	0.46	0.100	1.251	0.065
0.10	0.001	1.118	0.023	0.10	0.004	1.116	0.025