**U.S. NUCLEAR REGULATORY COMMISSION**

# STANDARD REVIEW PLAN

**OFFICE OF NUCLEAR REACTOR REGULATION**

## 2.4.10 FLOODING PROTECTION REQUIREMENTS

REVIEW RESPONSIBILITY

Primary - ~~Hydrologic and Geotechnical Engineering Branch (HGEB)~~Civil Engineering and Geosciences Branch (ECGB)[1]

Secondary - None

## I. AREAS OF REVIEW

The locations and elevations of safety-related facilities and of structures and components required for protection of safety-related facilities are compared with the estimated static and dynamic effects of design basis flood conditions identified in safety analysis report (SAR) Section 2.4.2.2, to determine whether flood effects need be considered in plant design or emergency procedures.

If flood protection is required, the type of flood protection ("hardened facilities," sandbags, flood doors, bulkheads, etc.) is reviewed. ~~Any emergency procedures required to implement flood protection and warning times available for implementation thereof are reviewed, based on the flood conditions identified in other sections.~~[2]

If there is evidence of potential structural effects from flooding,[3] ~~the Structural Engineering Branch (SEB) will be requested by HGEB to~~ECGB will[4] ascertain whether these effects are properly considered in the structural design bases for the plant.

Review Interfaces[5]

1. The ECGB will coordinate evaluations performed by other branches that interface with ECGB to complete the overall evaluation of the subject, as follows:[6]

   a. ~~similarly, Auxiliary~~ Plant Systems Branch (~~ASB~~ SPLB)[7] will be requested by ~~HGEB~~ ECGB[8] to ascertain whether the~~se~~ effects of flooding are properly considered in the systems design bases for the plant safety-related systems and components.[9] Guidance for determining whether these potential effects are considered properly is outlined in Standard Review Plan (SRP) Sections 3.4.1 and 3.4.2. ~~the appropriate SEB and ASB SRP sections.~~[10]

   b. The Human Factors Assessment Branch (HHFB) will be requested by ECGB to review any emergency procedures required to implement flood protection activities and warning times available for implementation thereof, based on the flood conditions identified in other sections.[11]

   c. The Technical Specifications Branch (TSB) will be requested to confirm that an appropriate item is included in the plant technical specifications whenever emergency procedures are required to ensure adequate flood protection for the plant.[12]

For those areas of review identified as part of the primary responsibility of other branches, the acceptance criteria and methods of application are contained in the referenced SRP section.[13]

II. ACCEPTANCE CRITERIA

~~HGEB~~ ECGB[14] acceptance criteria for this SRP section relate to the following regulations:

1. 10 CFR ~~Part 50,~~ [15]50.55a requires structures, systems, and components to be designed and constructed to quality standards commensurate with the importance of the safety function to be performed.

2. General Design Criterion 2 (GDC 2) requires structures, systems, and components important to safety to be designed to withstand the effects of floods.

3. 10 CFR Part 100 requires, in part,[16] that hydrologic characteristics be considered in the evaluation of the site.

Specific criteria necessary to meet the relevant flood protection requirements of 10 CFR ~~Part 50,~~ 50.55a, GDC 2, and 10 CFR Part 100 are as follows:

1. The flood design basis for each facility must be comparable with the positions in Regulatory Guide 1.59.[17] For construction permit (CP) reviews, the types of flood protection (discussed in Regulatory Guide 1.102) proposed must be capable of protecting those safety-related structures, systems, and components identified in Regulatory Guides 1.59 and 1.29.

2. For operating license (OL) or combined license (COL)[18] reviews, the specific designs of flood protection measures are reviewed to ~~assure~~ ensure[19] the protection levels are adequate (including static and dynamic effects) for the controlling flood conditions and that any necessary technical specifications are considered.

3. Standard engineering practice in positive flood control and shore protection, such as that developed by the Corps of Engineers, provides the basis for acceptance of methods to be employed for protection. Where sites are not[20] "hardened," that is, where emergency action is required, the time available to implement emergency procedures must be estimated by analysis of the hydrologic design event. The environmental conditions likely to prevail during all potential flooding events up to and including events of the severity of the controlling event are compared with the requirements for implementing flood emergency procedures. If the environmental conditions likely are such that the procedures can be carried out, they will be considered acceptable. An appropriate item in the plant Technical Specifications will be required in cases where emergency procedures are required to ~~assure~~ ensure adequate flood protection.

4. "Hardened" flood protection (as discussed in Regulatory Guide 1.59, for facilities identified in Regulatory Guide 1.29) will be interpreted to mean "almost always in place."

Technical Rationale[21]

The technical rationale for application of these acceptance criteria to the review of flooding protection requirements for a nuclear power plant is discussed in the following paragraphs:[22]

1. Compliance with 10 CFR 50.55a requires that structures, systems, and components be designed, fabricated, erected, constructed, tested, and inspected in accordance with the requirements of applicable codes and standards commensurate with the importance of the safety function to be performed.

   The criteria specified in 10 CFR 50.55a apply to this SRP section because the reviewer verifies the use of appropriate codes and standards for the design, construction, and inspection of safety-related structures and components that might be required to protect against flooding. To demonstrate compliance with 10 CFR 50.55a, the applicant's SAR must contain a description of flooding phenomena that could have potentially adverse impacts on safety-related systems, structures, or components. The description must be sufficient to provide a basis for evaluating the acceptability of the site and for assessing the adequacy of any flood protection that might be required for plant structures, systems or components designated as important to safety.

   Meeting the requirements of 10 CFR 50.55a provides assurance that plant structures, systems, or components designated as important to safety are designed to withstand, or are protected against, the effects of flooding.[23]

2. Compliance with GDC 2 requires that nuclear power plant structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as earthquake, tornado, hurricane, flood, tsunami, and seiche without loss of capability to perform their safety functions. The criterion further specifies that the design bases for these structures, systems, and components shall reflect the following:

   a. Appropriate consideration of the most severe natural phenomena historically reported for the site and its surrounding area, with sufficient margin for the limited accuracy, quantity, and time period in which the historical data have been accumulated;

   b. Appropriate combinations of the effects of normal and accident conditions with those of the natural phenomena; and

c. The importance of the safety functions to be performed.

The first specification was adopted in recognition of the relatively short history available for severe natural phenomena (e.g., flooding) on the North American continent and, consequently, the potential for underestimating the severity of a natural phenomenon based solely on probabilistic considerations. This problem is avoided by the use of a deterministic approach that considers the practical physical limitations of those phenomena contributing to the severity of the event in order to assess the design basis event. These data are then used during reviews conducted for a CP, OL, COL, or early site permit to specify flood design or protection requirements for nuclear power plant components, thereby ensuring the capability of these components to continue functioning as required. GDC 2 is imposed to ensure that portions of the facility designated as important to safety will continue functioning to maintain the plant in a safe condition.

This criterion is applicable to SRP Section 2.4.10 because it specifies the hydrologic phenomena that must be addressed by this section. In general terms, it also specifies the level of conservatism that must be used to assess the severity of these phenomena for the purpose of determining the design bases (or protection) requirements for structures, systems, and components important to safety.

Meeting the requirements of GDC 2 provides assurance that structures, systems, and components important to safety have been designed (or are protected) so as to withstand the most severe flooding likely to occur.[24]

3. Compliance with 10 CFR 100.10(c) requires that the site's physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining its acceptability for a nuclear power reactor.

To satisfy the hydrologic requirements of 10 CFR Part 100, the applicant's SAR must contain a description of the surface hydrologic characteristics of the site and region, as well as an analysis of the area's flood potential. The description must be sufficient to assess the acceptability of the site for a nuclear power plant of the proposed design. In addition, it may be necessary to assess the potential of those hydrologic characteristics to influence the design of structures, systems, and components important to safety and to define any special flood protection requirements therefor.

Meeting this requirement provides assurance that structures, systems or components important to safety are designed to withstand, or are protected against, the effects of potentially severe flooding.[25]

## III. REVIEW PROCEDURES

The estimated design basis flood level is compared with the locations and elevations of safety-related components. The staff will independently determine from analyses of postulated individual hydrologic events whether flood protection is required, and if so, what protective levels (including static and dynamic effects) are applicable. Based on t~~T~~hese data, ~~are transmitted to Structural Engineering Branch (SEB) for determination of~~ the ECGB will determine the[26] structural design criteria adequacy. ~~and~~ These data are also transmitted to ~~Auxiliary~~ Plant Systems Branch (~~ASB~~SPLB) ~~and Equipment Qualification Branch (EQB)~~[27] for determination of safety system adequacy. For flood protection requiring emergency action, the design basis flood conditions, and other less severe events, are reviewed to establish the minimum time available for implementation of emergency procedures. Physical parameters such as rate-of-rise (of river or lake levels), as well as evaluation (based on experience and engineering judgment) of flood warning networks, provide the staff with an independent

estimate of available time. These data are provided to ~~ASB and EQB for their~~ SPLB and HHFB for their[28] independent evaluation of the time required to implement shutdown and flood protective measures.

For OL and COL[29] reviews, the design of flood protection measures is reviewed to ~~assure~~ ensure compatibility with the original design basis. For those plants for which shutdown (if required under Regulatory Guide 1.59, Position 2) and installation of protective measures is required in the event of a major flood, the procedures for carrying out these measures are reviewed by HHFB[30] for compatibility of available and required times as established above. The Technical Specifications must reference an emergency plan which allows for the orderly installation of required flood protection.

The above reviews are performed only when applicable to the site or site region. Some items of review may be done on a generic basis.

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.[31]

## IV. EVALUATION FINDINGS

For CP and early site permit[32] reviews, the findings will consist of statements of flood design bases for safety-related facilities. If emergency procedures are required, the findings will indicate staff conclusions that time for implementation and methods of providing flood protection provide the necessary protection. For OL and COL[33] reviews the findings will indicate the flood protection measures provided for safety-related facilities, and will indicate the type of technical specifications required to ~~assure~~ ensure that the protection will be in place.

If Regulatory Guide 1.59, Position 2, is elected by the applicant, a statement describing lesser design bases will be included in the findings with the staff's conclusion of adequacy.

A sample CP-stage statement follows:

> The staff concludes that the flood protection design of the plant is acceptable and meets the requirements of 10 CFR ~~Part 50,~~ 50.55a, GDC 2, and 10 CFR Part 100. This conclusion is based upon the following evaluation:
>
> The probable maximum surge produces a maximum calculated stillwater level that is ~~3.9 feet~~ 1.2 m (3.9 ft)[34] above the plant grade elevation ~~(583.0 feet)~~ (177.7 m or 583.0 ft).[35] Wave runup associated with the coincident wind wave activity results in calculated flooding levels at safety-related structures that are higher than the stillwater level. Subsequent to our review of the preliminary safety analysis report, the applicant proposed a breakwater fronting the plant to attenuate the effects of the probable maximum meteorological event on plant structures. The breakwater will be a rubble mound structure using an armor cover of stone. The toe of the structure will be at ~~572.0 feet~~ 174.3 m (572.0 ft)[36] and the crest will be at ~~583.0 feet~~ 177.7 m (583.0 ft).[37] The front (lakeward) slope will be 2 horizontal to 1 vertical. To determine the design wave for the breakwater, the toe was conservatively assumed to scour ~~3 feet~~ 0.9 m (3 ft)[38] to elevation ~~569.0 feet~~ 173.4 m (569.0 ft).[39] The maximum significant breaking wave was estimated to be ~~12.2 feet~~ 3.7 m (12.2 ft)[40] during the probable maximum surge. Based on

these conditions, the armor layer was designed to be ~~7.5 feet~~ 2.3 m (7.5 ft)[41] thick using 3.0-metric ton (3.3-ton)[42] to 4.5 metric ton (5-ton,[43] stone. Underlayers were specified as follows:

> the secondary layer will be ~~3.5 feet~~ 1.1 m (3.5 ft)[44] thick with ~~600-pound~~ 272-kg (600-lb)[45] to ~~1000-pound~~ 454-kg (1000-lb)[46] stone; and
>
> the filter layer will be ~~1.5 feet~~ 0.5 m (1.5 ft)[47] thick with ~~30-pound~~ 14-kg (30-lb)[48] to ~~50-pound~~ 23-kg (50-lb)[49] stone.

The staff independently evaluated the proposed design using the Coastal Engineering Research Center's "'Shore Protection Manual" and concluded that the proposed breakwater design was conservative and therefore meets the criteria of 10 CFR ~~Part 50,~~ 50.55a.

During the probable maximum surge, the breakwater will be submerged by up to ~~3.9 feet~~ 1.2 m (3.9 ft)[50] of water (maximum stillwater elevation is ~~586.9 feet~~ 178.9 m or 586.9 ft).[51] Waves that would impinge on safety-related structures are limited by this maximum depth of water, and the maximum breaking wave that can be supported in this depth of water is approximately ~~3 feet~~ 0.9 m (3 ft).[52] Waves that are transmitted over the breakwater will approach the service building and radwaste building which are nearest to the lake. These buildings are not seismic Category I structures, but do afford some protection for seismic Category I structures from direct wave attack. Waves traveling around the ends of the breakwater, however, can reach and runup on seismic Category I structures, and the applicant used the resulting wave forces in the design of the structures. Seismic Category I structures considered in these analyses were the reactor building, the auxiliary building, and the residual heat removal building. In addition to considering the wave forces under the above postulated conditions, the applicant also provided airlocked and waterproofed doors that are normally closed for all openings in seismic Category I structures that are below the level of the maximum wave runup. We therefore conclude that the design of these structures meets the requirements of 10 CFR ~~Part 50,~~ 50.55a with respect to wave forces.

We have independently evaluated the effects of the probable maximum surge stillwater elevation plus wind-generated waves on all seismic Category I structures and have concluded that the wave forces and wave runup estimates used by the applicant are conservative and therefore meet the requirements of 10 CFR ~~Part 50,~~ 50.55a, GDC 2, and 10 CFR Part 100.

The findings will address the envelope of site-related hydrologic parameters, which should be representative of the most severe hydrologic characteristics expected to occur.[53]

For design certification reviews, the findings will also summarize, to the extent that the review is not discussed in other safety evaluation report sections, the staff's evaluation of inspections, tests, analyses, and acceptance criteria (ITAAC), including design acceptance criteria (DAC), site interface requirements, and combined license action items that are relevant to this SRP section.[54]

## V. IMPLEMENTATION

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

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52.[55] Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.[56]

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

## VI. REFERENCES

Other SRP sections in the 2.4 series provide hydrologic design basis flood levels and environmental condition descriptions. Reports of the Corps of Engineers, United States Geologic Survey, Bureau of Reclamation, National Oceanic and Atmospheric Administration, and others will be used on an "as available" basis to evaluate flood warning systems, if applicable. The references for acceptability of protection will be completed projects of the Corps of Engineers and other Federal, State, and local agencies, and similar types of protection previously reviewed and found acceptable for other nuclear plants.


1. 10 CFR ~~Part 50,~~ 50.55a, "Codes and Standards "

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

3. 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants."[57]

4. 10 CFR Part 100, "Reactor Site Criteria."

5. Regulatory Guide 1.70, "Standard Format and Contents of Safety Analysis Reports for Nuclear Power Plants."

6. Regulatory Guide 1.59, "Design Basis Flood for Nuclear Power Plants."

7. Regulatory Guide 1.29, "Seismic Design Classification."

8. Regulatory Guide 1.102, "Flood Protection for Nuclear Power Plants."

9. ANSI N170-1976[58], "Standards for Determining Design Basis Flooding at Power Reactor Sites."[59]

10. Regulatory Guide 1.125, "Physical Models for Design and Operation of Hydraulic Structures and Systems for Nuclear Power Plants."

[This Page Intentionally Left Blank]

## SRP Draft Section 2.4.10
Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

| Item | Source | Description |
|---|---|---|
| 1. | Current PRB name and abbreviation | Changed PRB to Civil Engineering and Geosciences Branch (ECGB). |
| 2. | SRP-UDP format item | Relocated sentence to "Review Interfaces." Responsibility for review of procedures rests with HHFB. |
| 3. | Editorial | Provided clarification of what effects are being considered. |
| 4. | Current PRB abbreviation | Changed PRB to ECGB. |
| 5. | SRP-UDP format item | Added "Review Interfaces" to AREAS OF REVIEW to describe how ECGB coordinates the review of flood protection with those of other branches. |
| 6. | SRP-UDP format item | Added lead-in sentence to "Review Interfaces." |
| 7. | Current PRB name and abbreviation | Changed PRB to Plant Systems Branch (SPLB). |
| 8. | Current PRB abbreviation | Changed PRB to ECGB. |
| 9. | Editorial | Provided clarification of which effects and systems are to be considered. |
| 10. | SRP-UDP format item | Provided references to specific sections for guidance related to "Review Interfaces" rather than vague, outdated references related to section responsibilities. |
| 11. | SRP-UDP format item | Revised and relocated sentence to "Review Interfaces." Responsibility for review of procedures rests with HHFB. See note 2. |
| 12. | SRP-UDP format item | Added sentence to "Review Interfaces" to cover the review responsibility of the Technical Specifications Branch (TSB), making the subsection consistent with the last sentence of specific criterion 3 of subsection II, ACCEPTANCE CRITERIA. |
| 13. | Editorial | Provided boilerplate paragraph on interrelationship of review branch responsibilities. |
| 14. | Current PRB abbreviation | Changed PRB to ECGB. |
| 15. | Editorial | Used citation format approved by the Office of the Federal Register to reference the Code of Federal Regulations (global change for this section). |

| Item | Source | Description |
|---|---|---|
| 16. | Editorial | Provided clarification of 10 CFR Part 100 requirements. |
| 17. | Integrated Impact No. 516 | ANSI N170-1976 is referenced in Regulatory Guide 1.59. This standard was revised in 1981 to ANSI/ANS-2.8, which was further revised in 1992. This reference in RG 1.59 should be updated to ANSI/ANS-2.8-1992 if a detailed comparison of the two versions supports the adoption of the more recent standard. |
| 18. | SRP-UDP format item | Revised guidance on OL reviews to include combined license (COL) reviews. |
| 19. | Editorial | Changed "assure" to "ensure" (global change for this section). |
| 20. | Editorial | Corrected an obvious error. |
| 21. | SRP-UDP format item | Added "Technical Rationale" to ACCEPTANCE CRITERIA subsection and organized in paragraph form to describe the bases for referencing specific NRC regulations. |
| 22. | SRP-UDP format item | Added lead-in sentence for "Technical Rationale." |
| 23. | SRP-UDP format item | Added technical rationale for 10 CFR Part 50, Section 50.55a. |
| 24. | SRP-UDP format item | Added technical rationale for GDC 2. |
| 25. | SRP-UDP format item | Added technical rationale for 10 CFR Part 100. |
| 26. | Current PRB abbreviation and responsibility | Changed PRB to ECGB and modified discussion of responsibility. |
| 27. | Current PRB abbreviation and responsibility | Changed PRB to SPLB, which now has a responsibility for the determination of safety system adequacy in the area of flood protection previously assigned to ASB and EQB. |
| 28. | Current PRB abbreviation and responsibility | Changed PRBs to SPLB and HHFB, which now have the responsibility for review of the time required to implement shutdown and flood protection measures, previously assigned to ASB and EQB. |
| 29. | SRP-UDP format item | Revised guidance on OL reviews to include COL reviews. |
| 30. | Added abbreviation and responsibility for current PRB | Added HHFB, since responsibility for review of procedures now rests with that branch. |

| Item | Source | Description |
|---|---|---|
| 31. | SRP-UDP Guidance, Implementation of 10 CFR 52 | Added standard paragraph to address application of Review Procedures in design certification reviews. |
| 32. | SRP-UDP format item | Added reference to early site reviews. |
| 33. | SRP-UDP format item | Revised guidance on OL reviews to include COL reviews. |
| 34. | Conversion to SI units | Converted 3.9 feet to 1.2 m. |
| 35. | Conversion to SI units | Converted 583.0 feet to 177.7 m. |
| 36. | Conversion to SI units | Converted 572.0 feet to 174.3 m. |
| 37. | Conversion to SI units | Converted 583.0 feet to 177.7 m. |
| 38. | Conversion to SI units | Converted 3 feet to 0.9 m. |
| 39. | Conversion to SI units | Converted 569.0 feet to 173.4 m. |
| 40. | Conversion to SI units | Converted 12.2 feet to 3.7 m. |
| 41. | Conversion to SI units | Converted 7.5 feet to 2.3 m. |
| 42. | Conversion to SI units | Converted 3.3 ton to 3.0 metric ton. |
| 43. | Conversion to SI units | Converted 5 ton to 4.5 metric ton. |
| 44. | Conversion to SI units | Converted 3.5 feet to 1.1 m. |
| 45. | Conversion to SI units | Converted 600 pound to 272 kg. |
| 46. | Conversion to SI units | Converted 1000 pound to 454 kg. |
| 47. | Conversion to SI units | Converted 1.5 feet to 0.5 m. |
| 48. | Conversion to SI units | Converted 30 pound to 14 kg. |
| 49. | Conversion to SI units | Converted 50 pound to 23 kg. |
| 50. | Conversion to SI units | Converted 3.9 feet to 1.2 m. |
| 51. | Conversion to SI units | Converted 586.9 feet to 178.9 m. |
| 52. | Conversion to SI units | Converted 3 feet to 0.9 m. |
| 53. | SRP-UDP format item | Added paragraph to identify scope of design certification. |

| Item | Source | Description |
|---|---|---|
| 54. | SRP-UDP Format Item, Implement 10 CFR 52 Related Changes | To address design certification reviews a new paragraph was added to the end of the Evaluation Findings. This paragraph addresses design certification specific items including ITAAC, DAC, site interface requirements, and combined license action items. |
| 55. | SRP-UDP Guidance, Implementation of 10 CFR 52 | Added standard sentence to address application of the SRP section to reviews of applications filed under 10 CFR Part 52, as well as Part 50. |
| 56. | SRP-UDP Guidance | Added standard paragraph to indicate applicability of this section to reviews of future applications. |
| 57. | SRP-UDP format item | Added reference to 10 CFR Part 52. |
| 58. | **Integrated Impact 1468** | Added the applicable version date to the reference for ANSI N170. |
| 59. | Integrated Impact No. 516 | ANSI N170-1976 was revised in 1981 to ANSI/ANS-2.8, which was further revised in 1992. This reference should be updated to ANSI/ANS-2.8-1992 if a detailed comparison of the two versions supports the adoption of the more recent standard. |

## SRP Draft Section 2.4.10
Attachment B - Cross Reference of Integrated Impacts

| Integrated Impact No. | Issue | SRP Subsections Affected |
|---|---|---|
| 516 | Regulatory Guide 1.59 references ANSI N170-1976 that was revised in 1981 to ANSI/ANS-2.8, which was further revised in 1992. In addition, ANSI N170 is referenced in this and several other sections of the SRP. Such references should be updated to ANSI/ANS-2.8-1992 in RG 1.59 and the SRP if a detailed comparison of the two versions supports the adoption of the more recent standard.<br><br>No changes were made to SRP Section 2.4.10. | Section II, second paragraph<br><br>Section VI, Reference 8 |
| 1468 | Update the citation of ANSI N170 to cite the 1976 version. | Subsection VI |