U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

2.5.2 VIBRATORY GROUND MOTION

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of ~~seismological~~seismic ground motion hazards

Secondary ~~--~~ None

I. AREAS OF REVIEW

Chapter 2 of the Standard Review Plan (SRP) discusses the site characteristics that could affect the safe design and siting of the plant. The staff reviews information presented by the applicant for a construction permit (CP), operating license (OL), ~~design certification (DC),~~ early site permit (ESP), or combined license (COL) concerning the seismological, geological, geophysical, and geotechnical investigations carried out to determine the site-specific ground motion response ~~spectrum~~spectra (GMRS), and eventually the Safe Shutdown Earthquake (SSE) ground motion ~~(SSE)~~ for the site. ~~This SRP section applies to~~ The staff reviews ~~performed~~information presented by the applicant for ~~each~~a design certification (DC) to determine if the site

parameters postulated for the design, with respect to seismic ground motion, are correctly identified, are representative of ~~these types~~a reasonable number of ~~applications.~~ sites that has

been or may be considered for a COL application, and are appropriately justified. This SRP section applies to reviews performed for each of these types of applications.

The site-specific GMRS ~~is~~are defined as the free-field horizontal and vertical ground motion response spectra at the plant site determined on the ground surface or on the uppermost competent material using performance-based response procedures in accordance with Regulatory Guide (RG) 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion." The GMRS represent the ground motion levels at the site based on the analyses of regional and local seismic sources surrounding the site as well estimates of ground motions from these seismic sources. The development of the GMRS is based upon a detailed evaluation of earthquake potential, taking into account the regional and local geology, Quaternary tectonics, seismicity, and site-specific geotechnical engineering characteristics of the site subsurface material. The principal regulation used by the staff in determining the scope and adequacy of the submitted seismologic and geologic information and attendant procedures and analyses is ~~10 CFR~~Title 10 of the *Code of Federal Regulations* (10 CFR) 100.23. The GMRS satisfy the requirements of 10 CFR 100.23 with respect to the development of the SSE. ~~Additional information (regulations, regulatory guides, and reports) is provided in References 2 through 9.~~

~~The~~To use the GMRS ~~represents the first part of~~ as the ~~development of the~~ site-specific SSE ~~for~~ spectra, the design requirements specified in Section IV(a ~~site as a characterization of the regional and local seismic hazard.~~) of Appendix S to 10 CFR Part 50 must be met. The SSE ~~represents~~spectra represent the design earthquake ground ~~motion at the site and is the vibratory ground motion~~motions of the plant for which ~~certains~~safety related structures, systems, and components (SSC) are designed to remain functional. ~~The~~ As such, the SSE must satisfy both 10~~-~~ CFR~~-~~ 100.23 and the design requirements specified in Appendix S to 10 CFR Part 50. ~~Guidance~~Additional guidance on the development of the SSE is provided in SRP Section 3.7.1.

Guidance on seismological and geological investigations is provided in ~~Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion" and Regulatory Guide 1.208, "A Performance-Based Approach to~~

~~Define the Site-Specific Earthquake Ground Motion".~~RG 1.208. These investigations describe the seismicity of the site region and the correlation of earthquake activity with seismic sources. Seismic sources that have any parts within 320 km (200 miles) of the site are identified and characterized, including the rates of occurrence of earthquakes associated with each seismic source. ~~Seismic sources that have any part within 320 km (200 miles) of the site must be identified.~~ More distant seismic sources that have a potential for earthquakes large enough to affect the total site hazard must also be ~~identified. Seismic sources can be capable tectonic sources or seismogenic sources.~~evaluated for inclusion in the site probabilistic seismic hazard analysis (PSHA).

The review covers the following specific areas:

1. Seismicity (Subsection 2.5.2.1)

2. Geologic and tectonic characteristics of the site and region (Subsection 2.5.2.2)

3. Correlation of earthquake activity with seismic sources (Subsection 2.5.2.3)

4. Probabilistic seismic hazard analysis and controlling earthquakes (Subsection 2.5.2.4)

5. Seismic wave transmission characteristics of the site (Subsection 2.5.2.5)

6. Site-specific ground motion response ~~spectrum~~spectra (Subsection 2.5.2.6)

Additional information will be presented dependent on the type of application. For a COL application, the additional information is dependent on whether the application references an ESP, a DC, both or neither. Information content requirements are prescribed within the ~~"~~"Contents of Application~~"~~" sections of the applicable Subparts to 10 CFR Part 52 and RG 1.206.

COL Action Items and Certification Requirements and Restrictions. For a DC application, the review will also address COL action items and requirements and restrictions (e.g., interface requirements and site parameters).

A COL applicant referencing a DC must address COL action items (referred to as COL license information in certain DCs) included in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements and site parameters) included in the referenced DC.

Review Interfaces

Other SRP sections interface with this section as follows:

1. ~~The~~ Basic geologic and seismic information reviewed under SRP Section 2.5.1.

2. Potential for future seismic surface deformation within the site vicinity reviewed under SRP Section 2.5.3.

3. Stability of subsurface materials and foundations and the geotechnical engineering aspects of the site ~~and the models and methods employed in the analysis of soil and~~

~~foundation response to the ground motion environment~~ are reviewed under SRP Section 2.5.4.

~~2. The results of the geosciences review are used in SRP Sections 2.4.6 ("Probable Maximum Tsunami Flooding") and 3.7.1 ("Seismic Design Parameters").~~

~~3~~4. Probable maximum tsunami hazards reviewed under SRP Section 2.4.6.

5. Seismic design parameters described in SRP Section 3.7.1.

6. The organization responsible for quality assurance performs reviews of design, construction, and operations phase quality assurance programs under SRP Chapter 17. In addition, while conducting regulatory audits in accordance with Office Instruction NRR-LIC-111 or NRO-REG-108, "Regulatory Audits," the technical staff might identify quality-related issues. If this occurs, the technical staff should contact the organization responsible for quality assurance to determine if an inspection should be conducted.

7. For DC applications and COL applications referencing a DC rule or DC application, review of the site parameters in the Design Control Document (DCD) Tier 1 and Chapter 2 of the DCD Tier 2[1] submitted by the applicant is performed under SRP Section 2.0, ~~"~~"Site Characteristics and Site Parameters~~."~~." Review of site characteristics and site-related design parameters in ESP applications or in COL applications referencing an ESP is also performed under Section 2.0.

8. The reviewers of SRP Chapter 19 will coordinate the review of the seismic vibratory ground motion related to the seismic risk evaluation with the reviewers of this SRP section.

The specific acceptance criteria and review procedures are contained in the referenced SRP sections.

II. ACCEPTANCE CRITERIA

Requirements

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. 10 CFR Part 100, ~~"~~"Reactor Site Criteria~~,"~~," as it relates to the evaluation of the suitability of proposed sites for nuclear power and test reactors.

2. 10 CFR 100.23, ~~"~~"Geologic and Seismic Siting Factors~~,"~~," requires the applicant to determine the SSE and its uncertainty~~, the potential for surface tectonic and nontectonic deformations, the design bases for seismically induced floods and water waves, and other design conditions.~~.

[1] Additional supporting information of prior DC rules may be found in DCD Tier 2 Section 14.3.

3. 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 2 for ~~CP and OL~~COL applications, as it relates to consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity and period of time in which the historical data have been accumulated.

~~4. For ESP applications, GDC are not applicable. However, the GDC 2 requirement to identify site characteristics that consider~~

4. 10 CFR Part 50, Appendix S as it is applicable to applications for a design certification or combined license to 10 CFR Part 52 or a construction permit or operating license pursuant to 10 CFR Part 50 on or after January 10, 1997. For SSE ground motions, SSCs will remain functional and within applicable stress, strain, and deformation limits. The required safety functions of SSCs must be assured during and after the vibratory ground motion through design, testing, or qualification methods. The evaluation must take into account soil-structure interaction effects and the expected duration of the vibratory motion. If the operating basis earthquake (OBE) is set at one-third or less of the SSE, an explicit analysis or design is not required. If the OBE is set at a value greater than one-third of the SSE, an analysis and design must be performed to demonstrate that the applicable stress, strain, and deformation limits are satisfied. Appendix S also requires that the horizontal component of the SSE ground motion in the free-field at the foundation level of the structures must be an appropriate response spectrum with a peak ground acceleration of at least 0.1g.

5. For ESP applications, 10 CFR 52.17(a)(1)(vi) “Content of applications; technical information” requires identification of site characteristics that considers the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated ~~is specifically identified in 10 CFR 52.17(a)(1)(vi).~~ .

SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the ~~NRC's~~NRC’s regulations identified above are as follows for ~~the~~ review described in this SRP section. The SRP is not a substitute for the ~~NRC's~~NRC regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with the NRC regulations.

Appropriate sections of the following Regulatory Guides (RGs) are used by the staff for the identified acceptance criteria:

~~Regulatory Guide~~ RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants," ~~-~~ describes programs of site investigations related to geotechnical aspects that would normally meet the needs for evaluating the safety of the site from the standpoint of the performance of foundations and earthworks under anticipated loading conditions, including earthquakes. It provides general guidance and recommendations for

developing site-specific investigation programs as well as specific guidance for conducting subsurface investigations, such as borings and sampling.

Regulatory GuideRG 4.7, "General Site Suitability Criteria for Nuclear Power Stations," discusses the major site characteristics related to public health and safety that the staff considers in determining the suitability of sites for nuclear power stations.

Regulatory GuideRG 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," states that smoothed response spectra are generally used for design purposes. The Regulatory Guide RG 1.60 standard spectral shape has been frequently used for certified seismic design response spectra (CSDRS). Under the combined license (COL)For recent DC applications of plants to be located in the Central and Eastern United States (CEUS), RG 1.60 standard spectra have been modified to account for high frequency motions. Under the COL procedure, the GMRS are used to determine the adequacy of the CSDRS for a site. If adequate, then the CSDRS becomes the SSE for the site. However, for some site-specific structures the SSE could be site-specific SSE and not the CSDRS.

Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," describes acceptable methods to: (1) conduct geological, seismological, and geophysical investigations of the site and region around the site, (2) identify and characterize seismic sources, (3) perform probabilistic seismic hazard analysis (PSHA), and (4) determine the GMRS for the site (see SRP Section 2.5.2.6) using the reference-probability approach.

Regulatory GuideRG 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants," describes laboratory investigations and testing practices acceptable for determining soil and rock properties and characteristics, together with their uncertainties, needed for site geotechnical investigations and evaluations.

RG 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites," describes acceptable methods for evaluating the potential for earthquake induced instability of soil resulting from liquefaction and strength degradation in complying with 10 CFR 100.23 and 10 CFR Part 50, Appendix S.

RG 1.208, ""A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," " describes acceptable methods to: (1) conduct geological, seismological, and geophysical, and geotechnical investigations of the site and region around the site, (2) identify and characterize seismic sources, (3) perform PSHA, (4) perform site response analysis, and (45) determine the GMRS for the site (see SRP Section 2.5.2.6) using the performance-based approach.

Regulatory GuideRG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," provides guidance regarding the information to be submitted in a COL application for a nuclear power plant.

The principal geologic and seismic considerations for site suitability are given in 10 CFR 100.23. Regulatory Guides 1.165 andRG 1.208 provideprovides more detailed guidance on

investigations and application of PSHA and development of the GMRS. The GMRS is based on consideration of the regional and local geology and seismology and on the characteristics of the subsurface materials at the site. However, no comprehensive definitive rules can be promulgated regarding the investigations needed to determine the GMRS; the requirements vary from site to site.

1. 2.5.2.1 Seismicity. To meet the requirements in 10 CFR 100.23, this subsection is ~~accepted~~acceptable when the complete historical ~~record~~catalog of earthquakes in the region is listed and when all available parameters are given for each earthquake in the historical record. The listing should include all earthquakes having Modified Mercalli Intensity (MMI) greater than or equal to IV or moment magnitude greater than or equal to 3.0 that have been reported within 320 km (200 miles) of the site. Large earthquakes outside of this area that potentially would impact the SSE~~,~~ should be reported. A regional~~--~~scale map should be presented showing all listed earthquake epicenters and should be supplemented by a larger~~--~~scale map showing earthquake epicenters of events within 80 km (50 miles) of the site. The following information concerning each earthquake should be provided whenever it is available: epicenter coordinates~~,~~ depth ~~of focus~~, date, origin time, highest intensity, magnitude, seismic moment, source mechanism, source dimensions, distance from the site~~,~~ and any strong~~--~~motion recordings (sources from which the information was obtained should be identified). All magnitude designations such as m_b, M_L, M_s, M_w should be identified. In the ~~Central and Eastern United States (~~CEUS~~),~~, relatively little information is available on magnitudes for historic earthquakes which are reported but for which there are no instrumental recordings; hence, it may be appropriate to rely on intensity observations (descriptions of earthquake effects) or the dimensions of the area in which the event was felt to estimate magnitudes of historic events ~~(e.g., Refs. 11).~~, as described in EPRI Report TR-102293 and NUREG-2115, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities." In addition, any reported earthquake~~--~~induced geologic failure, such as liquefaction (including paleoseismic evidence of large prehistoric earthquakes), landsliding, landspreading~~,~~ and lurching~~,~~ should be described completely, including the estimated level of strong motion that induced failure and the physical properties of the materials. The completeness of the earthquake history of the region is determined by comparison to the published sources of information. When conflicting descriptions of individual earthquakes are found in the published references, the ~~staff~~applicant should ~~determine~~ assess and document which is appropriate for licensing decisions and the staff reviews the documentation to determine that the assessment meets the requirements in 10 CFR 100.23.

2. 2.5.2.2 Geologic and Tectonic Characteristics of Site and Region. For sites in the CEUS, the seismic source characterization model described in NUREG-2115, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities" (CEUS-SSC) provides an acceptable starting model for nuclear power plant PSHA studies. The CEUS-SSC model is primarily a regional-scale model and therefore local seismic sources ~~identified and~~ need to be analyzed for potential inclusion in the PSHA. Hence, COL, CP, and ESP applicants will need to conduct local geologic investigations to determine if local seismic sources should be included as part of the site characterization.

The larger regional seismic sources characterized by the ~~Lawrence Livermore National Laboratory (LLNL) and the Electric Power Research Institute (EPRI) were used for studies in the CEUS in the past. For CEUS sites, the LLNL and EPRI seismic source~~ model will also need to be evaluated as future studies and data ~~bases may need to be updated.~~might indicate that updates are appropriate. Before deciding whether new models and/or updates to existing models are needed, rather than using a pre-established percentage increase in the seismic hazard, applicants should consider factors such as the views of the scientific community, uncertainty in estimations, and the final impact on the seismic hazard calculations. Updates to any seismic sources or ground motion prediction equations (GMPEs) should be conducted consistent with the methods described in NUREG/CR-6372, "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts" and NUREG-2117, "Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies." Therefore to meet the requirements of 10 CFR 100.23, this subsection is acceptable when adequate information is provided to demonstrate: (1) that a thorough investigation has been conducted to identify seismic sources that could be significant in estimating the seismic hazards of the region if they exist; and (2) that existing sources (in the PSHA) are consistent with the results of site and regional investigations or the sources have been updated in accordance with ~~Appendix E of~~ Regulatory ~~Guide 1.165 or~~Position 3 and Appendix C of ~~Regulatory Guide~~RG 1.208.

For sites where the ~~LLNL or EPRI~~CEUS-SSC data bases ~~have~~do not ~~been used,~~provide coverage, such as in the Western United States (WUS), and it is necessary to identify and characterize seismic sources in meeting the requirements of 10 CFR 100.23, adequate information must be provided in this subsection to demonstrate that all seismic sources that are potentially significant in determining the earthquake potential of the region have been identified, or that an adequate investigation has been carried out to ~~provide reasonable assurance~~establish that there are no unidentified significant seismic sources. Identification and characterization of seismic sources should be conducted consistent with the methods described in NUREG/CR-6372, "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts" and NUREG-2117, "Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies."

Information presented in Section 2.5.1 of the applicant's ~~safety analysis report~~Safety Analysis Report (SAR) and information from other sources dealing with the current tectonic regime should be developed into a coherent, well~~-~~documented discussion to be used as the basis for characterizing the earthquake~~-~~generating potential of seismic sources. Specifically, each seismic source, any part of which is within 320 km (200 miles) of the site, should be identified. In the CEUS, the seismic sources will most likely be seismogenic sources with large regions of diffuse seismicity, each characterized by its own recurrence model. ~~The staff interprets seismogenic sources to be regions of assumed uniform seismicity (same frequency of occurrence) distinct from the seismicity of the surrounding area.~~ The proposed seismogenic sources may be based on seismicity studies, active tectonics indicators, paleoseismic evidence, differences in geologic history, differences in the current tectonic regime, or other seismic, geologic, and tectonic considerations.

The staff considers that the most important factors for the determination of seismic sources include both (1) development and characteristics of the current tectonic regime of the region that is most likely reflected in the Quaternary period (approximately the last ~~1.8~~2.6 million years ~~and younger geologic history~~) and (2) the pattern and level of ~~historical~~ seismicity observed both in the instrumental and pre-instrumental time periods. Those characteristics of geologic structure, tectonic history, present and past stress regimes, and seismicity that distinguish the various seismic sources and the particular areas within those sources where historical earthquakes have occurred should be described. Alternative regional tectonic models derived from available literature should be discussed. The model that best conforms to the observed data is ~~accepted.~~acceptable. In addition, in those areas where there are capable tectonic sources, the results of the additional investigative requirements described in SRP Section 2.5.1 must be presented. The discussion should be augmented by a regional~~-~~ scale map showing the seismic sources, earthquake epicenters, locations of geologic structures, and other features that characterize the seismic sources.

3. 2.5.2.3~~-~~ Correlation of Earthquake Activity with Seismic Sources. To meet the requirements in 10 CFR 100.23, acceptance of this subsection is based on the development of the relationship between the history of earthquake activity and seismic sources of a region. For CEUS sites, when the GMRS ~~is~~are determined using ~~LLNL or EPRI PSHA~~CEUS SSC data bases~~,~~ and ~~Regulatory Guide 1.165 or Regulatory Guide~~RG 1.208, this subsection is acceptable when adequate information is provided to demonstrate (1) that a thorough investigation has been conducted to assess the seismicity and identify seismic sources that could be significant in estimating the seismic hazards of the region if they exist, and (2) that existing sources (in the PSHA) are consistent with the results of site and regional investigations or the sources have been updated in accordance with ~~the Appendix E of~~ Regulatory ~~Guide 1.165 or the~~Position 3 and Appendix C of ~~Regulatory Guide~~RG 1.208.

For sites where ~~LLNL or EPRI~~CEUS-SSC data bases are not used and it is necessary to identify and characterize seismic sources in meeting the requirements of 10 CFR 100.23, adequate information must be provided in this subsection to demonstrate that all seismic sources that are significant in determining the earthquake potential of the region have been identified, or that an adequate investigation has been carried out to provide reasonable assurance that there are no unidentified significant seismic sources. Identification and characterization of seismic sources should be conducted consistent with the methods described in NUREG/CR-6372, “Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts” and NUREG-2117, “Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies.”

The applicant's presentation is ~~accepted~~acceptable when the earthquakes discussed in Subsection~~-~~ 2.5.2.1 of the SAR are shown to be associated with seismic sources. Whenever an earthquake hypocenter or concentration of earthquake hypocenters can be reasonably correlated with geologic structures, the rationale for the association should be developed considering the characteristics of the geologic structure (including geologic and geophysical data, seismicity, and the tectonic history) and the regional tectonic model. The discussion should include identification of the methods used to locate the earthquake hypocenters, an estimation of their accuracy, and a detailed account that compares and contrasts the geologic structure involved in the earthquake

activity with other areas within the seismogenic source. Particular attention should be given to determining the recency and level of activity of faults with which instrumentally located earthquake hypocenters may be associated. Acceptance of the proposed seismic sources (those identified by the investigations) is based on the staff's independent review of the geologic and seismic information presented by the applicant and available in the scientific literature.

4. 2.5.2.4 ~~ ~~Probabilistic Seismic Hazard Analysis and Controlling Earthquakes. For CEUS sites relying on ~~LLNL or EPRI methods~~CEUS-SSC model and data bases, the staff will review the applicant's PSHA, including the underlying assumptions and how the results of the site investigations are used to update the existing sources in the PSHA, how they are used to develop additional sources, or how they are used to develop a new data base. To meet the requirements of 10 CFR 100.23, this subsection is acceptable when adequate information is provided to demonstrate that the PSHA adequately characterizes the regional and local seismic hazard with respect to ground motion and its uncertainty and the controlling earthquakes for the site~~.~~, as defined in RG 1.208.

In addition to seismic sources, the staff will also review the ground motion attenuation models used in the PSHA. For the CEUS, the staff has previously reviewed and accepted ground motion models developed ~~by~~ in Electric Power Research Institute (EPRI ~~(Ref. 14).~~) Report 1009684. Use of the EPRI ground motion models ~~(Ref. 14)~~ is acceptable as long as an adequate investigation has been carried out to provide ~~reasonable assurance~~confidence that there are no significant updates or new models that may impact on the results of the PSHA.

For sites located in the WUS, the latest attenuation relationships (based on current and extensive strong motion data bases) should be used for the PSHA. Updates or modifications to existing attenuation relationships should be conducted consistent with the methods described in NUREG/CR-6372, “Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts” and NUREG-2117, “Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies.” Specifically, the staff will review (1) the rationale for the inclusion of each model, (2) consideration of both aleatory and epistemic uncertainty, (3) model weighting, (4) magnitude conversion, (5) distance measure adjustments, and (6) the model parameters for each spectral frequency. For each PSHA, the staff will also examine how logic trees for seismic source parameters and models (maximum magnitude, recurrence, source geometry) and attenuation models were used to incorporate model uncertainty.

Epsilon, the number of standard deviations included in defining the distribution of ground motions for each magnitude and distance scenario, can have a significant impact on the results of the PSHA. The staff will review the ground motion models used for the PSHA to ensure that the value for epsilon is large enough such that natural aleatory variability in the ground motions is adequately addressed. ~~A recent study (Ref. 17)~~EPRI Report 1013105 found no technical basis for truncating the ground motion distribution at a specified number of standard deviations (epsilons) below that implied by the strength of the geologic materials. Even though very large ground motions have a low probability of occurrence, when the hazard is calculated for low annual frequencies of exceedance, low probability events need to be considered.

For determining recurrence relationship parameters, the entire seismicity catalog developed in Subsection 2.5.2.1, should be used. For the seismic hazard evaluation, the use of Cumulative Absolute Velocity (CAV) provides an alternative approach to the use of minimum magnitude truncation for the PSHA ~~(Ref. 16).~~, as described in EPRI Report 1012965. To remove non-damaging lower-magnitude earthquakes from the hazard characterization, applicants should either use a lower bound magnitude cutoff of moment magnitude (Mw) 5 or the CAV filter for the PSHA. If used, the CAV filter should be limited to Mw less than or equal to 5.5.

The staff will review the controlling earthquakes and associated ground motions at the site derived from the applicant's PSHA to be sure that they adequately represent the local and regional seismic hazard as represented by both historical seismicity and paleoseismicity. The applicant's probabilistic analysis, including the derivation of controlling earthquakes, is considered acceptable if it follows the procedures in ~~Appendix C of~~ Regulatory ~~Guide 1.165 or~~ Position 3 and Appendix D of ~~Regulatory Guide~~RG 1.208. For applicants that use ~~Regulatory Guide 1.165, one pair of low and high frequency controlling earthquakes should be determined at the reference probability value. For applicants that use Regulatory Guide~~RG 1.208, three pairs of low and high frequency controlling earthquakes should be determined for the mean 10^{-4}, 10^{-5}, and 10^{-6} annual probabilities~~.~~ of exceedance. For applicants that do not use PSHA, the staff will review the method used to derive the controlling earthquakes and, in particular, the methods used to address uncertainties on a case-by-case basis.

For sites not in the CEUS, the staff will review the PSHA or other methods in detail. As in the reviews of CEUS sites, the staff will particularly review the approaches used to ~~address~~evaluate uncertainties. The staff will assess the controlling earthquakes for the site derived from the applicant's method to be sure that they adequately represent the local and regional seismic hazard as represented by both historical seismicity and paleoseismicity.

The determination of the controlling earthquakes and the seismic hazard information base for sites not in the CEUS is carried out using procedures similar to those used for CEUS. However, because of differences in seismicity rates and ground motion attenuation characteristics at these sites, alternative magnitude~~-distance parameters may have to be used. In addition, if Regulatory Guide 1.165 is used, an alternative reference probability may also have to be developed, particularly for sites in the active plate margin region and for sites at which a known tectonic structure dominates the hazard.~~-distance parameters may have to be used. The staff will perform an independent evaluation of the earthquake potential associated with each seismic source that could affect the site.

For guidance in evaluating the earthquake potential and characterizing the uncertainty for sites that are assessed using methods other than the ~~LLNL or EPRI methods~~CEUS-SSC method and data bases, or for sites outside the CEUS, refer to ~~the Senior~~NUREG/CR-6372, "Recommendations for Probabilistic Seismic Hazard Analysis ~~Committee (~~: Guidance on Uncertainty and Use of Experts" and NUREG-2117, "Practical Implementation Guidelines for SSHAC~~) Report (Ref. 10).~~ Level 3 and 4 Hazard Studies."

~~5. 2.5.2.5 Seismic Wave Transmission Characteristics of the Site. In the PSHA procedure described in Regulatory Guide 1.165, the controlling earthquakes are determined for generic rock conditions.~~ 5. 2.5.2.5 Seismic Wave Transmission Characteristics of the Site. To meet the requirements of 10 CFR 100.23 for sites that have subsurface materials with a shear wave velocity different from the hard rock velocity used in the PSHA GMPEs, this subsection is acceptable when a site response analysis is performed. The site subsurface profile used for the site response analysis consists of all the soil and rock layers between the ground surface and the elevation below which shear wave velocities match those used in the GMPEs. When the GMRS are determined as free-field outcrop motions on the uppermost competent material, the site response analysis is based on the subsurface profile beneath the chosen location of the GMRS (not including the soil above). However, the calculation should capture the effect of the weight of the soil overburden in producing confinement that affects the soil properties and includes the effects of the soil column frequency of the overburden soil. Therefore, the computation of overburden pressures should include the weight of the soil column above the outcrop elevation to ensure that the computation of nonlinear effects in the strain iteration process is done consistently to match the final configuration of the site profile.

Since the site-specific soil modifies the input ground motion from the base, and because the engineering properties of soil are variable, uncertainties associated with the properties of each layer are incorporated in the subsurface profile to perform the site amplification analysis to obtain the UHS at the free surface in the free field. To consider variation and uncertainties in dynamic soil properties, dynamic soil properties are randomized (using a Monte Carlo type of sampling from the properties of each layer, such as shear moduli and damping values) and a suite of typically 60 randomized soil profiles are generated for amplification analysis. To develop the randomized subsurface profiles, correlation models appropriate for the site geotechnical information need to be selected. The correlation models used should correspond to the range of correlation from fully correlated to fully uncorrelated, unless otherwise justified. As described in RG 1.208, the mean site amplification curves are then calculated using the different correlation models for each input earthquake scenario to determine the response motion at the free surface.

Site amplification analysis is performed and the response motion at the free surface is obtained as the mean response motion at the two levels of the input motion corresponding to mean annual probabilities of exceedance of 10^{-4} and 10^{-5}. RG 1.208 describes the development of performance-based motion in detail. NUREG/CR-6728, "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines," describes methods of site response calculation based on one-dimensional subsurface structure approximation, or a flat layer structure. For sites where subsurface structure does not approximate one-dimensional or flat layering, two- or three-dimensional analysis might be necessary. During COL reviews, comparison and verification of compliance with appropriate DCD parameters regarding subsurface homogeneity is necessary as well, as it may inform which type of site response analysis is needed.

Site amplification studies are performed in a distinct separate step as a part of the determination of the GMRS. In this section, the applicant's site amplification studies are

reviewed in conjunction with the geotechnical and structural engineering reviews. Particular emphasis is placed on how the uncertainties inherent in this process are ~~addressed~~evaluated. To meet the requirements of 10 CFR 100.23, this subsection is acceptable when adequate information is provided to demonstrate that the site response analysis adequately estimates both the mean and variability of the site response in accordance with Regulatory Position 4 and Appendix E of ~~Regulatory Guide~~RG 1.208.

To be acceptable, the seismic wave transmission characteristics (amplification or deamplification) of the materials overlying bedrock at the site are described as a function of the significant frequencies ~~(Ref. 11).~~, as described in EPRI Report TR-102293. The following material properties should be determined for each stratum under the site: thickness, seismic compressional and shear wave velocities, bulk densities, soil index properties and classification, shear modulus and damping variations with strain level, and the water table elevation and its variations ~~(Ref. 15).~~, as described in RG 1.138. Site and laboratory investigations and testing are performed to obtain data defining the static and dynamic engineering properties of soil and rock materials, and their spatial distribution. The procedures identified in RG 1.132, RG 1.138, and Subsection C.2.2.2 of Appendix C of RG 1.208 are used to identify the soil and rock engineering properties. Additional guidance for determining the static and dynamic properties of soil and rock strata, including soil dynamic tests, is described in SRP Section 2.5.4. In each case, methods used to determine the properties should be described in Subsection 2.5.4 of the applicant's SAR and cross~~-~~referenced in ~~this subsection.~~Subsection 2.5.2 of the SAR.

Where vertically propagating shear waves ~~may~~might produce the maximum ground motion, a one~~-~~dimensional iterative equivalent~~-~~linear analysis or nonlinear analysis may be appropriate and is reviewed in conjunction with geotechnical and structural engineering. However, site characteristics (such as a dipping bedrock surface, topographic effects or other impedance boundaries) may require that analyses are also able to account for inclined waves. During COL reviews, DCD parameters regarding subsurface homogeneity should be compared with the site characteristics to verify that the COL application's site parameters are appropriate for use as set forth in the DCD.

The staff will review the ground motions developed for each of the controlling earthquakes. ~~Reference 12~~RG 1.132 and ~~13~~RG 4.7 contain a database of recorded time histories on rock for both CEUS and WUS. The staff will also review the simulation method (such as Monte Carlo) used to incorporate the variability in soil depth, shear wave velocities, layer thicknesses, and strain-dependent dynamic nonlinear material properties at the site. A sufficient number of simulations should be performed (at least 60) in order to define the mean and the standard deviation of the site response.

6. 2.5.2.6~~.~~ Ground Motion Response Spectra. In this subsection, the staff reviews the applicant's procedure to determine the GMRS. ~~If~~Following the site response analysis to determine the ground motion at the free surface, the applicant ~~uses the reference probability approach, the GMRS are considered acceptable if they meet Regulatory Position~~ should calculate a frequency-dependent design factor using the uniform hazard soil surface motions corresponding to the 10^{-4} and ~~Appendix F~~10^{-5} MAPE. The design factor is then applied to the soil response motion at the MAPE of ~~Regulatory Guide 1.165. If the applicant uses the~~ 10^{-4}, and the horizontal performance-based ~~approach,~~

~~the~~site-specific GMRS is determined. RG 1.208 and American Society of Civil Engineers (ASCE)/Software Engineering Institute (SEI) Standard 43-05 describe the development of the performance-based motion in detail. The performance-based site-specific GMRS are considered acceptable if they meet Regulatory Position 5 of ~~Regulatory Guide~~RG 1.208.

The staff also reviews the method used to determine the vertical GMRS. ~~Vertical~~For near surface site elevations, vertical response spectra are developed by combining the appropriate horizontal response spectra and the ~~most recent~~ appropriate vertical and horizontal (V/H) spectral ratios for either CEUS or WUS sites obtained from the available empirical database. Appropriate V/H ratios should be determined from the most recent ground motion attenuation models. However, as there are currently no CEUS attenuation models that predict vertical motions, appropriate V/H ratios for CEUS sites should be developed in accordance with Regulatory Position 5 of ~~Regulatory Guide 1.208~~RG 1.208. For deeper site elevations, V/H ratios for the deep soil profile need to be developed and the methodology used is reviewed on a case-by-case basis.

To meet the requirements in 10 CFR 100.23, the horizontal and vertical GMRS are determined in the free field on the ground surface. For sites with soil layers near the surface that will be completely excavated to expose competent material, the GMRS ~~is~~are specified on an outcrop or a hypothetical outcrop that will exist after excavation. Motions at ~~this~~the hypothetical outcrop should be developed as a free surface motion, not as an in-column motion. Although the definition of competent material is not mandated by regulation, a number of reactor designs have specified a shear wave velocity of 1000 fps (305 m/s) as the definition of competent material. When the GMRS are determined as free-field outcrop motions on the uppermost in-~~-~~situ competent material, only the effects of the materials below this elevation are included in the site response analysis. However, as discussed in Subsection II.2.5.2.5 of this SRP, the site response analysis needs to capture the effects of the overburden soils on the soil properties to be included in the definition of the site profiles.

The time duration and number of cycles of strong ground motion are required for analysis and design of many plant components. The adequacy of the time history for structural analysis is reviewed under SRP Section 3.7.1. For evaluation of the liquefaction potential at the site, the time duration and number of cycles of strong ground motion are critical parameters and require additional consideration. If the controlling earthquakes for the site have magnitudes of less than 6, the time history selected for the evaluation of liquefaction potential ~~must~~should have a duration and number of strong motion cycles corresponding to at least an event of magnitude 6.

Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this SRP section is discussed in the following paragraphs:

GDC 2, or 10 CFR 52.17(a)(1)(vi) for ESP applications, require consideration of the most severe of the natural phenomena. 10 CFR 100.23(c) requires that the geologic and seismic characteristics of the site and its environs be investigated in sufficient scope and detail to permit an adequate evaluation of the proposed site; provide sufficient information to support estimates

of the SSE ground motion; and permit adequate engineering solutions to actual or potential geologic and seismic effects at the proposed site. 10 CFR Part 100.23(c) further specifies that all geologic and seismic factors that may affect design and operation of the proposed nuclear power plant must be investigated. 10 CFR 100.23(d)(1) requires ~~that~~ the ~~geologic and seismic siting factors considered for design include a~~ determination of the ~~potential for surface tectonic and non-tectonic deformations.~~Safe Shutdown Earthquake Ground Motion. Application of GDC 2, or 10 CFR 52.17(a)(1)(vi) for ESP applications, and 10 CFR ~~Part~~ 100.23 provide assurance that the most severe geologic and seismic conditions at the chosen plant site have been identified, and that geologic and seismic elements of the site have been adequately investigated and characterized.

III. REVIEW PROCEDURES

~~The reviewer will select material from the procedures described below, as may be appropriate for a particular case.~~

The procedures outlined below are used to review CP applications, ESP applications, DC applications, and COL applications that do not reference an ESP to determine whether data and analyses for the proposed site meet the acceptance criteria given in Subsection II of this SRP section. For reviews of OL applications, these procedures are used to verify that the data and analyses remain valid and that the ~~facility's~~facility's design specifications are consistent with these data. As applicable, reviews of OLs and COLs include a determination on whether the content of technical specifications related to vibratory ground motion is acceptable and whether the technical specifications reflect consideration of any identified unique conditions. DC applications do not contain site specific characteristics; however, site parameters postulated for the design should to be reviewed using the procedures described below.

These review procedures are based on the identified SRP acceptance criteria. For deviations from these acceptance criteria, the staff ~~should review~~reviews the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II of this SRP.

General Review Procedures

Upon receiving the applicant's SAR or Early Site Evaluation Report (ESR~~,~~), an acceptance review is conducted to determine compliance with the investigative requirements of 10 CFR 100.23. The reviewer also identifies any site~~-~~-specific problems, the resolution of which could result in extended delays in completing the review. After SAR or ESR acceptance and docketing, the reviewer identifies areas that need additional information to support the review of the applicant's seismic design. These are transmitted to the applicant as requests for additional information.

A site visit ~~may~~might need to be conducted, during which the reviewer inspects the geologic conditions at the site and the region around the site as shown in outcrops, borings, geophysical data, trenches, and those geologic conditions exposed during construction. The reviewer also discusses ~~the~~clarifying questions with the applicant and his consultants ~~so that it is clearly understood~~to identify what additional information is required by the staff to continue the review. ~~information is required by the staff to continue the review.~~

The reviewer evaluates the ~~applicant's response to the questions~~information obtained from the site visit, prepares requests for any additional information needed, and formulates positions that may agree or disagree with those of the applicant. ~~These are formally transmitted to~~If further clarification and/or information needed, the staff communicates with the applicant~~.~~ about the staff's position and submits supplementary requests for additional information.

The SAR or ESR and amendments responding to the requests for additional information are reviewed to determine that the information presented by the applicant is acceptable according to the criteria described in Section II (Acceptance Criteria) above. Based on information supplied by the applicant and information obtained from site visits, staff consultants, or literature sources, the reviewer independently identifies and evaluates the relevant seismic sources, including their capability, and determines the earthquake potential for each using procedures noted in Section II, Acceptance Criteria, above. The reviewer evaluates the ~~vibratory ground motion~~ GMRS as determined by the ~~PSHA for~~applicant using the site~~ and compares~~ specific conditions to ensure that ~~ground motion to~~ the GMRS ~~used for development of~~adequately characterizes the ~~SSE~~regional and local seismic hazard.

To ensure that the safety implications of any new geologic information are reviewed, as described in SRP Sections 2.5.1 and 2.5.3, the staff proposes a geologic mapping license condition in the SER for each COL site where plant excavation and geologic mapping have not been completed prior to a license being granted.

Through carrying out these procedures, the NRC staff reviews that the SAR uses methods acceptable for (1) conducting geological, geophysical, seismological, and geotechnical investigations; (2) identifying and characterizing seismic sources; (3) conducting a PSHA; (4) determining seismic wave transmission (soil amplification) characteristics of soil and rock sites; and (5) determining a site-specific, performance-based GMRS, satisfying the requirements of paragraphs (c), (d)(1), and (d)(2) of 10 CFR 100.23, and leading to the establishment of an SSE to satisfy the design requirements of Appendix S to 10 CFR Part 50. The steps necessary to develop the final SSE are described in Chapter 3, "Design of Structures, Components, Equipment and Systems," of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants.".

Review Procedures Specific to 10 CFR Part 52 Application Type

1. Early Site Permit Reviews

   Subpart A to 10 CFR Part 52 specifies the requirements and procedures applicable to the ~~Commission's~~Commission's review of an ESP application for approval of a proposed site. Information required in an ESP application includes a description of the site characteristics and design parameters of the proposed site. The scope and level of detail of review of data parallel ~~that~~those used for a CP review.

   In the absence of certain circumstances, such as a compliance or adequate protection issue, 10 CFR 52.39 precludes the staff from imposing new site characteristics, design parameters, or terms and conditions on the early site permit at the COL stage. Accordingly, the reviewer should ensure that all physical attributes of the site that could

affect the design basis of SSCs important to safety are reflected in the site characteristics, design parameters, or terms and conditions of the ~~early site permit~~ESP.

2. Standard Design Certification Reviews

DC applications do not contain general descriptions of site characteristics because this information is site-specific and will be addressed by the COL applicant. However, pursuant to 10 CFR 52.47(a)(1), a DC applicant must provide site parameters postulated for the design. The reviewer verifies that:

a. The postulated site parameters are representative of a reasonable number of sites that ~~have~~has been or may be considered for a COL application;

b. The appropriate site parameters are included as Tier 1 information. This convention has been used by previous DC applicants. Additional guidance on site parameters is provided in SRP Section 2.0;

c. Pertinent parameters are stated in a site parameters summary table; and

d. The applicant has provided a basis for each of the site parameters.

3. Combined License Reviews

For a COL application referencing a certified standard design, NRC staff reviews that application to ensure that sufficient information is presented to demonstrate that the characteristics of the site fall within the site parameters specified in the DC rule. Should the actual site characteristics not fall within the certified standard design site parameters, the COL applicant will need to demonstrate by some other means that the proposed facility is acceptable at the proposed site. This might be done by re-analyzing or redesigning the proposed facility.

For a COL application referencing an ESP, NRC staff reviews the application to ensure the applicant provides sufficient information to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the early site permit as applicable to this SRP section. In accordance with 10 CFR 52.79(b)(2), should the design of the facility not fall within the site characteristics and design parameters, the application shall include a request for a variance from the ESP that complies with the requirements of 10 CFR 52.39 and 10 CFR 52.93.

In addition, long-term environmental changes and changes to the region resulting from human or natural causes may have introduced changes to the site characteristics that could be relevant to the design basis. In the absence of certain circumstances, such as a compliance or adequate protection issue, 10 CFR 52.39 precludes the staff from imposing new site characteristics, design parameters, or terms and conditions on the early site permit at the COL stage. Consequently, a COL application referencing an ESP need not include a re-~~-~~investigation of the site characteristics that have previously been accepted in the referenced ESP. However, in accordance with 10 CFR 52.6, "“Completeness and Accuracy of Information~~,~~",” the applicant or licensee is responsible for identifying changes of which it is aware, that would satisfy the criteria specified in

10 CFR 52.39. Information provided by the applicant in accordance with 10 CFR 52.6(b) will be addressed by the staff during the review of a COL application referencing an ESP or a DC.

For a COL application referencing either an ESP or DC or both, the staff should review the corresponding sections of the ESP and DC FSER to ensure that any ~~early site permit~~ESP conditions, restrictions to the DC, or COL action items identified in the FSERs are appropriately handled in the COL application.

For review of a DC application, the reviewer should follow the above procedures to verify that the design, including requirements and restrictions (e.g., interface requirements and site parameters), set forth in the FSAR meets the acceptance criteria. DCs have referred to the FSAR as the DCD. The reviewer should also consider the appropriateness of identified COL action items. The reviewer may identify additional COL action items; however, to ensure these COL action items are addressed during a COL application, they should be added to the DC FSAR.

IV. EVALUATION FINDINGS

The review should document the ~~staff's~~staff's evaluation of geologic and seismic site characteristics with respect to the relevant regulatory criteria. The evaluation should support the ~~staff's~~staff's conclusions as to whether the regulations are met. The reviewer should state what was done to evaluate the ~~applicant's~~applicant's safety analysis report. The ~~staff's~~staff's evaluation ~~may include~~includes verification that the applicant followed applicable regulatory guidance~~,~~ and might include performance of independent calculations, and/or validation of appropriate assumptions. The reviewer ~~may~~might state that certain information provided by the applicant was not considered essential to the ~~staff's~~staff's review and was not reviewed by the staff. While the reviewer ~~may~~might summarize or quote the information offered by the applicant in support of its application, the reviewer should clearly articulate the bases for the ~~staff's~~staff's conclusions.

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations (if applicable) support conclusions of the following type to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

1. Early Site Permit Reviews

A typical staff finding at the conclusion of the review can be illustrated as follows.

In its review of the seismic aspects of the plant, the staff has considered pertinent information gathered by the applicant in support of the license application. The information reviewed includes data from site and regional investigations, an independent review of recently published literature; and discussions with knowledgeable scientists with the ~~USGS,~~U.S. State Geological Surveys, local universities, consulting firms, or other non-governmental and professional organizations.

Based on the review by the staff:

(1) The seismological investigations and other information provided by the applicant as required by 10 CFR 52.17 and 10 CFR 100.23 have been combined with the staff's independent review of the data and other information sources. These results provide an adequate basis to establish that ~~no seismic sources exist in the plant site area that would cause earthquakes to be centered in the area~~the most severe seismic factors for the site have been adequately characterized and have accounted for uncertainties.

(2) Based on the results of the applicant's regional and site seismological investigations and the staff's independent evaluation, the staff concludes that all seismic sources significant to determining the site-specific ~~ground motion response spectrum (~~GMRS~~)~~ have been identified and appropriately characterized by the applicant in accordance with ~~Regulatory Guide 1.165 or Regulatory Guide~~RG 1.208 and ~~Standard Review Plan (~~SRP~~)~~ Section 2.5.2.

2. Design Certification Reviews

The following statement should be preceded by a summary of geologic and seismic parameters used for the plant:

> The applicant has selected the site parameters referenced above for plant design inputs (a subset of which is included as Tier 1 information), and the staff agrees that they are representative of a reasonable number of sites that have been or may be considered for a COL application. Local and regional geologic and seismic parameters are specific to the site and region and will be addressed by the COL applicant. This should include the provision of information sufficient to demonstrate that the design of the plant falls within the values of the actual site characteristics specified in a COL or CP application.

3. Construction Permit, Operating License, and Combined License Reviews

If the staff completes review of geologic and seismic aspects of the plant site and confirms that the applicant has met all applicable requirements (i.e., appropriate portions of GDC 2 in 10 CFR~~-~~ Part 50, Appendix A to 10 CFR Part 50; and 10 CFR 100.23) and guidelines (i.e., ~~Regulatory Guides 1.165, RG-~~RGs 1.208, 1.132, 1.138, 1.198, 4.7,and 1.206), the conclusion in the SER should state that investigations and analyses performed and information provided support the applicant's conclusions regarding geologic and seismic suitability of the proposed nuclear power plant site. Licensing conditions established by staff to resolve any significant deficiency identified in the application should be stated in sufficient detail to make clear the precise nature of the concerns and the required resolution. The application is also reviewed for any significant new information derived from site vicinity, site area, or site location geologic, seismic, geophysical, and geotechnical investigations that had not been previously applied to tectonic and ground motion models used in the PSHA.

Determinations ~~regarding~~regarding geologic and seismic suitability of the site are made by staff after CP, OL, or COL application reviews. Conclusions regarding an OL application will include evaluation of excavations for Seismic Category I structures. For COL applications that do not

reference a previous ESP, staff evaluation findings will include the evaluation findings identified above for ESP reviews. ~~Otherwise, conclusions relating to geologic and seismic suitability of a site following a COL application review will be made when the applicant has committed to (1) notifying staff immediately if previously unknown geologic features that could represent a hazard to the plant are discovered in the construction excavations; (2) at a minimum, undertaking detailed geologic mapping of walls and floors of all excavations for Seismic Category I facilities; and (3) notifying staff when the excavations and associated geologic maps are available for examination and evaluation. Staff will visit the COL application site to examine walls and floors of excavations at an appropriate time after licensing to confirm that no evidence exists in the excavations for previously unknown geologic features (e.g., faults, paleoliquefaction features indicative of seismically-induced ground motions, solution cavities) or potentially problematical geologic materials (e.g., soil or rock zones that may result in unanticipated engineering concerns due to liquefaction, heave, excessive settlement, or groundwater flow during or after construction). This staff site visit, in addition to determining whether there is new information of significance for site suitability and safety that was revealed after review of the COL application was completed, will ensure that recommendations or conditions formulated by staff during the COL application review have been implemented. The site visit will also include an appraisal by staff of the applicant's engineering solutions for mitigating any potential non-tectonic geologic hazards.~~

A typical staff finding at the conclusion of the review can be illustrated as follows:

> The staff evaluation of the geologic and seismic information pertaining to this site, as presented by the applicant, is discussed in SER ~~sections~~Sections 2.5.1, 2.5.2, 2.5.3, and 2.5.~~3~~4. The staff concludes that the site is acceptable from geologic and seismic standpoints and meets the requirements of 10 CFR Part 50, Appendix A, General Design Criterion 2 (GDC 2); and 10 CFR 100.23. This conclusion is based on the applicant having met the requirements and guidelines of:
>
> a. General Design Criterion 2 ~~("~~("Design Bases for Protection Against Natural Phenomena~~")~~") of Appendix A ~~("~~("General Design Criteria for Nuclear Power Plants~~")~~") to 10 CFR Part 50 ~~("~~("Domestic Licensing of Production and Utilization Facilities~~")~~") with respect to protection against natural phenomena such as earthquakes, surface deformation, and seismically-induced floods and water waves.
>
> b. 10 CFR 100.23 ~~("~~("Geologic and Seismic Siting Criteria~~")~~") with respect to obtaining geologic and seismic information necessary to determine site suitability and ascertain that any new information derived from site-specific investigations does not impact the GMRS derived by a probabilistic seismic hazard analysis. In complying with this regulation, the applicant also meets guidance in ~~Regulatory Guides~~RGs 1.132 ~~("~~("Site Investigations for Foundations of Nuclear Power Plants~~");~~"); RG 1.~~165~~ ~~("Identification~~138 ("Laboratory Investigations of Soils for Engineering Analysis and ~~Characterization of Seismic Sources~~Design of Nuclear Power Plants"); and ~~Determination of Safe Shutdown Earthquake Ground Motion"); and~~RG 1.208 ~~("~~("A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion~~").~~").

V. IMPLEMENTATION

The staff will use this SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52. Except when the applicant proposes an acceptable alternative method for complying with specified portions of the ~~Commission's~~Commissions regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced ~~regulatory guides~~RGs.

The provisions of this SRP section apply to reviews of applications submitted six months or more after the date of issuance of this SRP section, unless superseded by a later revision.

VI. REFERENCES

1. ~~1. Section~~10 CFR 100.23, ~~"~~"Geologic and Seismic Siting Factors~~,"~~." of 10 CFR Part 100, ~~"~~"Reactor Site Criteria~~."~~."

~~2. General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena," in Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."~~

~~3.~~

2. 10 CFR Part 100, ~~"~~"Reactor Site Criteria~~."~~."

~~4. USNRC, "Site Investigations for Foundations of Nuclear Power Plants," Regulatory Guide1.132.~~

~~5. USNRC, "General Site Suitability Criteria for Nuclear Power Stations," Regulatory Guide 4.7.~~

~~6. USNRC, "Design Response Spectra for Seismic Design of Nuclear Power Plants," Regulatory Guide 1.60.~~

~~7. USNRC, "Combined License Applications for Nuclear Power Plants (LWR Edition)," Regulatory Guide 1.206.~~

3. ~~8. USNRC, "Identification and Characterization of Seismic Sources~~ASCE/SEI 43-05, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities," American Society of Civil Engineers/Structural Engineering Institute, 2005.

A. M. Kammerer, and

~~Determination of Safe Shutdown Earthquake Ground Motion," Regulatory Guide 1.165.~~

~~9. USNRC, "A Performance-Based Approach to Define the Safe Shutdown Earthquake Ground Motion," Regulatory Guide 1.208.~~

3.4. ~~10. Senior Seismic~~ J. P. Ake, "Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard ~~Analysis Committee, "Recommendations for Probabilistic Seismic Hazard~~

Analysis: Guidance on Uncertainty and Use of Experts," Lawrence Livermore National Laboratory, UCRL-ID-122160, August 1995,Studies," NUREG/CR-6372-2117.

4.5. 11. Electric Power Research Institute, 'GuidelinesEPRI, "Guidelines for Determining Design Basis Ground Motions,"," EPRI Report TR--102293, Vols. 1-4, May 1993.

13. 12. R. K. McGuire, W.J. Silva, and C.J. Costantino, "A Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard and Risk-Consistent Ground motion Spectra Guidelines," NUREG/CR-6728. USNRC, Washington DC, Oct. 2001.

14. 13. R. K. McGuire, W.J. Silva, and C.J. Costantino, "A Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Development of Hazard Risk-consistent Seismic Spectra for Two Sites," NUREG/CR-6769. USNRC, Washington DC, Oct. 2002.

5.6. 14. EPRI Report 1009684, ""CEUS Ground Motion Project Final Report,"," 2004.

~~15. USNRC," Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plant," Regulatory Guide 1.138.~~

~~16.~~
~~6.~~7. EPRI Report 1012965, ~~"~~"Use of CAV in Determining Effects of Small Earthquakes on Seismic Hazard Analysis~~,"~~," 2006.

~~7.~~8. ~~17.~~ EPRI Report 1013105, ~~"~~"Truncation of the Lognormal Distribution and Value of the Standard Deviation for Ground Motion Models in the Central and Eastern United States~~,"~~," 2006.

9. Technical Report: Central and Eastern United States Seismic Source Characterization for Nuclear Facilities, EPRI, Palo Alto, CA, U.S. DOE, and U.S. NRC: NUREG-2115, 2012.

10. GDC 2, "Design Bases for Protection Against Natural Phenomena," in Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."

11. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC.

12. RG 1.132, U.S. NRC, "Site Investigations for Foundations of Nuclear Power Plants,"

15. RG 4.7, U.S. NRC, "General Site Suitability Criteria for Nuclear Power Stations,"

16. RG 1.60, U.S. NRC, "Design Response Spectra for Seismic Design of Nuclear Power Plants,"

17. RG 1.206, U.S. NRC, "Combined License Applications for Nuclear Power Plants (LWR Edition),"

18. RG 1.198, U.S. NRC, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites,"

19. RG 1.208, U.S. NRC, "A Performance-Based Approach to Define the Safe Shutdown Earthquake Ground Motion,"

20. RG 1.138, U.S. NRC, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plant,"

~~15.~~21. R. K. McGuire, W.J. Silva, and C.J. Costantino, "A Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard and Risk-Consistent Ground motion Spectra Guidelines," NUREG/CR-6728. U.S. NRC, Washington DC, Oct. 2001.

~~16.~~22. R. K. McGuire, W.J. Silva, and C.J. Costantino, "A Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Development of Hazard Risk-consistent Seismic Spectra for Two Sites," NUREG/CR-6769. U.S. NRC, Washington DC, Oct. 2002.

23. ~~——~~Senior Seismic Hazard Analysis Committee, "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts," Lawrence Livermore National Laboratory, UCRL-ID-122160, August 1995, NUREG/CR-6372.

PAPERWORK REDUCTION ACT STATEMENT

The information collections contained in the Standard Review Plan are covered by the requirements of 10 CFR Part ~~50 and~~ 50 and 10 CFR Part 52, and were approved by the Office of Management and Budget, approval number 3150-0011 and 3150-0151.
~~10 CFR Part 52, and were approved by the Office of Management and Budget, approval number 3150-0011 and 3150-0151.~~

PUBLIC PROTECTION NOTIFICATION

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information
collection requirement unless the requesting document displays a currently valid OMB control number.

SRP Section 2.5.2
Description of Changes

Section 2.5.2 "VIBRATORY GROUND MOTION"

This SRP section affirms the technical accuracy and adequacy of the guidance previously provided in Revision 4, dated March 2007 of this SRP. See ADAMS Accession No. ML070730593. Changes include considerations in areas related to determination of site-specific vibratory ground motion based on lessons learned from past Section 2.5.2 reviews. Each section of the SRP has text that was updated for editorial and clarifying purposes. The technical changes incorporated in Revision 5 are as below:

I. AREAS OF REVIEW

1. Clarified the definition and use of the ground motion response spectra (GMRS).

2. Deleted reference to Regulatory Guide 1.165, which was withdrawn in March 2010 (see 75 FR 22868).

II. ACCEPTANCE CRITERIA

1. Clarified the use of high frequency spectra for plants located in the CEUS due to lessons learned during past reviews.

2. Deleted reference to Regulatory Guide 1.165, which was withdrawn in March 2010 (see 75 FR 22868).

3. Inserted Regulatory Guides 1.138 and 1.198 due to lessons learned during past reviews.

4. Incorporated Interim Staff Guidance document ISG-017.

5. Removed reference to the outdated probabilistic seismic hazard analysis (PSHA) studies of Lawrence Livermore National Laboratory (LLNL) and Electric Power Research Institute (EPRI).

6. Incorporated reference to NUREG-2115.

7. Incorporated reference to NUREG-2117.

8. Updated guidance on the use of the cumulative absolute velocity (CAV) filter in accordance with SECY-12-0025.

9. Clarified the use of vertical and horizontal (V/H) spectral ratios for proposed structures with deep site elevations.

III. REVIEW PROCEDURES

1. Insert reference to design certification (DC) applications.

2. Clarified link between the GMRS and the safe shutdown earthquake (SSE) spectra.

IV. EVALUATION FINDINGS

1. Clarified link with SRP 2.5.4.

2. Deleted reference to Regulatory Guide 1.165, which was withdrawn in March 2010 (see 75 FR 22868).

3. Inserted Regulatory Guides 1.138 and American Society of Civil Engineers/Structural Engineering Institute Standard 43-05 due to lessons learned during past reviews.

VI. REFERENCES

1. Deleted Regulatory Guide 1.165, which was withdrawn in March 2010 (see 75 FR 22868).

2. Inserted Regulatory Guide 1.198.

3. Inserted NUREG-2115.

4. Inserted NUREG-2117.

5. Inserted American Society of Civil Engineers/Structural Engineering Institute Standard 43-05 (ASCE/SEI43-05).

6. Inserted NUREG-0800.