U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

2.5.3 SURFACE FAULTING

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of basic geologic and seismic information

Secondary - None

I. AREAS OF REVIEW

Chapter 2 of the 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 potential for surface deformation due to faulting. This SRP section applies to reviews performed for each of these types of applications.

The information related to surface deformation due to faulting is collected by the applicant during site characterization investigations. The primary purposes for conducting these investigations are to determine site suitability in regard to whether there is a possibility of significant ground motion that could impact seismic design bases as determined by probabilistic seismic hazard analysis, or PSHA (References 1 through 4), and to provide the bases for plant design. The objective of this SRP section is to enable review of results of the investigations and assessment of surface deformation due to faulting as it may affect the site. Review and acceptance of basic data-gathering processes and findings presented by the applicant to support the assessment of surface faulting, and completeness of this information, are integral parts of the review responsibilities defined in this section.

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NRC staff reviews the geologic, seismic, geophysical, and geotechnical information submitted by an applicant. This technical information results primarily from detailed surface and subsurface geologic, seismic, geophysical, and geotechnical investigations, performed in progressively greater detail closer to the site, within each of three areas defined by circles drawn around the site using radii of 40 km (25 mi), 8 km (5 mi), and 1 km (0.6 mi). These three circumscribed areas correspond, respectively, to site vicinity, site area, and site location.

The geologic, seismic, geophysical, and geotechnical information provided by an applicant in the Safety Analysis Report (SAR) to support the license application addresses the following specific topics related to surface faulting (SAR Section 2.5.3): geologic, seismic, and geophysical investigations; geologic evidence, or absence of evidence, for tectonic surface deformation; correlation of earthquakes with capable tectonic sources; ages of most recent deformation; relationship of tectonic structures in the site area to regional tectonic structures; characterization of capable tectonic sources; designation of zones of Quaternary deformation in the site region; and potential for surface tectonic deformation at the site. As part of the process for review of potential surface faulting issues, the reviewer evaluates the technical information provided by the applicant, with an emphasis on the Quaternary Period. The Quaternary is defined as the geologic period running from 1.8 million years ago (mya) to the Present (Reference 5).

1. Geologic, Seismic, and Geophysical Investigations (SAR Section 2.5.3.1). The reviewer assesses information provided by an applicant related to Quaternary tectonics, structural geology, stratigraphy, geochronological methods used for age dating, paleoseismology, and geologic history of the site vicinity, site area, and site location to ensure it is complete; compares well with data from other studies carried out in the same areas; and is supported by detailed investigations conducted by the applicant. For coastal and inland sites near large bodies of water, similar detailed investigations are to be conducted by the applicant for onshore and offshore geology and seismology. The reviewer also assesses results of these detailed investigations.

2. Geologic Evidence, or Absence of Evidence, for Tectonic Surface Deformation (SAR Section 2.5.3.2). The reviewer assesses surface and subsurface information provided by an applicant for the site vicinity, site area, and site location to confirm presence or absence of tectonic surface deformation (i.e., faulting) and, if present, to demonstrate age of most recent fault displacement and chronology of previous displacements. If surface faulting is present, information provided must also include data on fault geometry (i.e., fault orientation, length, and width), amount and sense of displacement, and recurrence rate. Information provided by the applicant should enable the reviewer to determine that undetected fault offsets (e.g., blind faults) or other types of tectonic surface deformation (e.g., folding, uplift, or subsidence which may indicate a blind fault) are not likely to exist.

3. Correlation of Earthquakes with Capable Tectonic Sources (SAR Section 2.5.3.3). The reviewer evaluates information on all historically-reported earthquakes within 40 km (25 mi) of the site (i.e., in the site vicinity) in regard to hypocenter location accuracy and origin of source. To determine the potential for induced surface deformation, the reviewer also assesses information pertaining to capable tectonic sources that could, based on fault geometry (including fault orientation, length, and width), extend into the site area or to the site location.

4. Ages of Most Recent Deformations (SAR Section 2.5.3.4). The reviewer determines whether age of most recent fault displacement has been demonstrated, or acceptably estimated, by an applicant for each significant fault or fold associated with a blind fault, any part of which lies within 8 km (5 mi) of the site (i.e., in the site area). The reviewer also determines whether geologic evidence for previous displacements has been identified, and assesses sensitivity and resolution of the investigative methods applied by the applicant for acquiring the information.

5. Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures (SAR Section 2.5.3.5). The reviewer examines information presented by an applicant on structural and genetic relationships between site area faulting or other tectonic deformation features and regional tectonic framework to determine, if such relationships exist, that they are adequately described in regard to potential for inducing tectonic surface deformation at the site location.

6. Characterization of Capable Tectonic Sources (SAR Section 2.5.3.6). The reviewer evaluates the application to determine whether a sufficiently detailed investigation has been conducted by the applicant to define specific characteristics of all potential capable tectonic sources, any part of which is located within 8 km (5 mi) of the site (i.e., in the site area). This review should demonstrate that there is little likelihood of near-surface deformation hazard associated with capable tectonic sources existing, but undetected, at or near the site location.

7. Designation of Zones of Quaternary Deformation in the Site Region (SAR Section 2.5.3.7). The reviewer evaluates the application to determine whether the zone (or zones) designated by the applicant as requiring detailed fault investigations is of sufficient length and width to include all Quaternary deformation features potentially significant for the site.

8. Potential for Surface Tectonic Deformation at the Site (SAR Section 2.5.3.8). If investigations reveal that tectonically-induced surface displacement must be taken into account for the site, this section provides staff recommendations regarding re-location of the plant site.

9. Additional Information for 10 CFR Part 52 Applications. 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 requirements are prescribed within the “Contents of Application” sections of the applicable Subparts to 10 CFR Part 52.

The reviewer confirms that information provided by the applicant is documented through appropriate references to all relevant published and unpublished materials. Illustrative materials provided to document site characteristics should include, but are not necessarily limited to, structural, tectonic, physiographic, topographic, geologic, gravity, and magnetic maps; geologic cross-sections showing soil horizons, stratigraphy, lithology, and structure; geologic maps of trenches and test pits; seismic reflection or refraction and other geophysical survey profiles; soil and core boring logs; geophysical borehole logs; aerial photographs; and satellite imagery. Some sites may require maps illustrating areas of subsidence, karst features,

mechanically weak zones of soil and rock, paleoliquefaction features, irregular weathering conditions and weathering depths, landslide potential, locations of oil and gas wells, faults, and joints. Maps should include superimposed plot plans of plant facilities, and the relationship of all Seismic Category I facilities to subsurface geology should be illustrated. Locations of all plant structures, borings, trenches, test pits, seismic and geophysical data collection profiles, and geologic cross-sections should also be included on plot plans. All geologic terminology used should conform to that found in standard references (Reference 7).

Applying knowledge derived from the application, other published and unpublished scientific literature, and the reviewer's own academic background and practical experience in geoscience, the reviewer assesses adequacy of the geologic, seismic, geophysical, and geotechnical information cited in support of the applicant's conclusions concerning suitability of the plant site. Staff may bring the review to an earlier completion if the application contains sufficient data to enable an independent assessment of the conclusions therein. Depending on completeness of the application, staff also may conduct a literature search at an appropriate level of detail. However, the application and its supporting information should enable staff to logically progress from data and assumptions to conclusions drawn without the need for an extensive independent literature search. Staff should present and evaluate all pertinent data, including information which is potentially controversial.

Review Interfaces

Other SRP sections interface with this section as follows:

1. Review and acceptance of the applicant's basic data-gathering processes and findings that are presented in support of the geologic and seismic assessments, and completeness of this information, is performed under SRP Section 2.5.1 on "Basic Geologic and Seismic Information."

2. Review of historical earthquake data to determine the Ground Motion Response Spectrum (GRMS) is performed under SRP 2.5.2 on "Vibratory Ground Motion."

3. 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.

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

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

II. ACCEPTANCE CRITERIA

Requirements

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

1. 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena" 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.

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

3. 10 CFR 100.23, "Geologic and Seismic Siting Criteria," as it relates to determining the potential for surface tectonic and non-tectonic deformations at and in the region surrounding the site.

SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the 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 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 are used by the staff for the identified acceptance criteria:

Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motions," 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 and Reference 3).

Regulatory Guide 1.208, "A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion," describes methods acceptable for (1) conducting geologic, geophysical, seismologic, and geotechnical investigations; (2) identifying and characterizing seismic sources; (3) performing PSHA; (4) determining seismic wave transmission characteristics of soil and rock sites; and (5) determining site-specific,

performance-based earthquake ground motion leading to establishing an GMRS. This regulatory guide offers an alternative to Regulatory Guide 1.165 for satisfying requirements of 10 CFR 100.23 and Appendix S to 10 CFR Part 50.

Regulatory Guide 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. This regulatory guide 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 Guide 1.198, “Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites,” describes acceptable methods for evaluating potential for earthquake-induced instability of soils resulting from liquefaction and consequent strength degradation.

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

Regulatory Guide 1.206, “Combined License Applications for Nuclear Power Plants - LWR Edition,” discusses guidance for combined license applications for nuclear power plants (LWRs).

The reviewer should confirm that information provided in the application is complete; properly documented; consistent with requirements of 10 CFR 100.23; shows that methods described in Regulatory Guide 1.165, 1.208, or comparable methods, were employed for identifying and characterizing seismic sources and defining the GMRS; and conforms to format suggested in Regulatory Guide 1.206. For evaluating completeness and acceptability of the application, the reviewer should use published and unpublished scientific information derived from various sources that present geologic, geotechnical, seismic, geophysical, and related pertinent data for the site vicinity and site area in which the site is located. These sources include the United States Geological Survey (USGS); other Federal and State agencies; and academia, industry, and non-governmental and professional organizations. It is the responsibility of the reviewer to remain up-to-date on geologic, geotechnical, geophysical, and seismic information for the site vicinity, site area, and site location by regularly reviewing current scientific literature deemed pertinent and participating in professional meetings at which this information is presented.

The reviewer must ensure that investigations described in Regulatory Guides 1.165, 1.132, 1.198, 1.208, and 4.7 are conducted with an appropriate level of thoroughness by the applicant within each of the three areas designated in Regulatory Guide 1.165 and 1.208. These three areas are defined by circles drawn around the site using radii of 40 km (25 mi) for site vicinity, 8 km (5mi) for site area, and 1 km (0.6 mi) for site location. The site area and site location must be investigated by a combination of exploratory methods that include borings, trenching, geologic mapping, and geophysical, seismic, and geotechnical field investigations. Exploration results must be compared with other available data and evaluated by staff. The reviewer should confirm that sufficient information is presented in the application to enable a comparison

between new data derived from investigations in the site vicinity, site area, and site location and those data used in tectonic and ground motion models for PSHA.

1. Geologic, Seismic, and Geophysical Investigations. Requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17, and 10 CFR 100.23 are met and guidance in Regulatory Guides 1.165, 1.132, 1.198, 1.208, and 4.7 followed for this area of review if discussions of Quaternary tectonics, structural geology, stratigraphy, geochronologic methods used for age dating, paleoseismology, and geologic history of the site vicinity, site area, and site location are complete, compare well with studies conducted by others in the same area, and are supported by detailed investigations performed by the applicant. Site vicinity, site area, and site location-specific geologic maps and cross-sections constructed at scales adequate to clearly illustrate surficial and bedrock geology, structural geology, topography, and relationship of power plant foundations to these features should be included in the application.

   For coastal and inland sites near large bodies of water, similar detailed investigations are to be conducted and the application should include information regarding onshore and offshore geology and seismicity. In some cases, it may be possible to identify onshore expression of an offshore tectonic structure (i.e., a fault or fold) of potential concern. As expressed in Regulatory Guide 1.165, Appendix D, and RG 1.208, Appendix C, under this condition it is acceptable for the applicant to investigate expression of the offshore structure in the onshore environment, along with other investigations of the offshore feature when possible, to better evaluate characteristics of the tectonic structure in the site vicinity and site area and at the site location.

2. Geologic Evidence, or Absence of Evidence, for Surface Tectonic Deformation. Requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17, and 10 CFR 100.23 are met and guidance in Regulatory Guides 1.165, 1.132, 1.198, 1.208, and 4.7 followed for this area of review if sufficient surface and subsurface information is provided by the applicant for the site vicinity, site area, and site location to confirm presence or absence of surface tectonic deformation (i.e., faulting) and, if present, to demonstrate age of most recent fault displacement and ages of previous displacements. If surface faulting is present, the faults must be characterized in regard to fault geometry (i.e., fault orientation, length, and width), amount and sense of displacement, and recurrence rate.

   In addition to geologic field evidence that may indicate faulting, linear features interpreted from topographic maps, low and high altitude aerial photographs, satellite imagery, and other types of imagery should be examined and their use documented. To expedite the review process, an identification index and duplicates of remote sensing data used in the linear features study should be provided to staff for review. Data to assess presence or absence of tectonic deformation at or near the site is obtained by an applicant through conduct of surface (e.g., imagery analysis, geologic reconnaissance, and geologic mapping to define fault traces) and subsurface (e.g., using seismic instrumentation, geophysical surveys at the ground surface and in boreholes, geologic and geotechnical logging of soil materials and rock core in boreholes, and geologic mapping of trenches and test pits to define paleoseismic features and fault surfaces) investigations.

Nature of geologic, seismic and paleoseismic, geophysical, and geotechnical investigations to determine whether or not undetected fault displacements or other tectonic deformation features (e.g., folds related to blind faults) are likely to exist will vary in degree of detail and extent required based on geologic complexity of the specific site. In the Central and Eastern United States (CEUS) region, defined as that part of the United States east of the Rocky Mountain Front, with the exception of the New Madrid Seismic Zone of the Central Mississippi Valley (extending from northeast Arkansas, southeast Missouri, western Tennessee, and western Kentucky to southern Illinois), the Meers Fault in southwestern Oklahoma, and the Cheraw fault in eastern Colorado, earthquake-generating faults either do not extend to the ground surface or there is insufficient overlying soil or rock for reliable age dating. In the Western United States, many capable faults are exposed at the ground surface and can be more readily characterized with respect to seismic hazard potential. In the Western region, capable tectonic sources (including faults related to subduction zones) also exist as blind faults which may be expressed at the surface or near-surface only by folding, uplift, or subsidence, and these phenomena should be taken into account by an applicant for a site located in that region.

3. Correlation of Earthquakes with Capable Tectonic Sources. Requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17, and 10 CFR 100.23 are met for this area of review if all reported historical earthquakes within the site vicinity are evaluated with respect to accuracy of hypocenter location and source of origin, and if all capable tectonic sources that could, based on fault orientation and length, extend into the site area or site location are evaluated with respect to potential for causing surface deformation. The application should include a plot of earthquake epicenters superimposed on a map showing local capable tectonic sources.

4. Ages of Most Recent Deformation. Requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17, and 10 CFR 100.23 are met for this area of review if every significant surface fault and feature associated with a blind fault, any part of which lies within the site area, is investigated in sufficient detail to demonstrate, or allow relatively accurate estimates of, age of most recent fault displacement and enable identification of geologic evidence for previous displacements (if such evidence exists). The application should also provide an evaluation of sensitivity and resolution of the exploratory geologic and geophysical techniques used that is adequate for staff to determine whether or not appropriate techniques were applied to assess age of the most recent displacement.

5. Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures. Requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17, and 10 CFR 100.23 are satisfied for this area of review by discussion of structural and genetic relationships between site area faulting or other tectonic deformation and the regional tectonic framework. In regions of active tectonism, it may be necessary to conduct detailed geological and geophysical investigations for assessing possible relationships of site area faults to regional faults which are known to be seismically active.

6. Characterization of Capable Tectonic Sources. Requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17, and 10 CFR 100.23 are met for this area of review when it has been demonstrated that investigative techniques employed by the applicant are sufficiently sensitive to identify all potential capable tectonic sources, such as faults

or structures associated with blind faults, within the site area; and when fault geometry, length, sense of movement, amount of total displacement and displacement per faulting event, age of latest and any previous displacements, recurrence rate, and limits of the fault zone are provided for each capable tectonic source. Investigations must extend to at least 8 km (5 mi) beyond all plant site boundaries to encompass the site area, including for those sites adjacent to large bodies of water such as oceans, rivers, and lakes.

7. Designation of Zones of Quaternary Deformation in the Site Region. Requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17, and 10 CFR 100.23 regarding designation of zones of Quaternary deformation in the site region are met if the zone (or zones) designated by the applicant as requiring detailed faulting investigations is of sufficient length and width to include all Quaternary deformation features potentially significant to the site as described in Regulatory Guides 1.165 and 1.208.

8. Potential for Surface Tectonic Deformation at the Site Location. To meet requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17, and 10 CFR 100.23 for this area of review, information must be presented by the applicant in this subsection if field investigations reveal that surface or near-surface tectonic deformation along a known capable tectonic structure (i.e., a known capable tectonic feature related to a fault or blind fault) must be taken into account at the site location.

   It is important to note that no commercial nuclear power plant has ever been constructed on a known capable tectonic deformation feature, and it is questionable whether it may be feasible to design for surface or near-surface tectonic displacements with any degree of confidence that safety-related plant features would remain intact and functional if displacements were to occur. Consequently, it is NRC policy to recommend that any site determined, based on results of detailed fault investigations, to lie on a surface or near-surface tectonic structure capable of displacement be prudently re-located to an alternate site by the applicant. If it becomes feasible in the future to design for surface or near-surface faulting with confidence that safety-related plant features would remain intact and functional should displacements occur, it would be necessary for an applicant to present the design basis for faulting and all supporting data in a high degree of detail.

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 Safe Shutdown Earthquake (SSE) ground motion; and permit adequate engineering solutions to actual or potential geologic and seismic effects at the proposed site. The site-specific GMRS satisfies the requirements of 10 CFR 100.23 with respect to the development of the SSE. 10 CFR 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) requires that the geologic and seismic siting factors considered for design include a determination of the potential for surface tectonic and non-tectonic deformations. Application of GDC 2, or 10 CFR 52.17(a)(1)(vi) for ESP applications, and 10 CFR 100.23 provides assurance that the most severe geologic and seismic conditions at the proposed 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, and COL applications that do not reference an ESP to determine whether geologic and seismic information for the proposed site meets the acceptance criteria given in Subsection II of this SRP section. For reviews of OL applications, these procedures are used to verify that the geologic and seismic information remains valid and that the facility's design specifications are consistent with this information. As applicable, reviews of OLs and COLs include a determination on whether the content of technical specifications related to continued seismic surveillance is acceptable and whether the technical specifications reflect consideration of any unique geologic and seismic conditions which are identified.

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

Procedures for staff review enable evaluation to determine that an applicant has adequately performed investigations appropriate for fulfilling general requirements of 10 CFR Part 100, Section 100.23. Based on 10 CFR 100.23, applicants are required to investigate potential for surface and near-surface deformation at the site related to both tectonic and non-tectonic phenomena. Guidelines an applicant may follow to determine presence and extent of surface and near-surface tectonic deformation in the site vicinity or site area and at the site location and whether this deformation, if present, poses a potential seismic hazard at the site location are found in Appendices D and E of Regulatory Guide 1.165 and Appendix C of Regulatory Guide 1.208.

Three Phase Review Process

Three review phases are conducted by staff: (1) an acceptance review of the application; (2) a thorough, detailed technical review of the application; and (3) a review of supplemental information provided by the applicant in response to questions from staff. All three review phases may be applied for reviews of a CP, OL, ESP, or COL application.

Phase 1. Acceptance Review

The Phase 1 acceptance review is a brief review of the application to evaluate its completeness and identify safety issues that could cause delay in subsequent phases of

the review process. Acceptance or rejection of the application for Phase 2 review is governed by two criteria: (1) adherence to standard format for identifying and describing characteristics and features that may indicate surface deformation due to faulting and may adversely affect safety of the site; and (2) provision of adequate information and documentation as described in Regulatory Guides 1.165, 1.206, and 1.208 to enable an independent staff review of conclusions presented by the applicant.

Phase 2. Review of Application

In this review phase, which begins after the application is docketed, staff conducts a thorough, detailed technical review of material submitted in the application and an effort is made to identify all safety issues. The reviewer examines the application to confirm that all interpretations are based on standard geologic practices and do not exceed validity limits of either the applicant's data or other data sets from published scientific literature. The application is also reviewed for any significant new information derived from site-specific geologic, seismic, geophysical, and geotechnical investigations that had not been used in the PSHA. Appendix C of Regulatory Guide 1.208 and Appendix E of Regulatory Guide 1.165 describe acceptable methods for addressing significant new information in the PSHA.

At the beginning of this review phase, staff decides how consultants and advisors who are geoscience experts should be involved. Consultants and advisors may include geoscientists at the U.S. Geological Survey (USGS), State Geological Surveys, universities, and private industry who are able to provide first-hand knowledge of the site location, site area, and site vicinity in relation to Quaternary tectonics. Necessary information is made available to any consultants and advisors that are selected by staff, and they may be asked to perform such tasks as reviewing the tectonic setting of plants in regions of complex geology, evaluating potential for surface deformation due to faulting, verifying an applicant's geochronology for fault displacement, and providing advice on levels of earthquake ground motion for seismic evaluation of selected sites.

A literature search and review of relevant references (e.g., published geological reports, USGS professional papers and open-file reports, university theses, physiographic and geologic maps, and aeromagnetic and gravity maps) is conducted by NRC staff and its advisors and consultants to acquire additional pertinent information on regional and local geology and seismology. However, as publication of data and results commonly lags behind completion of research projects and construction investigations, a reviewer should not rely entirely on information submitted by the applicant or that in published literature. The reviewer should identify any pertinent studies underway in the site vicinity, site area, or at the site location and obtain information on preliminary results of these studies. Special provisions may be required to examine any pertinent data that are of a proprietary nature.

As part of the Phase 2 review, staff will conduct geologic reconnaissance of the site vicinity, site area, and site location as necessary to examine soil and rock samples from core borings and test pits and geologic features in trenches and excavations for plant facilities, if these information sources exist. Since geologic features (e.g., deformation due to faulting) which have the potential to adversely impact site safety may be

discovered in plant excavations or during other field investigations, this reconnaissance is deemed necessary in light of requirements and procedures specified in Subpart C of 10 CFR Part 52 which allows for a COL (i.e., a combined CP and OL) as an alternative to the two-step licensing process previously defined in 10 CFR Part 50 which includes a CP (Step 1) separate from an OL (Step 2).

Under the COL approach defined in 10 CFR Part 52, the Safety Evaluation Report (SER) will have been written by staff and a license granted to the applicant before plant construction excavations and geologic mapping of the excavations begin. Therefore, the geologic reconnaissance performed by staff notwithstanding, geologic features discovered in plant excavations of applicants granted a COL may not have been evaluated by staff. To alleviate potential problems, clear statements must be provided in the site-specific portion of the COL application that the applicant commits to (1) notifying staff immediately if previously unknown geologic features that could represent a safety hazard to the plant are discovered in the excavations; (2) at a minimum, undertaking detailed geologic mapping of walls and floors of all excavations for Seismic Category I facilities; and (3) notifying NRC staff when the excavations and geologic maps of those excavations are available for examination and evaluation. Furthermore, staff should also be contacted if a fault not previously identified in the application is found within 8 km (5 mi) of the site (i.e., in site area). Staff may collect samples from fault zones or other parts of an excavation for age dating and analysis. Previous applicants have often excavated trenches in areas where major facilities were to be located to reduce the chance of surprises when excavations were started for plant construction.

The two-step licensing process defined in 10 CFR Part 50 requires applicants to obtain a CP (Step 1), followed by an OL (Step 2) after construction excavations and required geologic mapping of all Seismic Category I excavations have been completed and plant design bases have been approved by staff. Seismic Category I excavations and the associated geologic maps are to be examined by staff prior to placement of backfill or concrete and before the SER is completed. This procedure should continue for future sites licensed under the two-step process of 10 CFR Part 50.

If faults are identified in the site vicinity, site area, or at the site location, including construction excavations, it must be demonstrated that they do not have a potential for causing surface or near-surface ground displacement and acting as a capable tectonic source at the site location. This demonstration is accomplished by determining ages of latest fault displacements. Stratigraphic methods may be employed to determine age of faulting by identifying datable soil horizons or a stratigrahic unit overlying the fault that is not offset to bound the age of faulting. Other methods include correlating the latest faulting event with regional tectonic activity of known age, providing geomorphologic indications of age, and determining the relationship between time of fault displacement and ages of marine or fluvial terraces. Viable age dating methods that can be used to assess chronology of faulting are referred to in Appendix C of Regulatory Guide 1.208 and described in Appendix D of Regulatory Guide 1.165 and NUREG/CR-5562 (Reference 17).

During the Phase 2 detailed technical review, staff develops questions and comments related to issues considered to be inadequately addressed by the applicant which may

either be revealed during this review phase or developed based on additional information provided by the applicant as a result of the acceptance review. Questions may also result from discovery of references not cited by the applicant that contain conclusions conflicting with those of the applicant. These first-round questions usually require the applicant to conduct additional investigations or supply clarifying information and are referred to as Requests for Additional Information (RAIs). When insufficient data are provided by the applicant to support interpretations and conclusions presented, and more conservative reasonable alternative interpretations are technically supported in the literature, staff will request additional investigations or require the applicant to adopt the more conservative interpretations. This review phase will commonly involve public meetings with the applicant to clarify questions and allow the applicant to present new data to justify conclusions presented. The applicant's responses to questions are reviewed and any remaining issues settled, either by a second round of questions or by staff positions. A staff position is usually in the form of a requirement for the applicant to provide confirmatory information or to design for a specific condition in a manner deemed to be sufficiently conservative and consistent with requisites of 10 CFR 100.23.

Phase 3. Review of Supplemental Information

The Phase 3 review is the final phase for resolving all open safety-related issues, an activity commonly associated with staff review of the applicant's responses to RAIs. Staff may either concur with decisions of the applicant on safety-related issues, or take a more conservative position if deemed necessary to assure the required degree of safety is imposed for the plant. When safety-related issues have been resolved, staff then provides input for its SER. Because plant construction excavations will not be completed until after staff has prepared the SER in cases where an applicant is granted a COL under Subpart C of 10 CFR Part 52, subsequent reviews of geologic data and examination of excavations for Seismic Category I structures will be necessary to confirm that site parameters lie within the certified design envelope specified in the COL application.

Procedures for Staff Evaluation of Specific Areas of Review

Procedures for staff evaluation of the specific Areas of Review defined in Subsection I of this SRP section to determine that an applicant has adequately performed appropriate investigations for fulfilling general requirements of 10 CFR Part 100, Section 100.23 are as follows. While performing the task of evaluating all Areas of Review for this section, it is important that reviewers of seismic and tectonic information provided by an applicant identify all significant new information (e.g., a seismic source or new tectonic model that was not included in the site PSHA) and coordinate closely with the PSHA reviewer.

1. Geologic, Seismic, and Geophysical Investigations. The reviewer evaluates results of the applicant's geologic, seismic, and geophysical investigations by conducting an independent literature search and comparing results of the literature search with information provided in the application. The comparison should show that conclusions presented by the applicant are based on sound data and are consistent with both reports published by area experts and conclusions of staff and its advisors and consultants. If conclusions and assumptions presented by the applicant conflict with the

literature and staff disagrees with the applicant's analysis and assumptions, the reviewer should require the applicant to submit additional investigative results supporting the conclusions in question.

2. Geologic Evidence, or Absence of Evidence, for Surface Deformation. The reviewer evaluates geologic evidence, or the lack thereof, for surface deformation by first determining, through a literature search and comparison with the applicant's data, that all evidence of tectonic deformation (e.g., fault offset) identified in the literature has been considered by the applicant. The reviewer analyzes results of the applicant's site investigations and compares them to results derived from the literature search to determine if there is evidence for existing or possible faulting. If evidence of faulting is found, additional field investigations (e.g., geologic mapping, surface and borehole geophysical investigations, borings, or trenching) must be carried out to completely define fault characteristics. The distinction should be made between tectonically-induced surface or near-surface deformation and deformation resulting from non-tectonic phenomena (e.g., growth faulting or collapse due to dissolution in karst terrane).

3. Correlation of Earthquakes with Capable Tectonic Sources. The reviewer assesses correlation of earthquakes with capable tectonic sources in conjunction with consideration of SRP Section 2.5.2. Historical earthquake data derived from review of SRP Section 2.5.2 are compared with known local tectonic features and a determination is made regarding whether any earthquakes can reasonably be associated with local tectonic structures. This determination includes an evaluation of the hypocentral error estimates of the earthquakes. When available, earthquake source mechanisms should be evaluated with respect to fault geometry. Applicants and licensees are encouraged to evaluate the relationship of fault parameters to earthquake magnitude. These parameters should include fault geometry (including fault orientation, length, and width), fault type, slip rate, recurrence intervals, and rupture area.

4. Ages of Most Recent Deformation. The reviewer evaluates ages of most recent deformation to determine if times of most recent activity have been reasonably estimated for tectonic features identified, and if there a sufficient technical basis exists for the age estimates. The reviewer determines whether geochronological methods used by the applicant are based on accepted procedures. In cases for which the applicant employs unusual or untested age-dating techniques, staff will require documentation of the techniques. Accuracy of all age-dating techniques used in the applicant's analysis should be carefully documented. Multiple samples should be tested, and more than one dating method applied to each horizon that is significant in estimating age of a paleoseismic event. To evaluate ages of most recent deformation, staff may require assistance of consultants or advisors with expertise in the specific age dating methods used by the applicant.

5. Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures. The reviewer evaluates relationships of tectonic structures within 8 km (5 mi) of the site (i.e., the site area) with regional tectonic structures by using a literature search to determine that the applicant's evaluation of the regional tectonic framework is consistent with that of recognized experts who have published technical reports on this topic in peer-reviewed literature. The reviewer confirms that conclusions reached by the

applicant are based on sound geologic principles and all available geologic and geophysical data. When special investigations are conducted to determine structural relationships between faults that pass within 8 km (5 mi) of the site and regional faults, the reviewer assesses resolution accuracy of the investigative technique used by the applicant.

6. Characterization of Capable Tectonic Sources. The reviewer evaluates information related to characterization of capable tectonic sources presented in the application to determine whether sufficiently detailed investigations have been conducted by the applicant to define specific characteristics of all potential capable tectonic sources, any part of which is located within 8 km (5 mi) of the site (i.e., within the site area). Characteristics of a structure that must be defined include fault orientation; relationship of the fault (or fold) to regional structures; type, amount, and chronologic history of displacements (Including slip rates and recurrence intervals) along the fault; and extent of the deformed zone as established by mapping the extent of Quaternary deformation both along and across the deformed zone to determine length and width of the zone. The reviewer assesses adequacy of the applicant's field investigations, including whether a large enough area was analyzed in sufficient detail to demonstrate that there is little likelihood of near-surface deformation within the site area associated with capable but undetected tectonic sources (e.g., blind faults).

7. Designation of Zones of Quaternary Deformation in the Site Region. The reviewer examines published literature to determine acceptability of the applicant's investigative results related to designation of zones of Quaternary deformation in the site region. The reviewer also evaluates investigative techniques employed by the applicant for defining the zones to ascertain whether they are consistent with state-of-the-art practices, and staff may ask technical experts to review specific aspects of the investigative program. The reviewer analyzes results of the investigations to determine whether analysis of Quaternary deformation at the outer limits of the 40 km (25 mi) radius (i.e., the site vicinity) zone are appropriately conservative.

8. Potential for Surface Tectonic Deformation of the Site. If detailed investigations for the proposed commercial nuclear power plant reveal a potential for surface or near-surface deformation at the site, staff recommends that an alternative location be considered for the proposed plant. No commercial nuclear power plant has ever been constructed on a known capable tectonic deformation feature, and it is questionable whether it may be feasible to design for surface or near-surface tectonic displacements with any degree of confidence that safety-related plant features would remain intact and functional if displacements were to occur. If it becomes feasible in the future to design for surface faulting with confidence that safety-related plant features would remain intact and functional, it will be necessary for an applicant to present the design basis for surface faulting and supporting data in a very high degree of detail.

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 review of an ESP application for approval of a proposed site. Information required in an ESP application includes number, type, and thermal power level of the facilities for which the site may be used; types of cooling systems used; and description of geologic, seismic, geophysical, geotechnical, and hydrologic characteristics of the proposed site. The scope and level of detail of review of data parallel that used for a CP review. The applicant should propose geologic site characteristics that will form a set of minimum values for design and construction of a new plant to be built at the site.

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 geologic and seismic site characteristics 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.

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 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 sufficient information was presented to demonstrate that the characteristics of the site fall within the site parameters specified in the DC rule. Should the actual geologic and seismic 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 for the proposed site. This demonstration might be accomplished by re-analyzing or redesigning the proposed facility.

For a COL application referencing an ESP, NRC staff reviews the application to ensure the applicant provided 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 conditions, restrictions to the DC, or COL action items identified in the FSERs are appropriately handled in the COL application.

IV. EVALUATION FINDINGS

The review should document the staff's evaluation of geologic and seismic site characteristics with respect to the relevant regulatory criteria. The evaluation should support the staff's conclusions as to whether the regulations are met. The reviewer should state what was done to evaluate the applicant's safety analysis report. The staff's evaluation may include verification that the applicant followed applicable regulatory guidance, performance of independent calculations, and/or validation of appropriate assumptions. The reviewer may state that certain information provided by the applicant was not considered essential to the staff's review and was not reviewed by the staff. While the reviewer may 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 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 geologic and seismic aspects of the plant site, staff has carefully considered pertinent information gathered by the applicant in support of the license application. The information reviewed includes data from the site vicinity, site area, and site location related to geologic, seismic, geophysical, and geotechnical investigations as well as geologic reconnaissance. Information considered also includes data from independent staff review of state-of-the-art published literature and other sources and discussions with knowledgeable geoscientists with the USGS, State Geological Surveys, local universities, consulting firms, or other non-governmental and professional organizations.
>
> As a result of this review, staff concludes that geologic, seismic, geophysical, and geotechnical investigations and information provided by the applicant in accordance with 10 CFR 52.17 and 10 CFR 100.23 provide an adequate basis to establish that no capable tectonic sources exist in the plant site vicinity or site area that would cause surface or near-surface deformation or localize earthquakes at or near the site location

2. Design Certification Reviews

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

> 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 staff completes review of geologic and seismic aspects of the plant site related to potential for surface deformation due to faulting and confirms that the applicant has met all applicable requirements (i.e., appropriate portions of GDC 2 in Appendix A to 10 CFR Part 50 and 10 CFR 100.23) and guidelines (i.e., Regulatory Guides 1.165, 1.132, 1.198, 1.208, 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 subject nuclear power plant site in relation to potential for surface deformation due to faulting. 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 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 excavations for Seismic Category I facilities; and (3) notifying NRC 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:

> Information reviewed for the proposed nuclear power plant concerning potential for surface and near-surface tectonic deformation is summarized in SER Section 2.5.3. Staff concludes that the site is acceptable from the perspective of tectonic surface and near-surface deformation and meets requirements of 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 2; and 10 CFR 100.23. This conclusion is based on the applicant having met the requirements and guidelines of:
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> 1. 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 faulting and resultant vibratory ground motion.
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> 2. 10 CFR 100.23 ("Geologic and Seismic Siting Criteria") with respect to obtaining geologic and seismic information necessary to determine site suitability and appropriate plant design, and ascertain that any new information derived from site-specific investigations does not impact the SSE derived by a probabilistic seismic hazard analysis. In complying with this regulation, the applicant also meets guidance in Regulatory Guides 1.132 ("Site Investigations for Foundations of Nuclear Power Plants"); 1.165 ("Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion"); 1.208 ("A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion"); 1.198 (" Procedures and Criteria for Assessing Seismic Soil

Liquefaction at Nuclear Power Plant Sites"); 4.7 ("General Site Suitability Criteria for Nuclear Power Plants"); and 1.206 ("Combined License Applications for Nuclear Power Plants - LWR Edition").

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 regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

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

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3. Electric Power Research Institute, "Probabilistic Seismic Hazard Evaluation of Nuclear Power Plant Sites inthe Central and Eastern United States," Volumes I through 10, NP-4726A, 1989.

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

5. Geological Society of America (GSA Website), Geologic Time Scale, 1999.

6. 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants."

7. K.K.E. Neuendorf, J.P. Mehl, Jr, and J. A. Jackson, Editors, "Glossary of Geology," Fifth Edition, American Geological Institute, Alexandria, Virginia, 2005.

8. 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."

9. Section 100.23, "Geologic and Seismic Siting Criteria," in 10 CFR Part 100, "Reactor Site Criteria."

10. Regulatory Guide 1.165, U.S. NRC, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion."

11. Regulatory Guide 1.208, U.S. NRC, “A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion.”

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

13. Regulatory Guide 1.198, U.S. NRC, “Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites.”

14. Regulatory Guide 4.7, US NRC, "General Site Suitability Criteria for Nuclear Power Stations."

15. Regulatory Guide 1.208, U.S. NRC, “Combined License Applications for Nuclear Power Plants - LWR Edition.”

16. Sowers, J.M., et al, “Dating and Earthquakes - Review of Quaternary Geochronology and its Application to Paleoseismology,” NUREG/CR-5562, USNRC, Washington, DC, 1998.
