U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN 2.5.2

VIBRATORY GROUND MOTION

SECOND PROPOSED REVISION 3

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Contact: A.J. Murphy
(301)415-6010

REVIEW RESPONSIBILITIES

Primary - Civil Engineering and Geosciences Branch (ECGB)

Secondary - None

AREAS OF REVIEW

The Civil Engineering and Geosciences Branch review covers the seismological, ~~and~~ geological, geophysical, and geotechnical investigations carried out to ~~establish~~ determine ~~the acceleration for~~ the safe shutdown earthquake ground motion (SSE) ~~and the operating basis earthquake (OBE)~~ for the site. ~~The safe shutdown earthquake is that earthquake that is based upon an evaluation of the maximum earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material. It is that earthquake that produces the maximum vibratory ground motion for which safety-related structures, systems, and components are designed to remain functional. The operating basis earthquake is that earthquake that, considering the regional and local geology, seismology, and specific characteristics of local subsurface material, could reasonably be expected to affect the plant site during the operating life of the plant; it is that earthquake~~

This standard review plan is being issued in draft form to involve the public in the early stages of its development. It has not received complete staff review and does not represent an official NRC staff position.

Public comments are being solicited on this draft standard review plan, wich is part of a group of drafts of regulatory guides and standard review plan sections on meeting proposed amendments to the regulations on siting nuclear power plants (59 FR 52255). Comments should be accompanied by appropriate supporting data. Written comments may be submitted to the Rules Review and Directives Branch, DFIPS, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555. Copies of comments received may be examined at the NRC Public Document Room, 2120 L Street NW., Washington, DC. Comments will be most helpful if received by May 12, 1995.

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~~that produces the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public are designed to remain functional.~~ The SSE represents the potential for earthquake ground motion at the site and is the vibratory ground motion for which certain structures, systems, and components are designed to remain functional. The SSE is based upon a detailed evaluation of earthquake potential, taking into account regional and local geology, Quaternary tectonics, seismicity, and specific geotechnical characteristics of the site's subsurface material. The SSE is defined as the free-field horizontal and vertical ground response spectra at the plant site.

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 Section 100.23 to 10 CFR Part 100 (Ref. 1). Additional ~~guidance~~ information (regulations, regulatory guides, and reports) is provided to the staff through References 2 through ~~8~~ 9.

Guidance on seismological and geological investigations is being developed in Draft Regulatory Guide DG-1032, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion." These investigations describe the seismicity of the site region and the correlation of earthquake activity with seismic sources. Seismic sources are identified and characterized, including the rates of occurrence associated with each seismic source. All seismic sources that have any part within 320 km (200 miles) of the site must be identified. More distant sources that have a potential for earthquakes large enough to affect the site must also be identified. Seismic sources can be capable tectonic sources or seismogenic sources; a seismotectonic province is a type of seismogenic source.

Specific areas of review include seismicity (Subsection 2.5.2.1), geologic and tectonic characteristics of the site and region (Subsection 2.5.2.2), correlation of earthquake activity with ~~geologic structure or tectonic provinces~~ seismic sources (Subsection 2.5.2.3), ~~maximum earthquake potential~~ probabilistic seismic hazard analysis (PSHA) and controlling earthquakes (Subsection 2.5.2.4), seismic wave transmission characteristics of the site (Subsection 2.5.2.5), and safe shutdown earthquake ground motion (Subsection 2.5.2.6)~~, and operating basis earthquake (Subsection 2.5.2.7)~~.

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. The results of the geosciences review are used in SRP Sections 3.7.1 and 3.7.2.

II. ACCEPTANCE CRITERIA

The applicable regulations (Refs. 1, 2, and 3) and regulatory guides (Refs. 4, 5, 6, and 9) and basic acceptance criteria pertinent to the areas of this section of the Standard Review Plan are:

1. 10 CFR Part 100, "Reactor Site Criteria" (Ref. 3). This part describes general criteria that guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors.

   Proposed Section 100.23 ~~10 CFR Part 100~~, "Geologic and Seismic Siting Factors," ~~Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants." These criteria~~ describes the ~~kinds of~~ geologic and seismic information needed to determine site suitability and identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants (Ref. 1).

2. 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants"; General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena" (Ref. 2). This criterion requires that safety-related portions of the structures, systems, and components important to safety ~~shall~~ be designed to withstand the effects of earthquakes, tsunamis, and seiches without loss of capability to perform their safety functions.

~~3. 10 CFR Part 100, "Reactor Site Criteria" (Ref. 3). This part describes criteria that guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors.~~

4 3. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants." This guide 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 under anticipated loading conditions, including an earthquake. It provides general guidance and recommendations for developing site-specific investigation programs as well as specific guidance for conducting subsurface investigations, including the spacing and depth of borings as well as sampling intervals (Ref. 4).

~~5~~ 4. Regulatory Guide 4.7 (Proposed Revision 2, DG-4004), "General Site Suitability Criteria for Nuclear Power Stations." This guide discusses the major site characteristics related to public health and safety ~~which~~ that the NRC staff considers in determining the suitability of sites for nuclear power stations (Ref. 5).

~~6~~ 5. Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants." ~~This guide gives one method acceptable to the NRC staff for defining the response spectra corresponding to the expected maximum ground acceleration (Ref. 6). See also~~ Smoothed response spectra are generally used for design purposes - for example, a standard spectral shape that has been used in the past is presented in Regulatory Guide 1.60 (Ref. 6). These smoothed spectra are still acceptable when the smoothed design spectra compare favorably with site-specific response spectra derived from the ground motion estimation procedures discussed in Subsection 2.5.2.6.

6. Draft Regulatory Guide DG-1032 (Ref. 9), "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," is being developed to describe acceptable methodologies for determining the controlling earthquakes and SSE ground motion for nuclear power plant sites.

The principal geologic and seismic consideration for site suitability and geologic and ~~primary required investigations are described in 10 CFR Part 100, in Section IV(a) of Appendix A (Ref. 1) The acceptable procedures for determining the~~ seismic design bases are given ~~in Sections V(a) and Section VI(a) of the appendix.~~ in the proposed Section 100.23 to 10 CFR Part 100. Draft Regulatory Guide DG-1032 (Ref. 9) is being developed to provide more detailed guidance on investigations. The seismic design bases are predicated on a reasonable, conservative determination of the SSE~~ and the OBE~~. ~~As defined in Section III of Appendix A (Ref. 1) to 10 CFR Part 100, the~~ The SSE ~~and OBE are~~ is based on consideration of the regional and local geology and seismology and on the characteristics of the subsurface materials at the site. ~~and are described in terms of the vibratory ground motion that they would produce at the site.~~ No comprehensive definitive rules can be promulgated regarding the investigations needed to establish the seismic design bases; the requirements vary from site to site.

2.5.2.1 Seismicity. ~~In~~ To meet~~ing~~ the requirements ~~of~~ proposed in Reference 1, this subsection is accepted when the complete historical record 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 magnitude greater than or equal to 3.0 that have been reported ~~in all tectonic provinces~~ for all seismic sources, any parts of which are within 320 km (200 miles) of the site. 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 all known events within 80 km (50 miles) of the site. The following information concerning each earthquake is required 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, relatively little information is available on magnitudes for the larger historic earthquakes; hence, it may be appropriate to rely on intensity observations (descriptions of earthquake effects) to estimate magnitudes of historic events (e.g., Refs. ~~34 and 35~~ 10 and 11). In addition, any reported earthquake-induced geologic failure, such as liquefaction (including paleoseimic 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 published sources of information ~~(e.g., Refs. 9 through 13)~~.

When conflicting descriptions of individual earthquakes are found in the published references, the staff should determine which is appropriate for licensing decisions.

2.5.2.2 Geologic and Tectonic Characteristics of Site and Region. In meeting the requirements of References 1, 2, and 3, this subsection is accepted when all ~~geologic structures within the region and tectonic activity~~ seismic sources that are significant in determining the earthquake potential of the region are identified, or when an adequate investigation has been carried out to provide reasonable assurance that all significant ~~tectonic structures~~ seismic sources have been identified. Information presented in Section 2.5.1 of the applicant's safety analysis report (SAR) and information from other sources ~~(e.g., Refs. 9 and 14 through 18)~~ 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. ~~the identified geologic structures~~ Specifically, each ~~tectonic province~~ seismic source, any part of which is within 320 km (200 miles) of the site, must be identified. The staff interprets seismotectonic provinces to be regions of uniform ~~earthquake potential (seismotectonic provinces)~~ seismicity (same frequency of occurrence) distinct from the seismicity of the surrounding area. The proposed seismotectonic provinces may be based on seismicity studies, differences in geologic history, differences in the current tectonic regime, or other tectonic considerations ~~etc~~.

The staff considers that the most important factors for the determination of seismic sources ~~tectonic provinces~~ include both (1) development and characteristics of the current tectonic regime of the region that is most likely reflected ~~in the neotectonics (Post Miocene or about 5~~ in the Quaternary period (approximately the last 2 million years and younger geologic history) and (2) the pattern and level of historical seismicity. Those characteristics of geologic structure, tectonic history, present and past stress regimes, and seismicity that distinguish the various seismic sources ~~tectonic provinces~~ and the particular areas within those sources ~~provinces~~ where historical earthquakes have occurred should be described. Alternative regional tectonic models derived from available literature ~~sources, including previous SARs and NRC staff Safety Evaluation Reports (SERs),~~ should be discussed. The model that best conforms to the observed data is accepted. In addition, in those areas where there are capable ~~faults~~ tectonic sources, the results of the additional investigative requirements described in ~~10 CFR Part 100, Appendix A, Section IV(a)(8) (Ref. 1),~~ SRP Section 2.5.1 must be presented. The discussion should be augmented by a regional-scale map showing the ~~tectonic provinces~~ seismic sources, earthquake epicenters, locations of geologic structures and other features that characterize the seismic sources. ~~, and the locations of any capable faults.~~

2.5.2.3 Correlation of Earthquake Activity with Seismic Sources ~~Geologic Structure or Tectonic Provinces~~. ~~In meeting~~ To meet the requirements proposed in ~~of~~ Reference 1, acceptance of this subsection is based on the development of the relationship between the history of earthquake activity and ~~the geologic structures or tectonic provinces~~ seismic sources of a region. The applicant's presentation is accepted when the earthquakes discussed in Subsection 2.5.2.1 of the SAR are shown to be associated with ~~either geologic structure or tectonic province~~ 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 ~~tectonic province~~ seismotectonic province. Particular attention should be given to determining the ~~capability~~ recency and level of activity of faults with which instrumentally located earthquake hypocenters ~~are~~ may be associated.

~~The presentation should be augmented by regional maps, all of the same scale, showing the tectonic provinces, the earthquake epicenters, and the locations of geologic structures and measurements used to define provinces.~~ Acceptance of the proposed ~~tectonic provinces~~ seismic sources is based on the staff's independent review of the geologic and seismic information presented by the applicant and available in the scientific literature.

2.5.2.4 ~~Maximum Earthquake Potential~~ Probabilistic Seismic Hazard Analysis (PSHA) and Controlling Earthquakes (CE). ~~In meeting the requirements of Reference 1, this subsection is accepted when the vibratory ground motion due to the maximum credible earthquake associated with each geologic structure or the maximum historic earthquake associated with each tectonic province has been assessed and when the earthquake that would produce the maximum vibratory ground motion at the site has been determined. The maximum credible earthquake is the largest earthquake that can reasonably be expected to occur on a geologic structure in the current tectonic regime. Geologic or seismological evidence may warrant a maximum earthquake larger than the maximum historic earthquake. Earthquakes associated with each geologic structure or tectonic province must be identified. Where an earthquake is associated with a geologic structure, the maximum credible earthquake that could occur on that structure should be evaluated, taking into account significant factors, for example, the type of the faulting, fault length, fault slip rate, rupture length, rupture area, moment, and earthquake history (e.g., Refs. 19 through 22).~~

~~In order to determine the maximum credible earthquake that could occur on those faults that are shown or assumed to be capable, the staff accepts conservative values based on historic experience in the region and specific considerations of the earthquake history and geologic history of movement on the faults. Where the earthquakes are associated with a tectonic province, the largest historic earthquake within the province should be identified. Isoseismal maps should also be presented for the most significant earthquakes. The ground motion at the site should be evaluated assuming appropriate seismic energy transmission effects and assuming that the maximum earthquake associated with each geologic structure or with each tectonic province occurs at the point of closest approach of the structure or province to the site. (Further description is provided in Subsection 2.5.2.6.)~~

~~The earthquake(s) that would produce the most severe vibratory ground motion at the site should be defined. If different potential earthquakes would produce the most severe ground motion in different frequency bands, these earthquakes should be specified. The description of the potential earthquake(s) is to include the maximum intensity or magnitude and the~~

~~distance from the assumed location of the potential earthquake(s) to the site. The staff independently evaluates the site ground motion produced by the largest earthquake associated with each geologic structure or tectonic province.~~

~~Acceptance of the description of the potential that would produce the largest ground motion at the site is based on the staff's independent analysis.~~

The staff will review the applicant's probabilistic seismic hazard analysis, including the underlying assumptions and how the results of the site investigations and findings of Sections 2.5.2.2 and 2.5.2.3 are used to update the existing sources in the probabilistic seismic hazard analysis, how they are used to develop additional sources, or how they are used to develop a new data base.

The staff will perform an independent evaluation of the earthquake potential associated with each seismic source that could affect the site. The staff will evaluate the applicant's controlling earthquakes based on historical and paleo-seismicity. In this evaluation, the controlling earthquakes for each source are at least as large as the maximum historic earthquake. The staff will review the controlling earthquakes and associated ground motions at the site derived from the applicant's probabilistic hazard analysis to be sure that they are either consistent with the controlling earthquakes/ground motions used in licensing of (a) other licensed facilities at the site, (b) nearby plants, or (c) plants licensed in similar seismogenic regions, or the reasons they are not consistent are understood.

The applicant's probabilistic analysis is considered acceptable if it follows the procedure proposed in Appendix C of DG-1032 (Ref. 9). The incorporation of results of site investigations into the probabilistic analysis is considered acceptable if it follows the procedure outlined in Appendix E of DG-1032 and is consistent with the review findings of Sections 2.5.2.2 and 2.5.2.3.

<u>2.5.2.5 Seismic Wave Transmission Characteristics of the Site</u>. In the PSHA procedure described in DG-1032 (Ref. 9), the controlling earthquakes are determined for actual or hypothetical rock conditions. The

site amplification studies are performed in a distinct separate step as a part of the determination of the SSE. In this section the applicant's site amplification studies are reviewed in conjunction with geotechnical and structural engineering.

~~In meeting the requirements of Reference 1, this subsection is accepted when~~ 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.12). 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 water table elevation and its variation (Ref. 13). In each case, methods used to determine the properties should be described in Subsection 2.5.4 of the SAR and cross-referenced in this subsection. ~~For the maximum earthquake determined in Subsection 2.5.2.4, the free-field ground motion (including significant frequencies) must be determined, and an analysis should be performed to determine the site effects on different seismic wave types in the significant frequency bands. If appropriate, the analysis should consider the effects of site conditions and material property variations upon wave propagation and frequency content.~~

~~The free-field ground motion (also referred to as control motion) should be defined to be on a ground surface and should be based on data obtained in the free field. Two cases are identified, depending on the soil characteristics at the site and subject to availability of appropriate recorded ground motion data. When data are available, for example, for relatively uniform sites of soil or rock with smooth variation of properties with depth, the control point (location at which the control motion is applied) should be specified on the soil surface at the top of the finished grade. The free-field ground motion or control motion should be consistent with the properties of the soil profile. For sites composed of one or more thin soil layers overlying a competent material, or in case of insufficient recorded ground motion data, the control point is specified on an outcrop or a hypothetical outcrop at a location on the top of the competent material. The control motion specified should be consistent with the properties of the competent material.~~

Where vertically propagating shear waves may produce the maximum ground motion, a one-dimensional equivalent-linear analysis (e.g., Ref. ~~23 or 24~~ 14 or 15) or nonlinear analysis (e.g., Refs. ~~25, 26, and 27~~ 16, 17, or 18) may be appropriate and is reviewed in conjunction with geotechnical and structural engineering. Where horizontally propagating shear waves, compressional waves, or surface waves may produce the maximum ground motion, other methods of analysis (e.g., Refs. ~~28 and 29~~ 19 and 20) may be more appropriate. However, since some of the variables are not well defined and the techniques are still in the developmental stage, no generally agreed-upon procedures can be promulgated at this time. Hence, the staff must use discretion in reviewing any method of analysis. To ensure appropriateness, site response characteristics determined from analytical procedures should be compared with historical and instrumental earthquake data, when available.

2.5.2.6 Safe Shutdown Earthquake Ground Motion. ~~In meeting the requirements of Reference 1, this subsection is accepted when the vibratory ground motion specified for the SSE is described in terms of the free field response spectrum and is at least as conservative as that which would result at the site from the maximum earthquake determined in Subsection 2.5.2.4, considering the site transmission effects determined in Subsection 2.5.2.5. If several different maximum potential earthquakes produce the largest ground motions in different frequency bands (as noted in Subsection 2.5.2.4), the vibratory ground motion specified for the SSE must be as conservative in each frequency band as that for each earthquake.~~

In this subsection, the staff reviews the applicant's procedure to determine the SSE, including the procedure used to derive spectral shape from the controlling earthquakes as described in Reference 9.

As a part of the review to judge the adequacy of the SSE proposed by the applicant, the staff performs an independent evaluation of ground motion estimates, as required. In these independent estimates, the staff may consider effects on ground motion from the controlling earthquakes discussed in Subsection 2.5.2.4 by assuming the controlling earthquake for each seismic source (geological structures or seismotectonic provinces) to be at its closest approach to the site.

~~The staff reviews the free field response spectra of engineering significance (at appropriate damping values). Ground motion may vary for different foundation conditions at the site. When the site effects are significant, this review is made in conjunction with the review of the design response spectra in Section 3.7.1 to ensure consistency with the free field motion. The staff normally evaluates response spectra on a case by case basis. The staff considers compliance with the following conditions acceptable in the evaluation of the SSE. In all these procedures, the proposed free field response spectra shall be considered acceptable if they equal or exceed the estimated 84th percentile ground motion spectra from the maximum or controlling earthquake described in Subsection 2.5.2.4.~~

The following procedures (in descending order of preference) should be used to develop the site-specific spectral shapes for controlling earthquakes. The staff will also use these procedures to make its independent ground motion estimates. In the following procedures, 84th percentile response spectra are used for both spectral shape as well as ground motion estimates.

~~The following steps summarize the staff review of the SSE.~~

1. Both horizontal and vertical component site-specific response spectra should be developed statistically from response spectra of recorded strong motion records that are selected to have similar source, propagation path, and recording site properties as the controlling earthquakes. It must be ensured that the recorded motions represent free-field conditions and are free of or corrected for any soil-structure interaction effects that may be present because of locations ~~and/~~or housing of recording instruments. Important source properties include magnitude and, if possible, fault type~~,~~ and tectonic environment. Propagation path properties include distance, depth, and attenuation. Relevant site properties include shear velocity profile and other factors that affect the amplitude of waves at different frequencies. A sufficiently large number of site-specific time-histories or response spectra or both should be used to obtain an adequate~~ly~~ broadband spectrum to encompass the uncertainties in these parameters. An 84th percentile response spectrum for the records should be presented for each damping value of interest. ~~and compared to the SSE~~

~~free field and design response spectrum~~ (e.g., Refs. ~~30, 31, 32, and 33~~ 21, 22, 23, and 24). The staff considers direct estimates of spectral ordinates preferable to scaling of spectra to peak accelerations. ~~In the Eastern United States, relatively little information is available on magnitudes for the larger historic earthquakes; hence, it may be appropriate to rely on intensity observations (descriptions of earthquake effects) to estimate magnitudes of historic events (e.g., Refs. 34 and 35).~~ If the data for site-specific response spectra were not obtained under geologic conditions similar to those at the site, corrections for site effects should be included in the development of the site-specific spectra.

2. Where a large enough ensemble of strong-motion records is not available, response spectra may be approximated by scaling that ensemble of strong-motion data that represent the best estimate of source, propagation path, and site properties (e.g., Ref. ~~36~~ 25). Sensitivity studies should show the effects of scaling.

3. If strong-motion records are not available, site-specific peak ground acceleration, velocity, and displacement (if necessary) should be determined for appropriate magnitude, distance, and foundation conditions. Then response spectra may be determined by scaling the acceleration, velocity, and displacement values by appropriate amplification factors (e.g., Ref. ~~37~~ 26). ~~Where only estimates of peak ground acceleration are available, it is acceptable to select a peak acceleration and use this peak acceleration as the high frequency asymptote to standardized response spectra such as described in Regulatory Guide 1.60 (Ref. 6) for both the horizontal and vertical components of motion with the appropriate amplification factors.~~ For each controlling earthquake, the peak ground motions should be determined using current relations between acceleration, velocity, and, if necessary, displacement, earthquake size (magnitude or intensity), and source distance. Peak ground motion should be determined from state-of-the-art relationships. Relationships between magnitude and ground motion are found, for example, in References 12 and 27. ~~Due to~~ Because of the limited data for high intensities greater than Modified Mercalli Intensity (MMI) VIII, the available empirical relationships between intensity and peak ground

motion may not be suitable for determining the appropriate reference acceleration for seismic design.

4. ~~Response~~ Spectra developed by theoretical-empirical modeling of ground motion may be used to supplement site-specific spectra if the input parameters and the appropriateness of the model are thoroughly documented (e.g., Refs. ~~19, 44, 45, and 46~~ 12, 27, and 28). Modeling is particularly useful for sites near capable ~~faults~~ tectonic sources or for deeper structures that may experience ground motion that is different in terms of frequency content and wave type from ground motion caused by more distant earthquakes.

~~5. Probabilistic estimates of seismic hazard should be calculated (e.g., Refs. 41 and 47) and the underlying assumptions and associated uncertainties should be documented to assist in the staff's overall deterministic approach. The probabilistic studies should highlight which seismic sources are significant to the site. Uniform hazard spectra (spectra that have a uniform probability of exceedance over the frequency range of interest) showing uncertainty should be calculated for 0.01, 0.001, and 0.0001 annual probabilities of exceedance at the site. The probability of exceeding the SSE response spectra should also be estimated and comparison of results made with other probabilistic studies.~~

The SSE ground motion response spectra proposed by the applicant are considered acceptable if they meet Regulatory Position 4 and Appendix F of Reference 9. If the independent staff estimates of ground motion are significantly different than those proposed by the applicant, the staff will review the reasons for differences and resolve them as appropriate.

The time duration and number of cycles of strong ground motion are required for analysis ~~of site foundation liquefaction potential~~ and ~~for~~ design of many plant components. The adequacy of the time history for structural analysis is reviewed under SRP Section 3.7.1. The time history is reviewed in this SRP section to confirm that it is compatible with the seismological and geological conditions in the site vicinity and with the accepted SSE model. At present, models for ~~deterministically~~ computing the time history of strong ground motion from a given source-site configuration ~~may be~~ may limited. It is therefore acceptable to use an ensemble of ground-motion time histories from earthquakes with similar size, site-source characteristics, and spectral characteristics or results of a statistical analysis of such an ensemble. Total duration of the motion is acceptable when it is as conservative as values determined using current studies such as References ~~48, 49, 50, and 51~~ 29, 30, 31, and 32.

For evaluation of the liquefaction potential at the site, the time duration and number of cycles of strong ground motion are more 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 have duration and number of strong motion cycles corresponding to at least an event of magnitude 6, unless a larger event is more appropriate.

~~2.5.2.7 Operating Basis Earthquake. In meeting the requirements of Reference 1, this subsection is acceptable when the vibratory ground motion for the OBE is described and the response spectrum (at appropriate damping values) at the site specified. Probability calculations (e.g., Refs. 41, 47, and 52) should be used to estimate the probability of exceeding the OBE during the operating life of the plant. The maximum vibratory ground motion of the OBE should be at least one-half the maximum vibratory ground motion of the SSE unless a lower OBE can be justified on the basis of probability calculations. It has been staff practice to accept the OBE if the return period is on the order of hundreds of years (e.g., Ref. 31).~~

III. REVIEW PROCEDURES

Upon receiving the applicant's SAR, an acceptance review is conducted to determine compliance with the proposed investigative requirements of 10 CFR Part 100, Section 100.23 ~~Appendix A~~ (Ref. 1). The reviewer also identifies any site-specific problems, the resolution of which could result in extended delays in completing the review.

After SAR acceptance and docketing, ~~those areas are identified where~~ the reviewer identifies areas that need additional information ~~is required~~ to support the review of the applicant's seismic design ~~determine the earthquake hazard~~. These are transmitted to the applicant as ~~draft~~ requests for additional information.

A site visit may 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 if the review is for an operating license. The reviewer also discusses the questions with the applicant and his consultants so that it is clearly understood what additional information is required by the staff to continue the review. ~~Following the site visit, a revised set of requests for additional information, including any additional questions that may have been developed during the site visit, is formally transmitted to the applicant.~~

The reviewer evaluates the applicant's response to the questions, prepares requests for any additional ~~clarifying~~ information, and formulates positions that may agree or disagree with those of the applicant. These are formally transmitted to the applicant.

The Safety Analysis Report 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, ~~or from~~ staff consultants, or literature sources, the reviewer independently identifies and evaluates the relevant ~~seismotectonic provinces~~ seismic sources, including their ~~evaluates the~~ capability~~ of faults in the region~~, and determines the earthquake potential for each ~~province and each capable fault or tectonic structure~~ using procedures noted in Section II (Acceptance Criteria) above. The reviewer evaluates the vibratory ground motion that the ~~potential earthquakes~~ controlling earthquakes could produce at the site and ~~defines~~ compares that ground motion to the SSE. ~~safe shutdown earthquake and operating basis earthquake~~.

IV. EVALUATION FINDINGS

~~If the evaluation by the staff,~~ On completion of the review of the geologic and seismologic aspects of the plant site, if the evaluation by the staff confirms that the applicant has met the requirements or guidance of applicable portions of References 1 through 6 and 9, the conclusion in the SER states that the *information provided and investigations performed support the* applicant's conclusions regarding the seismic integrity of the subject nuclear power plant site. In addition to the conclusion, this section of the SER includes an evaluation of (1) ~~definitions of tectonic provinces~~ seismic sources, (2) ~~evaluations of~~ the capability of geologic structures in the region, (3) ~~determinations of the SSE earthquake(s) and~~ controlling earthquakes and associated free-field response spectra ~~based on evaluation of the potential~~ ~~earthquakes~~, (4) the SSE, and (~~5~~ 4) the time history of strong ground motion~~, and (5) determinations of the OBE free-field response spectra~~. Staff reservations about any significant deficiency presented in the applicant's SAR are stated in sufficient detail to make clear the precise nature of the concern. In addition, the staff will also note the results of its independent analyses, if performed, and discuss how these results were used in the safety evaluation. The above evaluations ~~determinations or redeterminations~~ are made by the staff during ~~both~~ the construction permit (CP), ~~and~~ operating license (OL), combined license (COL), or early site permit phases of review as appropriate.

OL applications are reviewed for any new information developed subsequent to the CP ~~safety evaluation report~~ SER. The review will also determine whether the CP recommendations have been implemented.

A typical OL-stage summary finding for this section of the SER follows:

> In our review of the seismologic aspects of the plant site, we have considered pertinent information gathered since our initial seismologic review ~~which~~ that was made in conjunction with the issuance of the Construction Permit. This new information includes data gained from both site and near-site investigations as well as from a review of recently published literature.

As a result of our recent review of the seismologic information, we have determined that our earlier conclusion regarding the safety of the plant from a seismological standpoint remains valid. These conclusions can be summarized as follows:

1. Seismologic information provided by the applicant and required by ~~Appendix A~~ Section 100.23 ~~to~~ of 10 CFR Part 100 provides an adequate basis to establish that no ~~capable faults~~ seismic sources exist in the plant site area ~~which~~ that would cause earthquakes to be centered there.

2. The response spectrum proposed for the safe shutdown earthquake is the appropriate free-field response spectrum in conformance with ~~Appendix A~~ Section 100.23 of ~~to~~ 10 CFR Part 100.

The new information reviewed for the proposed nuclear power plant is discussed in Safety Evaluation Report Section 2.5.2.

The staff concludes that the site is acceptable from a seismologic standpoint and meets the requirements of (1) 10 CFR Part 50, Appendix A (General Design Criterion 2), (2) 10 CFR Part 100, and (3) 10 CFR Part 100, ~~Appendix A~~ Section 100.23. This conclusion is based on the following:

1. The applicant has met the requirements of:

   a. 10 CFR Part 50, Appendix A, General Design Criterion 2 with respect to protection against natural phenomena such as faulting.

   b. 10 CFR Part 100, Reactor Site Criteria, with respect to the identification of geologic and seismic information used in determining the suitability of the site.

   c. 10 CFR Part 100, ~~Appendix A (Seismic and Geologic Siting Criteria for Nuclear Power Plants)~~ Section 100.23 (Ref. 1) with respect to obtaining the geologic and seismic information necessary to determine (1) site suitability and (2) the appropriate design of the plant. Guidance for complying with this regulation is contained in Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants" (Ref. 4); Draft Regulatory Guide DG-1032, "Identification and Characterization of Seismic Sources and Safe Shutdown Earthquake Ground Motion" (Ref. 9); and Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations" (Proposed Revision 2) (Ref. 5)~~; and Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants" (Ref. 6)~~.

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant or licensee proposes an acceptable alternative method for complying with specific portions of the Commission's regulations, the methods described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides and NUREGs (Refs. 4 through ~~8~~ 9).

The provisions of this SRP section apply to reviews of construction permits (CP), operating licenses (OL), early site permits, ~~preliminary design approval (PDA), final design approval (FDA),~~ and combined license (CP/OL) applications docketed pursuant to the proposed Section 100.23 to 10 CFR Part 100. ~~after the date of issuance of this SRP section.~~

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