



NUREG-0800

# U.S. NUCLEAR REGULATORY COMMISSION STANDARD REVIEW PLAN

## 2.5.5 STABILITY OF SLOPES

### REVIEW RESPONSIBILITIES

**Primary** - Organization responsible for the review of slope and embankment stability

**Secondary** - None

#### I. AREAS OF REVIEW

Chapter 2 of the Standard Review Plan (SRP) discusses the site characteristics and parameters 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), early site permit (ESP), or combined license (COL) concerning the stability of all earth and rock slopes both natural and manmade (cuts, fill, embankments, dams, etc.) whose failure, under any of the conditions to which they could be exposed during the life of the plant, could adversely affect the safety of the plant. The staff reviews information presented by the applicant for a design certification (DC)

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#### USNRC STANDARD REVIEW PLAN

This Standard Review Plan (SRP), NUREG-0800, has been prepared to establish criteria that the U.S. Nuclear Regulatory Commission (NRC) staff responsible for the review of applications to construct and operate nuclear power plants intends to use in evaluating whether an applicant/licensee meets the NRC regulations. The SRP is not a substitute for the NRC regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide an acceptable method of complying with the NRC regulations.

The SRP sections are numbered in accordance with corresponding sections in Regulatory Guide (RG) 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)." Not all sections of RG 1.70 have a corresponding review plan section. The SRP sections applicable to a combined license application for a new light-water reactor (LWR) are based on RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

These documents are made available to the public as part of the NRC policy to inform the nuclear industry and the general public of regulatory procedures and policies. Individual sections of NUREG-0800 will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience. Comments may be submitted electronically by e-mail to [NRR\\_SRP@nrc.gov](mailto:NRR_SRP@nrc.gov)

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regarding the postulated site parameters for the design, with respect to stability of slopes, are correctly identified, are representative of a reasonable number of sites that has been or may be considered for a COL application, and are appropriately justified. This SRP section applies to reviews performed for each of these types of applications. The following subjects must be evaluated using the applicant's data in the technical submittal and information available from other sources:

- 1 Slope characteristics (Subsection 2.5.5.1)
- 2 Design criteria and design analyses (Subsection 2.5.5.2)
- 3 Results of the investigations including borings, shafts, pits, trenches, and laboratory tests (Subsection 2.5.5.3)
- 4 Properties of borrow material, compaction and excavation specifications (Subsection 2.5.5.4)

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 Title 10 of the *Code of Federal Regulations* Part 52 (10 CFR) Part 52.

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

For a COL application referencing a DC, a COL applicant must address COL information items specified in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements and site parameters) included in the referenced DC.

#### Review Interfaces

Other SRP sections interface with this section as follows:

- 1 The reviewer of this SRP section provides findings on the results of the stability evaluations of earth and rock slopes to the reviewers of the appropriate subsections within SRP Chapter 3, as necessary, to ensure that displacements or failure of site slopes as indicated in the applicant's technical submittal do not have an adverse impact on structural and transfer piping components.
- 2 The organization responsible for quality assurance performs reviews of design, construction, and operations phase quality assurance programs under Design-Specific Review Standard (DSRS) Chapter 17. In addition, while conducting regulatory audits in accordance with Office Instruction NRR-LIC-111 or NRO-REG-108, "Regulatory Audits,"

the technical staff may identify quality-related issues. If this occurs, the technical staff should contact the organization responsible for quality assurance to determine if an inspection should be conducted.

- 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<sup>1</sup> 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.
- 4 The reviewers of DSRS Chapter 19 will coordinate the review of the stability of slopes related to the seismic risk evaluation with the reviewers of this SRP section.

## II. ACCEPTANCE CRITERIA

### Requirements

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

1. 10 CFR 50.55a, "Codes and Standards." This rule requires that structures, systems, and components (SSCs) shall be designed, fabricated, erected, constructed, tested, and inspected in accordance with the requirement of applicable codes and standards commensurate with the importance of the safety function to be performed.
2. 10 CFR Part 50, Appendix A:
  - A. General Design Criterion 1 (GDC 1), "Quality Standards and Records," requires that SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. It also requires that appropriate records of the design, fabrication, erection, and testing of SSCs important to safety be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.
  - B. 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.
  - C. GDC 44, "Cooling Water," requires that a system be provided with the safety function of transferring the combined heat load from SSCs important to safety to an ultimate heat sink under normal operating and accidental conditions.

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<sup>1</sup> Additional supporting information of prior DC rules may be found in DCD Tier 2 Section 14.3.

- D. For ESP applications, GDC are not applicable. However, the GDC 2 requirement to identify 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 Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants," establishes quality assurance requirements for the design, construction, and operation of those SSCs of nuclear power plants that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public.
  4. 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," as it applies to the design of nuclear power plant SSCs important to safety to withstand the effects of earthquakes.
  5. 10 CFR Part 100, "Reactor Site Criteria," provides the criteria which guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors.
  6. 10 CFR 100.23, "Geologic and Seismic Criteria," provides 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.

#### SRP Acceptance Criteria

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

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

RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants," describes a basis acceptable to the staff that may be used to implement GDCs 2 and 44 with regard to the ultimate heat sink, including necessary retaining structures and the canals and conduits connecting the ultimate heat sink with the cooling water system intake structures.

RG 1.28, "Quality Assurance Program Requirements (Design and Construction)," describes a method acceptable to the staff for complying with the Commission's regulations with regard to 10 CFR Part 50, Appendix B, overall quality assurance program requirements during design and construction of nuclear power plants.

RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants," describes programs of site investigations related to geotechnical engineering aspects that would normally meet the needs for evaluating the safety of the site from the standpoint of the performance of foundation and earthworks under anticipated loading conditions including earthquake in complying with 10 CFR Part 100 and 10 CFR 100.23. 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.

RG 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants," describes laboratory investigations and testing practices acceptable for determining soil and rock properties and characteristics, together with their uncertainties needed for engineering analysis and design for foundations and earthwork for nuclear power plants in complying with 10 CFR Part 100 and 10 CFR 100.23.

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

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

RG 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," describes acceptable methods to: (1) conduct geological, seismological, and geophysical, and geotechnical investigations of the site and region around the site, (2) identify and characterize seismic sources, (3) perform probabilistic seismic hazard analysis (PSHA), (4) perform site response analysis, and (5) determine the ground motion response spectrum (GMRS) for the site.

A thorough evaluation of the dynamic and static stability of all slopes and embankments of the nuclear plant site as described in the following subsections must be presented along with the basic data supporting all conclusions. Sufficient information must be provided to allow the staff and its advisors to conduct independent analyses. The site investigations must be adequate in scope and in technique to provide the necessary data, including best estimate material properties together with their range of potential variability.

2.5.5.1 Slope Characteristics. In meeting the requirements of 10 CFR Parts 50 and 100, the discussion of slope characteristics is acceptable if the subsection includes:

- 1 Cross sections and profiles of the slope in sufficient quantity and detail to represent the slope and foundation conditions.
- 2 A summary and description of static and dynamic properties of the soil and rock comprised by seismic Category I embankment dams and their foundations, natural and cut slopes, and all soil or rock slopes whose stability would directly or indirectly affect

safety-related and Category I facilities. The text should include a complete discussion of procedures used to estimate, from the available field and laboratory data, conservative soil properties and profiles to be used in the analysis.

- 3 A summary and description of groundwater, seepage, and high and low groundwater conditions.

Plot plans, cross sections, and profiles of all slopes that affect the safety of the plant in relation to the topography and physical properties of the underlying materials are reviewed and compared with exploratory records to ascertain that the most critical conditions have been addressed and that the characteristics of all slopes have been defined. The soil and rock test data are reviewed to ensure that there is sufficient relevant test data to verify the soil strength characteristics assumed for the slopes, dikes, and dams under analysis. The evaluation is to some extent a matter of engineering judgment; however, if the safety factors resulting from the analysis are not appropriate to the hazards posed by a slope failure and other than clearly conservative soil properties and profiles were used, the applicant is required to obtain additional data to verify his assumptions, or to show that, even if the worst possible conditions are assumed, there is an adequate margin of safety. With respect to seismic analysis, this subsection and Subsection 2.5.5.2 are reviewed concurrently because different methods of analysis may involve different approximations, assumptions, and soil properties.

In addition to generic state-of-the-art literature, other potential sources of information are those containing design, construction, and performance records of natural slopes, excavation slopes, and dams that may have been constructed in the general vicinity of the nuclear power plant.

2.5.5.2 Design Criteria and Analyses. In meeting the requirements of 10 CFR Parts 50 and 100, the discussion of design criteria and analyses is acceptable if the criteria for the stability and design of all seismic Category I slopes are described and valid static and dynamic analyses have been presented to demonstrate that there is an adequate margin of safety. A number of different methods of analysis are available in the literature.

To be acceptable, the static analyses should include calculations with different assumptions and methods of analysis to assess the following factors:

- 1 The uncertainties with regard to the shape of the slope, boundaries of the several types of soil within the slope and their properties, the forces acting on the slope, and pore pressures acting within the slope.
- 2 Failure surfaces corresponding to the lowest factor of safety.
- 3 The effect of the assumptions inherent in the method of analysis used.
- 4 Adverse conditions such as high water levels due to the probable maximum flood (PMF), tsunamis, sudden drawdown, or steady seepage at various levels. In general, safety factors related to the slope hazard are needed; however, actual values depend somewhat

on the method of analysis, on the assumptions concerning the soil properties, on construction techniques, and on the range of material parameters.

To be acceptable, the dynamic analyses must account for the effect of cyclic motion of the earthquake on soil strength properties as well as the potential effects of both horizontal and vertical components of shaking. In general, both horizontal and vertical components of shaking should be applied simultaneously in the slope stability analysis, unless adequate technical justification is provided to show that the vertical component of earthquake ground motion has a negligible effect on the stability analysis and that sufficient conservatism exists in the stability analysis for the horizontal ground motion.

Actual test data are needed for both the in situ soils as well as for any materials used in the construction of dams or embankments. As discussed above, the various parameters, such as geometry, soil strength, modeling method (location and number of elements (mesh) if a finite-element analysis is used), and hydrodynamic and pore pressure forces, should be varied to show that there is an adequate margin of safety. Where liquefaction is possible, major dam foundation slopes and embankments should be analyzed by state-of-the-art finite-element or finite difference methods of analysis. Where there are liquefiable soils, changes in pore pressure due to cyclic loading must be considered in the analysis to assess not only the potential for liquefaction but also the effect of pore pressure increase on the stress-strain characteristic of the soil and the post-earthquake stability of the slopes.

For the certified design portion of the plant, the site-independent certified seismic design response spectra (CSDRS) are specified as the design basis of the plant and they must be maintained as the design basis. The use of any alternative ground motion would require an exemption or amendment. However, in the case of slope stability and liquefaction analyses, the DCD should specify that the COL applicant will utilize the site-specific GMRS in both the horizontal and vertical directions with appropriate consideration for the elevation of the slope and different subsurface materials. In addition, the GMRS must meet the requirements of Appendix S of, 10 CFR Part 50 with respect to the peak ground acceleration and appropriate shape. Descriptions of the CSDRS and GMRS are provided in SRP Subsections 2.5.2 and 3.7.1. The criteria, design techniques, and analyses are evaluated by the staff to ascertain that:

- 1 Appropriate state-of-the-art methods have been employed.
- 2 Conservative assumptions regarding soil and rock properties have been used in the design and analysis of slopes and embankments as discussed above in Subsection 2.5.5.1.
- 3 Appropriately conservative margins of safety have been incorporated in the design.

The criteria and design methods used by the applicant are reviewed to ascertain that state-of-the-art techniques are being employed. The design analyses are reviewed to be sure that the most conservative failure approach has been used and that all adverse conditions to which the slope might be subjected have been considered. Such conditions include ground motions, both horizontal and vertical, from the site-specific GMRS (along with satisfying the performance goal for the slopes), settlement, cracking, flood or low-water steady-state seepage, sudden drawdown of an adjacent reservoir, or a reasonable assumption of the possible

simultaneous occurrence of two natural events such as an earthquake and flood. The review is also concerned with determining whether or not the soil and rock characteristics derived from the investigations described in Subsection 2.5.5.3 have been completely and conservatively incorporated into the design. When marginal factors of safety are indicated by the independent analyses performed by the staff and its consultants, additional substantiation and refinement is required or the applicant must use more conservative assumptions.

No single method of analysis is entirely acceptable for all stability assessments; thus, no single method of analysis can be recommended. Relevant manuals issued by public agencies (such as the U.S. Navy Department, U.S., Army Corps of Engineers and U.S. Bureau of Reclamation) are often used in reviews to ascertain whether the analyses performed by the applicant are reasonable. Many of the important interaction effects cannot be included in current analyses and must be treated in some approximate fashion. Engineering judgment is an important factor in the staff's review of the analyses and in assessing the adequacy of the resulting safety factors. The staff review will typically include an independent confirmatory analysis of the stability of the slope or dam, employing both deterministic and probabilistic methods, as appropriate.

2.5.5.3 Boring Logs. In meeting the requirements of 10 CFR Parts 50 and 100, the applicant should describe the borings and soil testing carried out for slope stability studies and dam and dike analyses. If dams, dikes, and natural or cut slopes adjacent to the site, but its failure will affect the safety of the plant, additional exploration, tests, and analyses for these areas should also be presented in this subsection.

A comprehensive program of site investigations including borings, sampling, geophysical surveys, test pits, trenches, and laboratory and field testing must be carried out by the applicant to define the physical characteristics of all soil and rock beneath safety-related and seismic Category I slopes, and borrow material that is to be used to construct safety-related dams, fills, and embankments. The staff reviews these investigations to ascertain that the program has been adequate to define the in situ and earthwork soil and rock characteristics for both static and dynamic effects. The decision as to the adequacy of the investigation program is based on the methods and criteria discussed in SRP Section 2.5.4.

2.5.5.4 Compacted Fill. In meeting the requirements of 10 CFR Part 50, the applicant should describe the excavation, backfill, and borrow material planned for any dams, dikes, and embankment slopes. Planned construction procedures and control of earthworks should be described, including the potential long-term behavior of the fill material. To be acceptable, the information must be given as discussed in Subsection 2.5.4.5.

Some of this information could be presented in Subsection 2.5.4.5. If dams, dikes, and other earthworks adjacent to the site, but its failure will affect the safety of the plant, it is necessary to complete this information in this subsection. Quality control techniques and requirements during and following construction must also be discussed and referenced to quality assurance sections of the applicant's technical submittal.

The preliminary specifications and quality control techniques to be used during construction are reviewed by the staff to ascertain that all design conditions are likely to be met. During this part of the review the following are among those subjects reviewed for adequacy:



1. Proposed construction dewatering plan to ensure that it will not result in damage either to the natural or engineered foundation materials or to temporary or permanent structural foundations.
2. The excavation plan to remove all unsuitable materials from beneath the foundations and the quality control procedures which establish suitable materials.
3. The techniques and equipment to be used in compacting foundation and embankment materials.
4. The quality control and testing program to provide a high level of assurance that:
  - A. The selected borrow material is as good and as relatively homogeneous as anticipated from the investigation program.
  - B. The compacted foundation soil meets design specifications.
5. The techniques for improving the stability of natural slopes such as drainage, grouting, rock bolting, and applying shotcrete and/or gunite.
6. The plans for monitoring during and after construction to detect occurrences that could detrimentally affect the facility. Such monitoring includes periodic examination of slopes, survey of settlement monuments, and measurements of local wells and piezometers.

#### 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:

Compliance with 10 CFR 50.55a requires that SSCs be designed, fabricated, erected, constructed, tested, and inspected as specified by applicable codes and standards commensurate with the importance of the safety functions to be performed. Standards developed by the American Society for Testing and Materials (ASTM) are used to perform soil analyses and tests for determining the static and dynamic properties of soils and rock for all earth and rock slopes, natural or manmade. To satisfy the geotechnical engineering requirements of 10 CFR Part 100, the applicant's technical submittal must contain a description of soil and rock characteristics and include static and dynamic analyses of all cuts, fills, embankments, dams, and other earthworks at or on the proposed site. In addition, the performance goal for all cuts, fills, embankments, dams and other earthworks considered important to plant safety needs to be clearly defined. This information will permit the staff to assess the acceptability of the proposed site and to determine the potential influence of these characteristics on the design of SSCs designated as important to safety. Meeting these requirements provides assurance that plant SSCs important to safety will withstand appropriately severe static and dynamic loads.

Compliance with GDC1 requires that SSCs be tested in accordance with quality standards commensurate with the importance of their safety functions; that test standards be applicable and sufficient; and that appropriate records maintained. SRP Section 2.5.5 describes staff positions related to the analysis of slope stability and the evaluation of properties and characteristics of slopes for which failure could have adverse effects on SSCs important to

safety. This SRP section describes acceptable programs and laboratory test practices for such investigations. RG 1.132 and 1.138 describe acceptable static and dynamic test (and/or evaluation) qualification criteria, including requirements for documentation, for soil and rock borrow materials at nuclear power plants. Meeting the requirements for GDC 1 provides assurance that the nuclear power plant design and the engineering analyses for its slope stability and earthworks will meet established quality standards.

Compliance with GDC 2 requires that the SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunamis, and seiches without loss of capability to perform their intended safety functions. SRP Section 2.5.5 describes staff positions related to site investigations for determining soil and rock properties and characteristics needed in the analysis and design of slopes and earthworks for the proposed nuclear power plant. Analyses are performed to evaluate the responses of soil and rock embankments to seismic and dynamic loading for interaction between soils and structures as well as to determine the liquefaction potential. Stability and deformation characteristics of embankment materials under static loadings are also determined. Meeting the requirements of GDC 2 provides assurance that natural and manmade slopes and embankments will respond as predicted under static and seismic loads, thereby protecting the plant against loss of integrity in slopes and embankments important to safety.

Compliance with GDC 44 requires that a system be provided to transfer heat under normal operating and accident conditions from SSCs important to safety to an ultimate heat sink. GDC 44 applies to this SRP section because the ultimate heat sink for the cooling water system consists of complex water sources, including necessary retaining structures (e.g., a pond or river with a dam) and the associated canals and conduits connecting sources of water to the nuclear power plant. The earthworks, consisting of the dams and canals, must be constructed in such a way as to ensure that the integrity of the cooling water system will be maintained and that its safety function will be accomplished. Meeting the requirements of GDC 44 provides assurance that engineered safety features will not fail to operate as designed, thereby protecting the plant against loss of core cooling.

Compliance with Appendix B to 10 CFR Part 50 requires that an applicant establish and maintain an overall quality assurance program. SRP Section 2.5.5 describes staff positions specifically related to the design, testing, and documentation of procedures for the qualification of embankments and earthworks important to safety. Subsection 2.5.5.4 provides guidance acceptable to the staff for providing data on excavation, backfill, borrow material planned for any dams, dikes, and embankment slopes important to safety. The applicant will also discuss quality control techniques and requirements to be used during and after construction, referencing this information to quality assurance sections of the applicant's technical submittal. Meeting these requirements provides assurance that the static and seismic qualification of embankment slopes and earthworks important to safety will be performed and that the resulting designs, tests, and records will comply with established standards, thereby ensuring that slopes (natural or manmade) and earthworks will perform as required.

Compliance with Appendix S to 10 CFR Part 50 requires that nuclear power plant SSCs important to safety be designed to be able to withstand the effects of natural phenomena, such as earthquakes, without loss of capability to perform their safety functions. SRP Section 2.5.5 describes guidance acceptable to the staff for determining the static and dynamic stability,

including liquefaction, of any dams, dikes, and embankment slopes important to safety. Meeting the requirements of Appendix S to 10 CFR Part 50 provides assurance that the nuclear power plant will be designed to withstand anticipated seismic phenomena and that during normal operations or seismic events, the plant will pose no undue risk to the public as a result of instability, deformation, or failure of structural foundations and earthworks.

Compliance with 10 CFR Part 100 requires that the Commission evaluate the suitability of proposed sites for nuclear power and test reactors. Paragraph 100.20(c) requires that physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining each site's acceptability. To satisfy the geotechnical engineering requirements of 10 CFR Part 100, the applicant's technical submittal must contain a discussion of embankment dams and their foundations, natural and cut slopes, and all soil or rock slopes for which a lack of stability could adversely affect safety-related SSCs. Subsection 2.5.5.1 requires cross sections and profiles of the slopes and a description of the static and dynamic properties of soils and rock comprised by embankments. Groundwater and seepage conditions must also be described. Meeting this requirement provides assurance (a) that the nuclear power plant will be designed to withstand appropriately severe geologic, geotechnical, and seismic phenomena and (b) that, during normal operations or seismic events, the plant will pose no undue risk to the public as a result of instability, deformation, and failure of embankment structures and earthworks.

Compliance with 10 CFR 100.23 requires that the geologic and seismic conditions at the proposed site be considered during the siting and design of a nuclear power plant. It describes the investigations required to obtain the geologic and seismic data necessary to determine site suitability and to provide reasonable assurance that a nuclear power plant can be constructed and operated at a proposed site without undue risk to the health and safety of the public. 10 CFR 100.23(d)(4) requires that the stability of all slopes, natural or artificial, the failure of which could adversely affect the nuclear power plant, be considered. The static and dynamic engineering properties of soils and rock comprised by embankments and earthworks should be included in order to determine their behavior during earthquakes. Guidance on the geologic investigation of embankments and their foundations, natural and cut slopes, and borrow materials properties, is provided in RG 1.132. Guidance on laboratory testing of soil and rock properties is provided in RG 1.138. Guidance on procedures for assessing soil liquefaction is provided in RG 1.198. Meeting these requirements provides assurance that plant SSCs will withstand the effects of seismic events, thereby minimizing the probability that a failure would initiate an accident or exacerbate the consequences of an accident.

### III. REVIEW PROCEDURES

#### Overview

The procedures outlined below are used to review CP applications, ESP applications, and COL applications that do not reference an ESP to determine whether data and analyses for the proposed site meet the acceptance criteria given in Subsection II of this SRP section. For reviews of OL applications, these procedures are used to verify that the data and analyses remain valid and that the facility's design specifications are consistent with these data. As applicable, reviews of OLs and COLs include a determination on whether the content of technical specifications related to slope stability is acceptable and whether the technical specifications

reflect consideration of any identified unique conditions. DC applications do not contain site-specific characteristics; however, site parameters which are postulated for slope stability need to be reviewed using the procedures described below.

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

### General Review Procedures

The review process is conducted in a similar manner and concurrent with that described in SRP Sections 2.5.1. The services of consultants may be used to aid the staff in geotechnical engineering evaluations regarding foundation engineering and slope stability analyses, particularly in the evaluation of safety-related and seismic Category I earthworks, earth and rock-fill dams, dikes, and reservoirs.

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

All natural safety-related slopes are examined during at least one of the two site visits required of the staff. Because excavated slopes or embankments are not usually constructed until after a CP or COL has been granted, detailed as-built documentation of these slopes and embankments, as well as complete stability and safety analyses are necessary.

### Review Procedures Specific to 10 CFR Part 52 Application Types

#### 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 a description of the site characteristics and design parameters of the proposed site. However, the specific locations of safety-related slopes are generally not known at the ESP stage and, therefore, SRP Chapter 2.5.5 may not be complete. The subsections within SRP Chapter 2.5.5 that are not complete in the ESP application will be reviewed in detail as part of the COL or CP review.

In the absence of certain circumstances, such as a compliance or adequate protection issue, 10 CFR 52.39 precludes the staff from imposing new site characteristics, design parameters, or terms and conditions on the ESP at the COL stage. Accordingly, the reviewer should ensure that all physical attributes of the site that could affect the design basis of SSCs important to safety are reflected in the site characteristics, design parameters, or terms and conditions of the ESP.

#### 2. Standard Design Certification Reviews

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

- A. The postulated site parameters are representative of a reasonable number of sites that have been or may be considered for a COL application;
- B. The appropriate site parameters are included as Tier 1 information. This convention has been used by previous DC applicants. Additional guidance on site parameters is provided in SRP Section 2.0;
- C. Pertinent parameters are stated in a site parameters summary table; and
- D. The applicant has provided a basis for each of the site parameters.

### 3. Combined License Reviews

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

For a COL application referencing an ESP, NRC staff reviews the application to ensure the applicant provided sufficient information to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP 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 ESP 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 Final Safety Evaluation Report (FSER) to ensure that any ESP conditions, restrictions to the DC, or COL action items identified in the FSERs, in addition to the COL information items specified in the referenced DC, are appropriately handled in the COL application.

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

#### IV. EVALUATION FINDINGS

The review should document the staff's evaluation of 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 technical submittal. 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 SER. The reviewer also states the bases for those conclusions.

##### 1. Early Site Permit Reviews

Generally, ESP applicants do not perform slope stability analyses since the locations and designs of safety-related slopes have not been determined. As such, staff conclusions regarding slope stability are generally limited to the following statements: Section 2.5.5 of applicant's technical submittal does not provide sufficient information for the staff to complete its review. As such, at this time the staff is unable to reach any conclusions regarding the stability of slopes that have not been designed or constructed. Staff evaluation of slope stability will be performed as part of its review of the COL or CP application.

##### 2. Design Certification Reviews

The following statement should be preceded by a list of the applicable site parameters used for the plant:

The applicant has selected the site parameters referenced above for plant design inputs (a subset of which is included as Tier 1 information), and the staff agrees that they are

representative of a reasonable number of sites that have been or may be considered for a COL application. The stability of slopes is site-specific 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

The following statements should be preceded by a summary of the site characteristics and parameters used for the plant:

As set forth above, the applicant has presented and substantiated information to establish the stability of all earth and rock slopes, both natural and manmade at the plant site. The staff has reviewed the investigations performed for slope stability studies and dam and dike analyses and, for the reasons given above, concludes that the design analyses contain margins of safety which adequately demonstrate that natural and manmade slopes will remain stable under SSE, floods, tsunamis, and other potential adverse conditions and that safety-related earthwork will function reliably at the site to justify the soil and rock characteristics used in the design. The staff further concludes that the design analyses contain adequate margins of safety for construction and operation of the nuclear power plant and meets the requirements of 10 CFR Part 50, Appendix A (GDCs 1, 2, and 44); Appendices B and S of 10 CFR Part 50; and 10 CFR 100.23.

For DC and COL reviews, the findings will also summarize the staff's evaluation of requirements and restrictions (e.g., interface requirements and site parameters) and COL information items relevant to this SRP section

### 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 6 months or more after the date of issuance of this SRP section, unless superseded by a later revision.

### VI. REFERENCES

- 1 10 CFR 50.55a, "Codes and Standards."
- 2 10 CFR Part 50, Appendix A, General Design Criterion 1, "Quality Standards and Records."
- 3 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

- 4 10 CFR Part 50, Appendix A, General Design Criterion 44, "Cooling Water."
- 5 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants."
- 6 10 CFR Part 100, "Reactor Site Criteria."
- 7 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants."
- 8 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."
- 9 Bureau of Reclamation, "Earth Manual," Third Edition, U.S. Dept. of Interior, 1998.
- 10 Corps of Engineers, "Slope Stability," Manual N. EM 1110-2-1902, Office of the Chief of Engineers, Dept. of the Army, 2003.
- 11 Corps of Engineers, "Soils and Geology Procedures for Foundation Design of Buildings and Other Structures (Except Hydraulic Structures)," Tech. Report TM 5-818-1, Office of the Chief of Engineers, Dept. of the Army, 1983.
- 12 Department of the Navy, "Foundations, and Earth Structures," NAVFAC DM-7, September 1986.
- 13 RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants."
- 14 RG 1.28, "Quality Assurance Program Requirements (Design and Construction)."
- 15 RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants."
- 16 RG 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants."
- 17 RG 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites."
- 18 RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."
- 19 RG 1.208, "A Performance-Based Approach to Define the Safe Shutdown Earthquake Ground Motion."



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**PAPERWORK REDUCTION ACT STATEMENT**

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

**PUBLIC PROTECTION NOTIFICATION**

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

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## **SRP Section 2.5.5 Description of Changes**

### **Section 2.5.5 “STABILITY OF SLOPES”**

This SRP section affirms the technical accuracy and adequacy of the guidance previously provided in Revision 3, dated March 2007 of this SRP. See ADAMS Accession No. ML070730607. Changes include considerations in areas related to geotechnical engineering and foundation stability analysis based on lessons learned from past Section 2.5.5 reviews and newer reactor design. The technical changes incorporated in Revision 4, dated May 2013.

The title of this section is modified from the earlier Revision 3 as shown above.

The following changes were made throughout the sections:

1. Updated text and references to include Regulatory Guide 1.208.
  2. Updated text with editorial and clarifying statements.
- II. AREAS OF REVIEW
1. Updated text to include the review interface between organization responsible for quality assurance and the technical staff.
  2. Updated text to include a review interface with reviewers of DSRS Chapter 19 for the evaluation of stability of slopes related to seismic risk evaluation.
- III ACCEPTANCE CRITERIA
1. Updated text to include Regulatory Guide 1.208 as an acceptance criterion.
  2. Updated text to include clarification on the shaking components to be used in the slope stability analysis.
  3. Updated text to include that the GMRS must comply with Appendix S of 10 CFR Part 50 with respect to the peak ground acceleration and shape for slope stability analysis.
  4. Updated the text to include that the staff confirmatory analysis typically should include deterministic and probabilistic methods, as appropriate.
- IV REVIEW PROCEDURES
- Updated text with editorial and clarifying statements.

V. REFERENCES

1. Added Regulatory Guide 1.208 "A Performance-Based Approach to Define the Safe Shutdown Earthquake Ground Motion."
2. Added 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."