



U.S. NUCLEAR REGULATORY COMMISSION
STANDARD REVIEW PLAN
OFFICE OF NUCLEAR REACTOR REGULATION

2.5.3 SURFACE FAULTING

REVIEW RESPONSIBILITIES

Primary - Geosciences Branch (GB)

Secondary - None

I. AREAS OF REVIEW

GB reviews information in the applicant's safety analysis report (SAR) related to the existence of a potential for surface faulting affecting the site. The information presented in this section results largely from detailed surface and subsurface geological and geophysical investigations performed in the site and vicinity. The following specific subjects are addressed: the structural and stratigraphic conditions of the site and vicinity (subsection 2.5.3.1), any evidence of fault offset or evidence demonstrating the absence of faulting (subsection 2.5.3.2), earthquakes associated with faults (subsection 2.5.3.3), determination of age of most recent movement on faults (subsection 2.5.3.4), determination of structural relationships of site area faults to regional faults (subsection 2.5.3.5), identification and description of capable faults (subsection 2.5.3.6), zones requiring detailed fault investigations (subsection 2.5.3.7); and results of studies in zones requiring detailed fault investigations (subsection 2.5.3.8).

II. ACCEPTANCE CRITERIA

GB acceptance criteria are based on meeting the requirements of the following regulations:

1. 10 CFR Part 50, "Appendix A, "General Design Criteria for Nuclear Power Plants"; General Design Criterion 2 - "Design Bases for Protection Against Natural Phenomena." 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 (Ref. 1).

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USNRC STANDARD REVIEW PLAN

Standard review plans are prepared for the guidance of the Office of Nuclear Reactor Regulation staff responsible for the review of applications to construct and operate nuclear power plants. These documents are made available to the public as part of the Commission's policy to inform the nuclear industry and the general public of regulatory procedures and policies. Standard review plans are not substitutes for regulatory guides or the Commission's regulations and compliance with them is not required. The standard review plan sections are keyed to the Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants. Not all sections of the Standard Format have a corresponding review plan.

Published standard review plans will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, D.C. 20555.

2. 10 CFR Part 100, "Reactor Site Criteria." This part describes criteria which guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors (Ref. 2).
3. 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants." These criteria describe the nature of the investigations required to obtain the geologic and seismic data necessary 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. 3).

The following regulatory guides provide information, recommendations, and guidance and in general describe a basis acceptable to the staff for implementing the requirements of GDC 2, Part 100, and Appendix A to Part 100.

- a. 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 and earthworks under anticipated loading conditions including 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 and sampling (Ref. 4).
- b. Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations." This guide discusses the major site characteristics related to public health and safety which the NRC staff considers in determining the suitability of sites for nuclear power stations (Ref. 5).

The data and analyses presented in the SAR are acceptable if, as a minimum, they describe and document the information required by Reference 3 and should conform to the format suggested in Reference 15. References 8, 9, and 10 are used by the staff as the principal relevant guides to judge whether or not all of the current pertinent references have been consulted. Among others, References 6, 7, 11 through 14, and 16 are also used by the staff.

Specific criteria necessary to meet the relevant requirements of the Commission regulations identified above are as follows:

Subsection 2.5.3.1. In meeting the requirements of References 1 through 3 and the positions of References 4 and 5, this subsection is considered acceptable if the discussions of the stratigraphy, methods of fault dating, structural geology, and geologic history of the site are complete, compare well with studies conducted by others in the same area, and are supported by detailed investigations performed by the applicant. In the case of coastal and inland sites near large bodies of water, similar detailed investigations are to be conducted offshore as well as onshore. Site and regional geologic maps and profiles constructed at scales adequate to illustrate clearly the surficial and bedrock geology, structural geology, topography, and the relationship of the safety-related foundations of the nuclear power plant to these features should be included in the SAR.

Subsection 2.5.3.2. In meeting the requirements of References 1, 2, and 3, this subsection is acceptable if sufficient surface and subsurface information is provided and supported by detailed investigations, either to confirm the absence of faulting or, if faulting is present, to demonstrate its age. If faulting is present in the site vicinity, it must be defined as to fault geometry, amount and sense of movement, recurrence rate, and age of latest movement. In addition to geologic evidence which may indicate faulting, linears interpreted from topographic maps, low- and high-altitude aerial photographs, Landsat, Skylab, and other imagery should be documented and investigated. In order to expedite the review process, an identification list, index, and duplicates of the remote-sensing data used in the linear study should be provided to the staff. Evidence for absence of faulting is obtained by conducting site surface and subsurface investigations in such detail and areal extent to ensure that undetected offsets are not likely to exist. These investigations will vary in detail according to the geological complexity of the specific site.

Subsection 2.5.3.3. In meeting the requirements of References 1, 2, and 3, this subsection is acceptable if all historically reported earthquakes within 5 miles of the site or near faults which trend within 5 miles of the site, as discussed in SRP Section 2.5.2, are evaluated with respect to hypocenter accuracy and source origin. In conjunction with these discussions, a plot of the earthquake epicenters superimposed on a map showing the local tectonic structures as defined in SRP Section 2.5.1 should be provided. Hypocentral error estimates of the earthquakes should be shown.

Subsection 2.5.3.4. In meeting the requirements of References 1 and 3, this subsection is acceptable when every fault, any part of which is within 5 miles of the site, is investigated in sufficient detail using geological and geophysical techniques of sufficient sensitivity to demonstrate the age of most recent movement (Ref. 16). An evaluation of the sensitivity and resolution of the exploratory techniques used should be given.

Subsection 2.5.3.5. In meeting the requirements of References 1, 2, and 3, this subsection is acceptable when a discussion is given of the structural and genetic relationship between site area faulting and the regional tectonic framework. In regions of active tectonism it may be necessary to conduct detailed geologic and geophysical investigations to demonstrate the structural relationships of site area faults to regional faults known to be seismically active. Both a theoretical and an observational basis for the conclusions reached should be given.

Subsection 2.5.3.6. In meeting the requirements of References 1, 2, and 3, this subsection is acceptable when it has been demonstrated that the investigative techniques used have sufficient sensitivity to identify all faults greater than 1000 feet in length within 5 miles of the site and when the geometry, length, sense of movement, amount of offset, age of latest movement, and limits of the fault zone are given for each fault. Investigations are to extend at least 5 miles beyond all plant sites adjacent to large bodies of water such as oceans, rivers, and lakes.

Subsection 2.5.3.7. In meeting the requirements of Reference 3, this subsection is judged acceptable if the zone designated by the applicant as requiring detailed faulting investigation is consistent with the description of such a zone described in Reference 3.

Subsection 2.5.3.8. In meeting the requirements of References 1, 2, and 3, this subsection must be presented by the applicant if the aforementioned investigations reveal that surface displacement must be taken into account. No commercial nuclear power plant has been constructed on a known capable fault and it is an open question as to whether it is feasible to design for surface or near-surface displacement with confidence that the integrity of the safety-related features of the plant would remain intact should displacement occur. It is, therefore, staff policy to recommend relocation of plant sites found to be located on capable faults as determined by the detailed faulting investigation. If in the future it becomes feasible to design for surface faulting, it will be necessary to present the design basis for surface faulting and supporting data in considerable detail.

III. REVIEW PROCEDURES

The staff review procedure involves an evaluation to determine that the applicant has followed the investigations outlined in Reference 3. Consultants/advisors assist the staff in reviewing this section of the SAR, on a case-by-case basis. On request, the advisor/consultant provides expertise in numerous earth science disciplines and occasionally is able to provide first-hand knowledge of the site. A literature search is conducted concerning the regional and local geology. The staff also utilizes state geological surveys and contacts universities and private industry to obtain additional data.

Generally, the steps that applicants must follow in determining the presence and extent of faulting, and whether near-surface faulting (if present) represents a hazard or not, is outlined in the seismic and geologic siting criteria (Ref. 3). Specific investigative techniques are not given in the criteria, however. The site area must be investigated by a combination of exploratory methods which may include borings, trenching, seismic profiling, geologic mapping, and geophysical investigations. The results of these explorations are cross-compared and evaluated by the staff.

It has been the policy of the staff to encourage applicants to avoid areas where there is a possibility for surface faulting. As the question of whether or not a surface faulting condition exists is so critical in determining whether a particular site is suitable, this consideration is usually addressed very early in the review. Exceptions are those cases in which a fault, the existence of which was previously unknown, is revealed in excavations during construction or is discovered during the course of other investigations in the area. The staff is to be notified by the applicant when the excavations for critical structures are available for NRC inspection and when the detailed geologic maps to be used by the staff while examining the above excavations will be available for use. In addition, the staff is to be contacted immediately if a fault, not previously identified in the SAR, is found within 5 miles of the plant.

When faults are identified in the site vicinity, it must be demonstrated that the faults are not capable. This is accomplished by determining the ages of the faults by absolute age dating (radiometric), associating the faulting with regional tectonic activity of known age, stratigraphic or geomorphic evidence, etc. Numerous age-dating techniques (principally radiometric) are discussed in Reference 16. In such cases the staff will carry out limited site observations and investigations of its own such as examinations of excavations. In some cases, the staff may select samples from shear zones for subsequent dating analysis. Applicants usually trench in the areas where major facilities are to be located.

Subsection 2.5.3.1 is evaluated by conducting an independent literature search and cross-comparing the results with the information submitted in the SAR. The comparison should show that the conclusions presented by the applicant are based on sound data, are consistent with the published reports of experts who have worked in the area, and are consistent with the conclusions of the staff and its advisors/consultants. If the applicant's conclusions and assumptions conflict with the literature, substantive investigative results to support those conclusions must be submitted to the staff for review.

Subsection 2.5.3.2 is evaluated by first determining through a literature search that all known evidences of fault offset have been considered in the investigation. The results of the applicant's site investigations are studied and cross-compared in detail to see if there is evidence of existing or potential displacements. If such evidence is found, additional investigations such as field mapping, geophysical investigations, borings, trenching, etc., must be carried out to demonstrate that there is no offset or to define the characteristics of the fault if it does exist.

Subsection 2.5.3.3 is reviewed in conjunction with the consideration of SRP Section 2.5.2. Historic earthquake data derived from the review of SRP Section 2.5.2 are compared with known local tectonic features and a determination is made as to whether any of these earthquakes can reasonably be associated with the local structures. This determination includes an evaluation of the hypocentral error estimates of the earthquakes. When available, the earthquake source mechanisms should be evaluated with respect to fault geometry. In addition, applicants/licensees are encouraged to evaluate the relationship of fault parameters to earthquake magnitude. These parameters may include, but are not limited to, slip rate, recurrence intervals, length, and type of fault.

Subsection 2.5.3.4 is evaluated to determine if the age dating methodology used by the applicant is based on accepted geological procedures. In some cases unusual age dating techniques may be used. When such methods are employed, the staff will require extensive documentation of the technique and may treat it as a generic review item. The resolution of all age dating techniques should be carefully documented.

Subsection 2.5.3.5 is evaluated by determining through a literature search that the applicant's evaluation of the regional tectonic framework is consistent with that of recognized experts whose reports appear in the published literature. The conclusions reached by the applicant should be based on sound geologic principles and should explain the available geological and geophysical data. When special investigations are made to determine the structural relationship between faults which pass within 5 miles of the site and regional faults, the resolution of the investigative techniques should be given.

Subsection 2.5.3.6 is evaluated to determine if a sufficiently detailed investigation has been made by the applicant to define the specific characteristics of all capable faults located within 5 miles of the site. The fault characteristics requiring definitions include: length, orientation, relationship of the fault to regional structures; the nature, amount, and geologic history of displacements along the fault; and the outer limits of the fault zone established by mapping fault traces 10 miles along trends in both directions from the point of nearest approach to the site (Ref. 3). The staff must be satisfied that the investigation covers a large enough area in sufficient detail to demonstrate that there is little likelihood of near-surface displacement hazards associated with capable faults existing undetected near the site.

Subsection 2.5.3.7. Criteria for determining the zone requiring detailed faulting investigation are clearly outlined in Reference 3. The staff reviews the results of the applicant's faulting investigation together with the published literature. The investigative techniques employed by the applicant are evaluated to ascertain that they are consistent with the state of the art. As part of this phase, experts in specific disciplines are asked to review certain aspects of the investigative program. The results of the investigation are analyzed to determine whether the outer limits of the zone requiring faulting investigation are appropriately conservative. If there is insufficient data to substantiate the outer boundaries, more conservative assumptions are required.

Subsection 2.5.3.8. If the detailed faulting investigations for the proposed commercial nuclear power plant reveal that there is a potential for surface displacement at the site, the staff recommends that an alternate location for the proposed plant be considered. In the future, when it may be feasible to design a commercial nuclear power plant for displacements, substantial information will be required to support the design basis for surface faulting.

IV. EVALUATION FINDINGS

If the evaluation by the staff, on completion of the review of the geologic and seismologic aspects of the plant site, confirms that the applicant has met the requirements of applicable portions of 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena," 10 CFR Part 100, "Reactor Site Criteria," and 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," the conclusion in the SER states that the information provided and investigations performed support the applicant's conclusions regarding the geologic and seismic integrity of the subject nuclear power plant site. Staff reservations about any significant deficiency either presented in the applicant's SAR or identified by the staff are stated in sufficient detail to make clear the precise nature of the concern. The above evaluation determinations are made by the staff during both the construction permit (CP) and operating license (OL) phases of review.

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

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

In our review of the geologic and seismologic aspects of the plant site we have considered pertinent information gathered since our initial geologic and seismologic review which 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 geologic and seismologic information, we have determined that our earlier conclusion regarding the safety of the plant from a geological and seismological standpoint remains valid. These conclusions can be summarized as follows:

- (1) Geologic and seismologic investigations and information provided by the applicant and required by Appendix A to 10 CFR Part 100 provide an adequate basis to establish that no capable faults exist in the plant site area which would cause earthquakes to be centered there.
- (2) No evidence has been found to indicate that a potential exists for surface faulting at the plant site.

The new information reviewed for the proposed nuclear power plant is discussed in Safety Evaluation Report Section 2.5.3.

The staff concludes that the site is acceptable from a geologic and 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. 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 physical characteristics such as geology (faulting) and seismology (near site events) used in determining the suitability of the site.
 - c. 10 CFR Part 100, Appendix A (Seismic and Geologic Siting Criteria for Nuclear Power Plants) with respect to obtaining the geologic and seismic information necessary to determine (1) site suitability, and (2) to determine the appropriate design of the plant. In complying with this regulation, the applicant also meets with the staff's guidance described in Regulatory Guide 1.132, (Site Investigations for Foundations of Nuclear Power Plants) and Regulatory Guide 4.7 (General Site Suitability for Nuclear Power Stations).

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/licensee proposes an acceptable alternative method for complying with specific portions of the Commission's regulations, the method 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.

VI. REFERENCES

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

2. 10 CFR Part 100, "Reactor Site Criteria."
3. 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."
4. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants."
5. Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations."
6. R. L. Bates and J. A. Jackson, eds., "Glossary of Geology," American Geological Institute, Falls Church, Virginia (1980).
7. G. V. Cohee (Chairman) et al., "Tectonic Map of the United States," U.S. Geological Survey and American Association of Petroleum Geologists (1962).
8. American Petroleum Institute data base, accessible through RECON system.
9. GeoRef data base, American Geological Institute, Falls Church, Virginia.
10. RECON/Energy data base, Department of Energy
11. State geological maps and accompanying texts.
12. U.S. Geological Survey 7.5- and 15-minute topographic and geologic quadrangle maps.
13. Aerial photographs from Federal agencies such as the National Aeronautics and Space Administration, the U.S. Department of Agriculture, the U.S. Geological Survey, and the U.S. Forest Service.
14. Landsat, Skylab, and other imagery.
15. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants."
16. P. J. Murphy, J. Briedis, and J. H. Peck, "Dating Techniques in Fault Investigations," p. 153-168, in: Geology in the Siting of Nuclear Power Plants; A. W. Hatheway and C. R. McClure, Jr., eds., Reviews in Engr. Geol., v. 4, Geol. Soc. America, 1979.