



JAPAN LESSONS-LEARNED PROJECT DIRECTORATE

JLD-ISG-2012-05

**Guidance for Performing the Integrated
Assessment for External Flooding**

Interim Staff Guidance
Revision 0



U.S. NRC

UNITED STATES NUCLEAR REGULATORY COMMISSION

Protecting People and the Environment

JAPAN LESSONS-LEARNED PROJECT DIRECTORATE

JLD-ISG-2012-05

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**INTERIM STAFF GUIDANCE
JAPAN LESSONS-LEARNED PROJECT DIRECTORATE
GUIDANCE FOR PERFORMING THE INTEGRATED ASSESSMENT
FOR EXTERNAL FLOODING
JLD-ISG-2012-05**

PURPOSE

This interim staff guidance is being issued to describe to stakeholders methods acceptable to the staff of the U.S. Nuclear Regulatory Commission (NRC) for performing the integrated assessment for external flooding as described in NRC's March 12, 2012, request for information (Ref. 1) issued pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54, "Conditions of licenses," regarding Recommendation 2.1 of the enclosure to SECY-11-0093, "Recommendations for Enhancing Reactor Safety in the 21st Century, the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident" (Ref. 2). Among other actions, the March 12, 2012 letter requests that respondents reevaluate flood hazards at each site and compare the reevaluated hazard to the current design basis at the site for each flood mechanism. Addressees are requested to perform an integrated assessment if the current design basis flood hazard does not bound the reevaluated flood hazard for all mechanisms. This ISG will assist operating power reactor respondents and holders of construction permits under 10 CFR Part 50 with performance of the integrated assessment. The guidance provided in this ISG describes methods for use in performing the integrated assessment requested in Enclosure 2 of the March 12, 2012, letter. This guidance is not intended for use in design basis applications or in regulatory activities beyond the scope of performing the integrated assessment.

BACKGROUND

Following the events at the Fukushima Dai-ichi nuclear power plant, the NRC established a senior-level agency task force referred to as the Near-Term Task Force (NTTF). The NTTF conducted a systematic and methodical review of the NRC regulations and processes and determined if the agency should make additional improvements to these programs in light of the events at Fukushima Dai-ichi. As a result of this review, the NTTF developed a comprehensive set of recommendations, documented in the enclosure to SECY-11-0093 (Ref. 2). These recommendations were enhanced by the NRC staff following interactions with stakeholders. Documentation of the NRC staff's efforts is contained in SECY-11-0124, "Recommended Actions to be Taken without Delay from the Near-Term Task Force Report," dated September 9, 2011 (Ref. 3), and SECY-11-0137, "Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned," dated October 3, 2011 (Ref. 4).

As directed by the staff requirements memorandum for the enclosure to SECY-11-0093 (Ref. 5), the NRC staff reviewed the NTTF recommendations within the context of the NRC's existing regulatory framework and considered the various regulatory vehicles available to the NRC to implement the recommendations. SECY-11-0124 and SECY-11-0137 established the staff's prioritization of the recommendations based upon the potential safety enhancements.

As part of the staff requirements memorandum for SECY-11-0124, dated October 18, 2011 (Ref. 6), the Commission approved the staff's proposed actions, including the development

of three information requests under 10 CFR 50.54(f). The information collected would be used to support the NRC staff's evaluation of whether further regulatory action should be pursued in the areas of seismic and flooding design, and emergency preparedness.

In addition to Commission direction, the Consolidated Appropriations Act, Public Law 112-074, was signed into law on December 23, 2011, which contains the Energy and Water Development Appropriations Act, 2012. Section 402 of the law requires a reevaluation of licensees' design basis for external hazards.

In response to the aforementioned Commission and Congressional direction, the NRC issued a request for information to all power reactor licensees and holders of construction permits under 10 CFR Part 50 on March 12, 2012 (Ref. 1). The March 12, 2012, 50.54(f) letter includes a request that respondents reevaluate flooding hazards at nuclear power plant sites using updated flooding hazard information and present-day regulatory guidance and methodologies. The letter also requests the comparison of the reevaluated hazard to the current design basis at the site for each potential flood mechanism. If the reevaluated flood hazard at a site is not bounded by the current design basis, respondents are requested to perform an integrated assessment. The integrated assessment will evaluate the total plant response to the flood hazard, considering multiple and diverse capabilities such as physical barriers, temporary protective measures, and operational procedures. The NRC staff will review the responses to this request for information and determine whether regulatory actions are necessary to provide additional protection against flooding.

On September 28, 2012, the NRC staff issued a draft version of this ISG and published a notice of its availability for public comment in the *Federal Register* (77 FR 65417). The 30-day comment period ran September 28, 2012, through October 29, 2012, during which the staff received 61 public comments. Comments were received related to the following topical areas: (1) evaluation of mitigation capability, particularly the perceived limitations associated with use of the scenario-based evaluation method; (2) expectations and attributes of the peer review; (3) the availability of illustrative examples; (4) equipment redundancy and quantification of reliability; (5) the evaluation of manual actions associated with protective and mitigative actions; (6) the evaluation of flood protection and demonstration of reliability and margin using available performance criteria; and (7) general and miscellaneous other topics. In public meetings on October 24-25, 2012, and November 7, 2012, the NRC staff interacted extensively with external stakeholders to discuss and resolve public comments (including discussion of proposed modifications to the text of the ISG) related to the evaluation of mitigation capability, the expectations and attributes of peer review, and other topics. Significant modifications were made to text of the ISG in response to the public comments and the outcomes of the public meetings. In addition, to provide more detailed guidance, staff has augmented the ISG by providing additional references related to the evaluation of flood protection and significantly enhancing portions of the ISG related to the evaluation of manual actions. The comments, staff responses, and the staff's bases for changes to the ISG are contained in "NRC Response to Public Comments" to JLD-ISG-2012-05 (Docket ID NRC-2012-0222) (Ref. 7).

RATIONALE

On March 12, 2012, the NRC issued a request for information to all power reactor licensees and holders of construction permits under 10 CFR Part 50. The request was issued in accordance with the provisions of Sections 161.c, 103.b, and 182.a of the Atomic Energy Act of 1954, as amended (the Act), and NRC regulation in Title 10 of the *Code of Federal*

Regulations, Part 50, Paragraph 50.54(f). Pursuant to these provisions of the Act or this regulation, respondents were required to provide information to enable the staff to determine whether a nuclear plant license should be modified, suspended, or revoked.

The information request directed respondents to submit an approach for developing an integrated assessment report including criteria for identifying vulnerabilities. This ISG describes an approach for developing the integrated assessment report that is acceptable to the staff.

APPLICABILITY

This ISG shall be implemented on the day following its approval. It shall remain in effect until it has been superseded or withdrawn.

PROPOSED GUIDANCE

This ISG is applicable to holders of operating power reactor licenses and construction permits under 10 CFR Part 50 from whom an integrated assessment is requested (i.e., sites for which the current design basis flood hazard does not bound the reevaluated hazard for all potential flood mechanisms). For combined license holders under 10 CFR Part 52, the issues in NTF Recommendation 2.1 and 2.3 regarding seismic and flooding reevaluations and walkdowns are resolved and thus this ISG is not applicable.

IMPLEMENTATION

Except in those cases in which a licensee or construction permit holder under 10 CFR Part 50 proposes an acceptable alternative method for performing the integrated assessment, the NRC staff will use the methods described in this ISG to evaluate the results of the integrated assessment.

BACKFITTING DISCUSSION

This ISG does not constitute backfitting as defined in 10 CFR 50.109 (the Backfit Rule) and is not otherwise inconsistent with the issue finality provision in Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," of 10 CFR. This ISG provides guidance on an acceptable method for responding to a portion of an information request issued pursuant to 10 CFR 50.54(f). Neither the information request nor the ISG require the modification or addition to systems, structures, or components, or design of a facility. Applicants and licensees may voluntarily use the guidance in JLD-ISG-2012-06 to comply with the request for information. The information received by this request may, at a later date, be used in the basis for a backfit at a later date. In this case, the appropriate backfit review process would be followed at that time.

FINAL RESOLUTION

The contents of this ISG, or a portion thereof, may subsequently be incorporated into other guidance documents, as appropriate.

ENCLOSURE

1. Guidance for Performance of Integrated Assessment

REFERENCES

1. U.S. Nuclear Regulatory Commission, Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, March 12, 2012, Agencywide Documents Access & Management System (ADAMS) Accession No. ML12053A340.
2. U.S. Nuclear Regulatory Commission, "Recommendations for Enhancing Reactor Safety in the 21st Century, The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," Enclosure to SECY-11-0093, July 12, 2011, ADAMS Accession No. ML111861807.
3. U.S. Nuclear Regulatory Commission. "Recommended Actions to be Taken Without Delay From the Near Term Task Force Report," SECY-11-0124, September 9, 2011, ADAMS Accession No. ML11245A158.
4. U.S. Nuclear Regulatory Commission. "Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned," SECY-11-0137, October 3, 2011, ADAMS Accession No. ML11272A111.
5. U.S. Nuclear Regulatory Commission. Staff Requirements - SECY-11-0093 - Near-Term Report and Recommendations for Agency Actions Following the Events in Japan. , August 19, 2011, ADAMS Accession No. ML112310021.
6. U.S. Nuclear Regulatory Commission. Staff Requirements - SECY-11-0124 - Recommended Actions to be Taken Without Delay From the Near-Term Task Force Report, October 18, 2011, ADAMS Accession No. ML112911571.
7. U.S. Nuclear Regulatory Commission, NRC Responses to Public Comments, Japan Lessons-Learned Project Directorate Interim Staff Guidance (JLD-ISG-2012-05): Guidance for Performing the Integrated Assessment for Flooding in Response to the March 2012 Request for Information Letter, November 30, 2012, ADAMS Accession No. ML12311A216.

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1. Introduction

This document provides guidance for the performance of the integrated assessment. Based on the results of the site-specific flood hazard assessments, the integrated assessment evaluates the total plant response to external flood hazards, considering both the protection and mitigation capabilities of the plant. The purpose of the integrated assessment is to: (1) evaluate the effectiveness of the current licensing basis under the reevaluated flood hazard, (2) identify plant-specific vulnerabilities due to external flood hazards, and (3) assess the effectiveness of existing or planned plant systems and procedures in protecting against flood conditions and mitigating consequences for the entire duration of a flooding event.

In general, the types and attributes of flood protection features used at nuclear power plants are diverse because of differences in factors such as: hazard characteristics (e.g., flood mechanisms, flood durations, and debris quantity), site topography and surrounding environment, and other site-specific considerations (e.g., available warning time). As a result, this guidance must be capable of accommodating the unique environments and characteristics of nuclear power plant sites while ensuring that the information gathered, as part of the Nuclear Regulatory Commission's (NRC's) March 12, 2012, information request, provides a sufficient technical basis to determine if any additional regulatory actions are necessary to protect against external flood hazards. The Information request was issued pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f).

1.1 Actions and Information Requested

For the sites at which the reevaluated flood is not bounded by the current design basis for all flood-causing mechanisms, the March 12, 2012, 10 CFR 50.54(f) letter requests that licensees and construction permit holders¹ perform an integrated assessment of the plant to identify vulnerabilities and actions to address them.

Consistent with Enclosure 2 (p. 8-9) of the March 12, 2012, 10 CFR 50.54(f) letter, licensees and construction permit holders are requested to provide the following as part of the integrated assessment report:

- a) Description of the integrated procedure used to evaluate integrity of the plant for the entire duration of flood conditions at the site.
- b) Results of the plant evaluations describing the controlling flood mechanisms and its effects, and how the available or planned measures will provide effective protection and mitigation. Discuss whether there is margin beyond the postulated scenarios.
- c) Description of any additional protection and/or mitigation features that were installed or are planned, including those installed during the course of reevaluating the hazard. The description should include the specific features and their functions.

¹ This ISG is applicable to holders of operating power reactor licenses and construction permits under 10 CFR Part 50 from whom an integrated assessment is requested. For brevity, the term "licensees" will often be used in this ISG. It should be understood that, within this ISG, the term applies both to holders of operating power reactor licenses and construction permits.

- d) Identify other actions that have been taken or are planned to address plant-specific vulnerabilities.

This Interim Staff Guidance (ISG) provides guidance on methods that NRC staff considers acceptable for performing the integrated assessment as requested by the March 12, 2012, 10 CFR 50.54(f) letter.

1.2 Integrated Assessment Concept

Figure 1 provides a conceptual illustration of the integrated assessment process. The outcomes of the hazard reviews performed under the Near-Term Task Force (NTTF) Recommendation 2.1 flood hazard reevaluations² provide input into the integrated assessment process. Upon entering the integrated assessment process, licensees should evaluate the capability of flood protection systems to meet their intended safety functions under the reevaluated hazard.

If the licensee can demonstrate the site's flood protection is reliable and has margin, the licensee should proceed to documentation and justification of results. If the licensee cannot demonstrate that the site's flood protection is reliable and has margin, the licensee should evaluate the plant's ability to maintain key safety functions during a flood in the event that one or more flood protection systems are compromised and unable to perform their intended functions. In this ISG, this step of the integrated assessment process is referred to as an evaluation of mitigation capability. After evaluating the mitigation capability of the plant, the process proceeds to documentation and justification of results.

In lieu of flood protection, some sites may allow water to enter buildings (or other areas that house structures, systems, or components (SSCs) that are important to safety) by procedure or design. If the presence of water in these locations may adversely affect SSCs that are important to safety, then the integrated assessment process should proceed directly into the evaluation of the mitigation capability of the plant. This is represented by the large arrow on the rightmost side of Figure 1.

Subsequent sections of this document provide additional details on the integrated assessment process.

1.3 Scope of the Integrated Assessment

In accordance with the March 12, 2012, 10 CFR 50.54(f) letter, the scope of the integrated assessment includes full-power operations and other plant configurations that could be susceptible to damage due to impairment of flood protection features. The integrated assessment should evaluate the effectiveness of flood protection and mitigation capability of the plant for the mode(s) of operation that the plant will be in for the entire flood event duration. The integrated assessment should describe the expected total plant response under other modes of operation, including a discussion of controls (e.g., programmatic controls) that are in place in the event that a flood occurs during any of these modes (e.g., during refueling). The integrated assessment should also consider whether specific vulnerabilities may arise during normal and full-power configurations and other modes of

² See Section 2.2 for additional details on the NTTF Recommendation 2.1 hazard reevaluations and the relationship to the integrated assessment.

operation or configurations (e.g., conditions where flood protection features may be bypassed or defeated for maintenance or refueling activities).

The integrated assessment should consider plant conditions, including adverse weather that could reasonably be expected to occur simultaneously with an external flood event (Reference 1 provides guidance on combined events³) and should consider equipment that may be directly affected by the flood event (e.g., loss of the switchyard from inundation).

The scope of the integrated assessment also includes flood-induced loss of an ultimate heat sink (UHS) water source (e.g., due to failure of a downstream dam) that could be caused by the flood conditions. (The scope does not include the loss of the UHS from causes other than flooding, such as seismic failure.)

As previously stated, the March 12, 2012, 10 CFR 50.54(f) letter also requests that the integrated assessment address the entire duration of the flood conditions.

³ As part of the Recommendation 2.1 hazard reevaluations (see Section 2.2), Reference 1 should have been used in establishing the combined events applicable to a site.

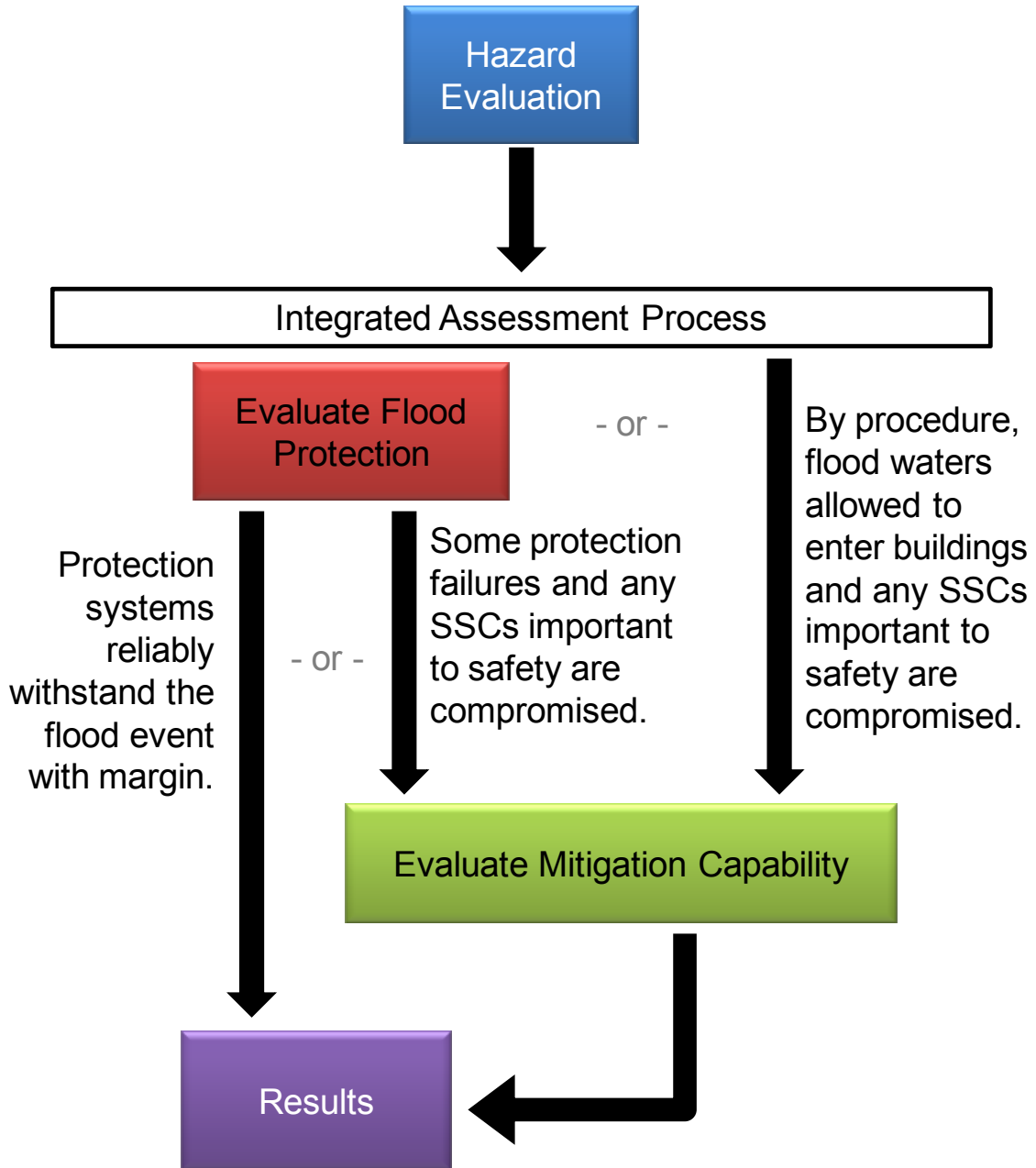


Figure 1: Conceptual illustration of integrated assessment process

2. Background

2.1 NTTF Recommendation 2.3 Flood Walkdowns

The March 12, 2012, 10 CFR 50.54(f) letter requires that licensees perform flood protection walkdowns to verify that plant features that are credited in the current licensing basis for protection and mitigation from external flood events are available, functional, and properly maintained. These walkdowns are interim actions to be performed while the longer-term hazard reevaluations and integrated assessments are performed. NRC and the Nuclear Energy Institute (NEI) worked collaboratively to develop guidelines for performing the walkdowns; this collaboration resulted in NEI 12-07, "Guidelines for Performing Verification Walkdowns of Plant Flood Protection Features," issued May 2012 (Ref. 2), which the NRC endorsed on May 31, 2012 (Ref. 3).

As part of the walkdowns, licensees and construction permit holders will verify that permanent SSCs, as well as temporary or portable flood protection and mitigation equipment, will perform their intended safety functions as credited in the current licensing basis. Verification activities will ensure that changes to the plant (e.g., security barrier installations and topography changes) do not adversely affect flood protection and mitigation equipment. In addition, the walkdown will verify that licensees can perform the procedures needed to install and operate equipment needed for flood protection or mitigation as credited in the current licensing basis. The walkdown will also verify that adverse weather conditions that could reasonably be expected to occur simultaneously with a flood event will not impede the licensee's ability to carry out the procedures. As part of the walkdowns, the licensee will enter observations of potential deficiencies, as well as observations of flood protection features with small margin and potentially significant safety consequences if lost, into its corrective action program.

It is anticipated that the walkdowns will be a valuable source of information that will be useful during the performance of the integrated assessment. In particular, the walkdowns will provide information on available physical margin (APM) under the current design basis hazard, the condition of flood protection features, the feasibility of manual actions, SSCs that are subjected to flooding, and the potential availability of systems necessary to mitigate flood events. However, it is emphasized that the walkdowns are performed to the current licensing basis. The reevaluated flood hazards performed under Recommendation 2.1 (see Section 2.2) may result in higher calculated water surface elevations and different associated effects when compared to the current licensing basis. Therefore, some of the information from the walkdowns may not be directly applicable to the integrated assessment. It is expected that any additional information related to the impact of the flooding hazard reassessment will be considered as part of the integrated assessment, and that this information would be used to evaluate the flood protection capabilities in light of potential additional flooding impacts to the site (e.g., higher elevations, accessibility issues) that may not have been fully considered during the implementation of the Recommendation 2.3 walkdown.

2.2 NTTF Recommendation 2.1 Flood Hazard Reevaluations

The NRC is implementing Recommendation 2.1 of the NTTF in two phases. In Phase 1, licensees and construction permit holders will reevaluate the flooding hazard(s) at each site using present-day regulatory guidance and methodologies. If the reevaluated hazard is not bounded by the design basis flood at the site, licensees and construction permit holders

should also perform an integrated assessment for external flooding. During Phase 2, NRC staff will use the Phase 1 results to determine whether additional regulatory actions are necessary (e.g., update the licensing basis and SSCs important to safety).

The NRC's March 12, 2012, 10 CFR 50.54(f) letter requires that licensees and construction permit holders reevaluate all appropriate external flooding sources, including the effects from local intense precipitation on the site, probable maximum flood on streams and rivers, storm surges, seiche, tsunamis, and dam failures. The reevaluation should apply present-day regulatory guidance and methodologies used for early site permit and combined license reviews, including the current techniques, software, and methods used in present-day standard engineering practice.

For the sites where the reevaluated flood is *not* bounded by the current design basis hazard for all flood mechanisms applicable to the site, licensees and construction permit holders are requested to submit an interim action plan with the hazard reevaluation report that documents actions planned or taken to address the reevaluated hazard. Subsequent to submission of the hazard reevaluation report, licensees and construction permit holders are also asked to perform an integrated assessment. In light of the reevaluated hazard, the integrated assessment will (1) evaluate the effectiveness of the current licensing basis (i.e., flood protection and mitigation systems), (2) identify plant-specific vulnerabilities, and (3) assess the effectiveness of existing or planned systems and procedures for protecting against and mitigating consequences for the entire duration of the flood event.

3. Framework of the Integrated Assessment

3.1 Integrated Assessment Process

The intent of the integrated assessment is to identify site-specific vulnerabilities and to provide other important insights.⁴ As described above, the integrated assessment is based on a graded approach to ensure the assessment performed is appropriate for the unique characteristics of a given site. Depending on site characteristics, the graded approach supports assessments that range from engineering evaluations of individual flood protection features to evaluations based on probabilistic risk assessment (PRA) techniques⁵ (e.g., system logic models and risk-insights). The integrated assessment process consists of up to five possible steps, depending on site characteristics:

1. the definition of peer review scope and the assembly of a peer review team
2. a determination of the controlling flood parameters
3. an evaluation of flood protection systems (if applicable⁶)
4. an evaluation of mitigation capability (if appropriate)
5. the documentation of the results

The flowchart in Figure 2 illustrates that integrated assessment process described below.

The first step of the integrated assessment process involves the assembly of an initial peer review team. Section 4 and Appendix B to this guidance provide additional details on the peer review and the composition of the peer review team.

The second step in the integrated assessment process involves the determination of the flood scenario parameters that the assessment should consider based on the results produced as part of the NITF Recommendation 2.1 flood hazard reevaluations (represented by Box 2 in Figure 2). Section 5 provides additional guidance on determining the flood scenario parameters that the integrated assessment should consider.

Box 3 in Figure 2 represents a decision point. If a site has flood protection to prevent the entry of water into buildings or other areas containing SSCs that are important to safety, the process proceeds to Step 3, which involves an evaluation of the effectiveness of the flood protection system(s) at the site. Section 6 provides additional guidance on the evaluation of flood protection. Conversely, if a site allows water to enter buildings or other areas with SSCs that are important to safety (by procedure or design) with potential effects on those SSCs, the integrated assessment process skips Step 3 and proceeds directly to Step 4. Step 4 involves the evaluation of the capability of the plant to maintain key safety functions⁷ during a flood event.

Another decision point occurs after the conduct of the flood protection evaluation (Step 3), as shown by Box 5 in Figure 2. If the evaluation demonstrates that on-site flood protection

⁴ It is expected that the integrated assessment will yield insights related to available physical margin, defense-in-depth, and cliff-edge effects.

⁵ This ISG describes the use of PRA techniques, however the approaches described in this document are not intended to be compliant with guidance provided in Reference 9.

⁶ Some sites may have no flood protection. In these cases, a flood protection evaluation would not be applicable.

⁷ See Section 9 for a definition of key safety functions.

is reliable and has margin, the integrated assessment process proceeds directly to Step 5 (documentation of the results). However, if the evaluation does not demonstrate that on-site flood protection is reliable and has margin, the process proceeds to Step 4 to evaluate the plant's capability to mitigate a loss of one or more flood protection systems by maintaining key safety functions (represented by Box 6 in Figure 2). Section 7 provides additional information on evaluation of the capability of a plant to mitigate the loss of one or more flood protection systems. Section 8 provides guidance on documentation of results.

3.2 Key Assumptions

The following subsections below provide information on key assumptions applicable to the integrated assessment.

3.2.1 Use of Available Resources for Protection and Mitigation

The integrated assessment evaluates the current licensing basis protection and mitigation capability of plants in response to the reevaluated flood hazards, as well as additional in-place or planned resources. In assessing the protection and mitigation capability of a plant, credit can be taken for all available (onsite and offsite) resources as well as the use of systems, equipment, and personnel in nontraditional ways. Temporary protection and mitigation measures, as well as nonsafety-related SSCs can be credited, provided there is sufficient technical bases to justify the effectiveness of these resources. In crediting use of systems, equipment, and personnel in nontraditional ways, nonsafety-related SSCs, temporary mitigation and protection features, or similar resources, the integrated assessment should account for the potentially reduced reliability of such resources in relation to permanent, safety-related equipment (Ref. 4). Moreover, if credit is taken for these resources, the licensee or construction permit holder should justify that the resources will be available and functional when they are required for the flood event duration.⁸ The assessment should consider the time required to acquire these resources and place them in service, as well as the functionality of the equipment when needed during the flood event duration. Sections 6 and 7 provide guidance on evaluation of flood protection and mitigation capability.

The NRC staff recognizes that other parallel activities related to Fukushima lessons learned are ongoing, the result of which will augment available onsite resources. It is the intent of this ISG to allow licensees to credit equipment that has been or will be installed by these efforts. It is important to recognize, though, that the goals associated with the other activities may differ from those of this ISG due to the difference in the intended uses (i.e., determining the acceptability for use in a beyond-design-basis event versus determining the acceptability of the current design basis). Therefore, much of the analyses and evaluations done for these other activities can likely be utilized. If crediting these resources, it is necessary to demonstrate that these resources also meet the intent of this ISG. This includes demonstration and justification that following NRC or industry guidance related to these other efforts meets the intent of this ISG.

3.2.2 Flood Frequencies

For most flood mechanisms, widely accepted and well-established methodologies are not available for assigning initiating event frequencies to severe floods for the performance of

⁸ See Section 9 for a definition of the flood event duration.

probabilistic flood hazard assessment (Ref. 5). For this reason, the integrated assessment does not require the computation of initiating flood-hazard frequencies. Using initiating event frequencies to screen out flood events in lieu of evaluation of flood protection features at the site is not acceptable. However, if desired and if given appropriate justification, the use of the flood event frequency is acceptable as part of a PRA to evaluate total plant response.

3.2.3 Human Performance

Human performance may take on added importance during flooding events compared to normal operations. The establishment of flood protection features may rely heavily on manual actions such as constructing sandbag barriers, deploying and operating portable pumps, or relocating equipment. Significant manual actions may also be associated with mitigation actions, including actions that may leverage equipment, personnel, or other resources in nontraditional ways. In addition, failed or degraded instrumentation and controls in the main control room (MCR), as well as the unavailability of equipment and systems, may challenge the operating crew's ability to monitor and control the plant to ensure that key safety functions are maintained. Access to and the functionality of local or remote control stations may also be compromised. The addition of responsibilities to oversee and manage flood response activities will increase operators' workload.

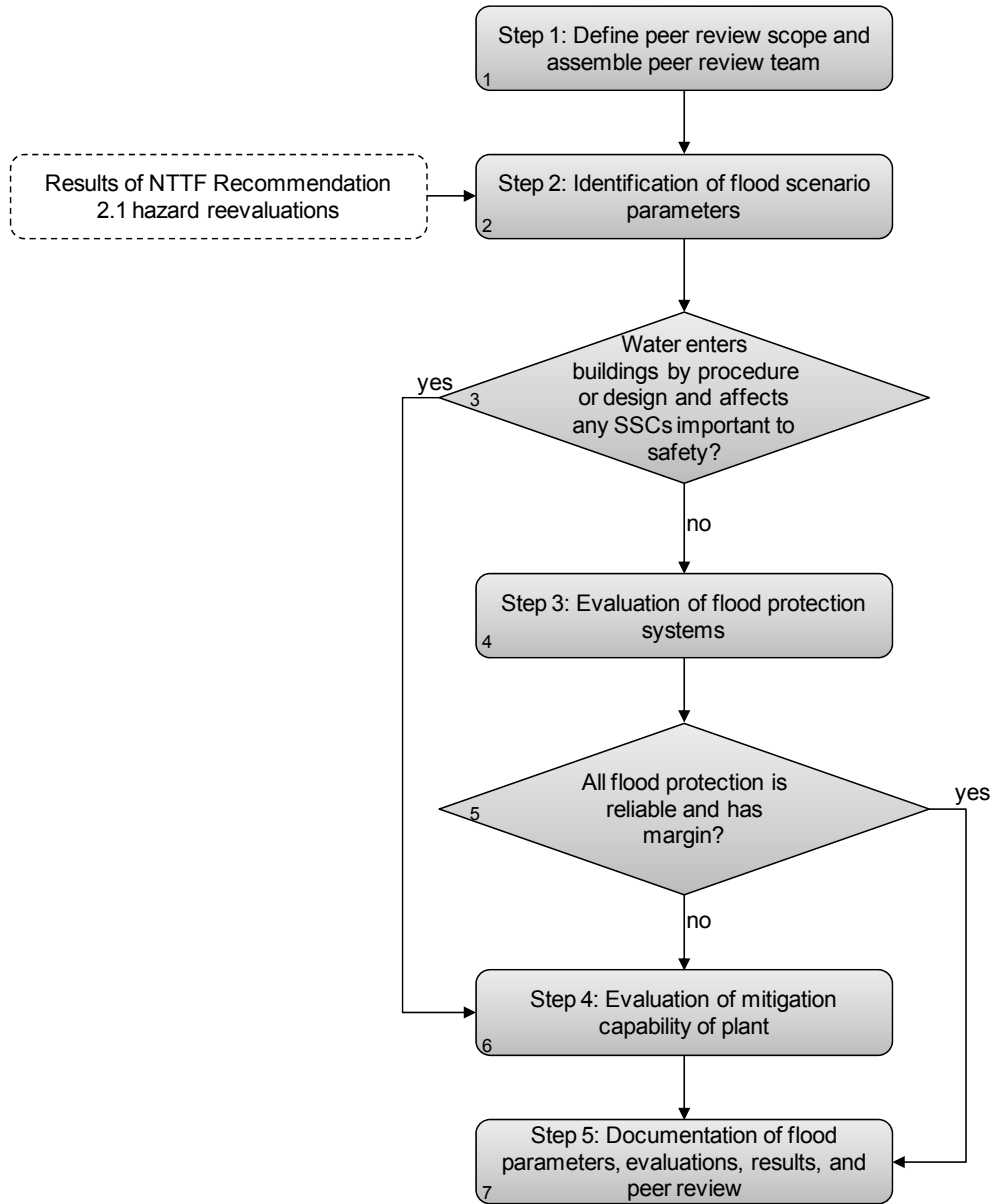


Figure 2: Integrated assessment process flowchart

4. Peer Review

An independent peer review is an important element for ensuring technical adequacy. The technical adequacy of the integrated assessment is measured in terms of the appropriateness of the scope, level of detail, methodologies employed, and plant representation, which should be consistent with this guidance and commensurate with the site-specific hazard and inherent flood protection reliability. Specifically, technical adequacy is determined by ensuring:

- the scope of effort is sufficient
- state of the art methodologies are correctly employed
- input parameters, including plant configurations, are justified
- the integrated assessment is performed consistent with this guidance

The licensee's integrated assessment submittal should discuss measures that it used to ensure technical adequacy, including the documentation of peer review. Appendix B to this guidance provides additional details on peer review for the integrated assessment.

5. Hazard Definition

5.1 Identification of Applicable Flood Mechanisms and Plant Conditions

The hazard reevaluations performed under Recommendation 2.1 (see Section 2.2 for background information) identify the external flood mechanisms applicable to a site. Before the licensee performs the integrated assessment, it should collect or review the flood height and associated effects⁹ for all applicable flood mechanisms from the hazard review for use in the integrated assessment. In addition, for each flood mechanism, the licensee should collect the following information for use in the integrated assessment:¹⁰

- the expected plant mode(s) during the flood event duration
- available instrumentation and communication mechanisms associated with each flood mechanism, if applicable (e.g. river forecasts, dam condition reports, river gauges)
- the availability of and access to onsite and offsite resources (including personnel) and consumables (e.g., fuel)
- accessibility considerations to and from the site and around the site that may affect protective and mitigating actions
- the effect of flood conditions on the availability of the UHS and offsite power
- other relevant plant-specific conditions

5.2 Identification of Controlling Flood Parameters

As described above, the flood parameters considered as part of the integrated assessment for a plant are based on the Recommendation 2.1 hazard reevaluations (see Section 2.2 for background information). Flood hazards do not need to be considered individually as part of the integrated assessment. Instead, the integrated assessment should be performed for a set(s) of flood scenario parameters defined based on the results of the Recommendation 2.1 hazard reevaluations.

The licensee should define the following flood scenario parameters and should consider them as part of the integrated assessment:

- flood height and associated effects
- flood event duration, including warning time and intermediate water surface elevations that trigger actions by plant personnel
- plant mode(s) of operation during the flood event duration
- other relevant plant-specific factors

In some cases, only one controlling flood hazard may exist for a site. In this case, licensees should define the flood scenario parameters based on this controlling flood hazard. However, sites that have a diversity of flood hazards to which the site may be exposed should define multiple sets of flood scenario parameters to capture the different plant effects from the diverse flood parameters associated with applicable hazards. In addition, sites may use different flood protection systems to protect against or mitigate different flood

⁹ See Section 9 for the definition of flood height and associated effects.

¹⁰ This information may be available, in part, from the Recommendation 2.3 walkdown report or licensee walkdown records (see Section 2)

hazards. In such instances, the integrated assessment should define multiple sets of flood scenario parameters.

If appropriate, it is acceptable to develop an enveloping scenario (e.g., the maximum water surface elevation and inundation duration with the minimum warning time generated from different hazard scenarios) instead of considering multiple sets of flood scenario parameters as part of the integrated assessment. For simplicity, the licensee may combine these flood parameters to generate a single bounding set of flood scenario parameters for use in the integrated assessment.

5.3 Collection of Critical Plant Elevations and Protection of Equipment

To facilitate the performance of the integrated assessment, the licensee should collect or otherwise understand following information:

- the critical elevations¹¹ of plant equipment that is important to safety and the safety functions affected when the critical elevation of the equipment is reached
- the flood protection features or systems used to protect each piece or group of critical plant equipment (e.g., a site levee, a Category 1 wall and flood doors, or a sandbag barrier) and any procedures required to install, construct, or otherwise implement the flood protection
- the manner by which the equipment could be subjected to flooding (e.g., site inundation or building leakage)
- potential pathways for ingress of water (e.g., through conduits or ducts)

¹¹ See Section 9 for the definition of critical elevations.

6. Evaluation of Effectiveness of Flood Protection

As part of the integrated assessment, the licensee should perform an evaluation of the capability of the site flood protection to protect SSCs important to safety for each set of flood scenario parameters.

Site flood protection may include incorporated, exterior, and temporary features¹² with passive and active functions that are credited to protect against the effects of external floods. In addition to physical barriers, flood protection at nuclear power plants may involve a variety of manual actions performed by personnel. These manual actions may be associated with installation of features (e.g., floodgates, portable panels, and the placement of portable pumps in service), the construction of barriers (e.g., sandbag barriers), and other actions.

6.1 Process Overview

The flowchart in Figure 3 illustrates an acceptable process to evaluate flood protection. The evaluation begins by selecting a set of flood scenario parameters for evaluation. Next, a flood protection system¹³ is selected for evaluation. An evaluation is then performed of the selected flood protection system under the flood scenario parameters. The type of methodology considered appropriate for evaluating a flood protection system is based on the types of flood protection features employed in the flood protection system. The flood protection evaluation should assess the performance of the flood protection at both the feature- and system-levels. Sections 6.2 and 6.3, as well as Appendix A to this guidance, provide additional information on the evaluation of flood protection.

If the evaluation demonstrates that the flood protection can reliably accommodate the flood scenario parameters with margin (Figure 3, Box 4) based on available performance criteria (see Section 6.2) or on the quantification of flood protection reliability, then the licensee should document and justify the integrity of the system (Box 5) and should repeat the evaluation for the next flood protection system. Conversely, if the flood protection system is not able to reliably accommodate the flood scenario parameters with margin, and modifications will not be made (Box 6), the licensee should document the credible failure modes and vulnerabilities along with the direct consequences (e.g., inundation of a room) of each failure mode and vulnerability. The analysis is then repeated for the next flood protection system. If modifications to the flood protection system are in-place or planned (Box 6), the modified flood protection system should be defined (Box 7) and the evaluation repeated for the modified flood protection system.

¹² Section 9 provides definitions of incorporated, exterior, and temporary flood protection features.

¹³ Section 9 defines the term flood protection system. A site may have multiple and diverse flood protection systems. For example, a site may be protected by a levee around the entire site as well as incorporated barriers at the structure/environment interface for each individual building. The site levee would constitute one flood protection system while a set of barriers that protects an individual building, which can be isolated from other buildings (either through separation by location or flood protection features), would comprise a separate flood protection system.

6.2 Performance Criteria

To provide confidence in the reliability and margin of flood protection, considering both qualitative and quantitative performance criteria, the flood protection evaluation should do the following:

- Provide an understanding of potential failure modes of the flood protection system, including consideration of potential ingress pathways for floodwaters (e.g., through conduits or ducts).
- Demonstrate the soundness of the individual flood protection features under the loads (i.e., flood height and associated effects) due to the flood scenario parameters and confirm that the features are:
 - in satisfactory condition;
 - higher than the reevaluated flood height; and
 - structurally adequate based on quantitative engineering evaluations.
- Demonstrate that the performance, characteristics, and configuration of the flood protection feature(s) conforms to accepted practices and is sufficiently robust (e.g., demonstrates an appropriate factor of safety) by:
 - comparison against appropriate, present-day design codes and standards
 - comparison against NUREG-0800, Sections 3.4.1 and 3.4.2 (Refs. 6 and 7)
 - assessment of exterior and incorporated flood protection features as described in Section A.1.1 to Appendix A of this guidance
 - justification and quantification (if applicable) of the reliability of active features as described in Section A.1.2 of Appendix A to this guidance
 - assessment of temporary features as described in Section A.1.3
- Perform a qualitative assessment of operational requirements such as surveillance, inspection, design control, maintenance, procurement, and testing.
- Develop a timeline showing all manual actions, including cues, indications, and notifications.
- Ensure that the capacity of pumping or drainage systems is sufficient to handle any inflow through flood protection features for the entire flood event duration.
- Evaluate whether manual actions (including construction, installation, or other actions) are feasible and reliable as described in Appendix C to this guidance, including justification and documentation as described in Section C.6 of Appendix C. Also evaluate the continued ability of the operating crew to monitor and control the plant to maintain key safety functions.
- Demonstrate that necessary consumables are available and will remain accessible for the entire flood event duration.
- Evaluate the flood protection system as a whole as described in Section A.2 of Appendix A to this guidance.
- Include sensitivity studies, if uncertainty about the construction or characteristics of a flood protection feature or system exists (e.g., uncertainty about the parameters of concrete used in the construction of a concrete wall).

Probabilistic evaluation of the fragility of exterior and incorporated features under the flood scenario parameters is also acceptable, given adequate justification.

6.3 Justification of Flood Protection Performance

If, based on the flood protection evaluation, a flood protection system is deemed capable of withstanding the flood height and associated effects for a set of flood scenario parameters,

the integrated assessment should justify this conclusion. In addition, the limiting margin associated with the flood protection system as well as the margin associated with individual flood protection features should be identified.

Margin should be characterized with respect to physical barrier dimensions,¹⁴ structural or other performance capacity, and time and staffing associated with the performance of manual actions to establish flood protection systems. Demonstration of the aforementioned items requires an understanding of the capability of flood protection systems for a range of flood heights and associated effects (including reasonable variation in warning time and flood event duration). Physical margin and structural capacity can be demonstrated by increasing the flood elevation (while accounting for associated effects) and showing the elevation beyond which the system is no longer capable of reliably performing its intended function.

The integrated assessment should identify any flood protection features or systems that are unable to reliably accommodate the flood height and associated effects for a set of flood scenario parameters with margin. Any flood protection feature or system determined to be incapable of performing its intended safety function under the reevaluated hazard should be documented as a vulnerability (see Section 8) for all susceptible plant configurations. In addition, if a flood protection feature or system cannot accommodate the flood scenario parameters, the flood protection evaluation should determine at what flood height and under what associated effects, the flood protection feature or system is able to reliably accommodate a flood. If the licensee proposes modifications to address vulnerabilities, improve margin, or otherwise improve the effectiveness of site flood protection, the integrated assessment should justify that the modified flood protection is reliable and has margin through comparison to established performance criteria or quantification of reliability (as appropriate).

¹⁴ Margin with respect to physical barrier dimensions is analogous to the concept of APM defined under the NTTF Recommendation 2.3 flood walkdowns (see Reference 2). However, APM was computed as part of the NTTF Recommendation 2.3 flood walkdowns with respect to the current licensing basis flood protection height. In the context of the integrated assessment, margin with respect to physical barriers is defined with respect to the reevaluated hazard (including flood height and associated effects).

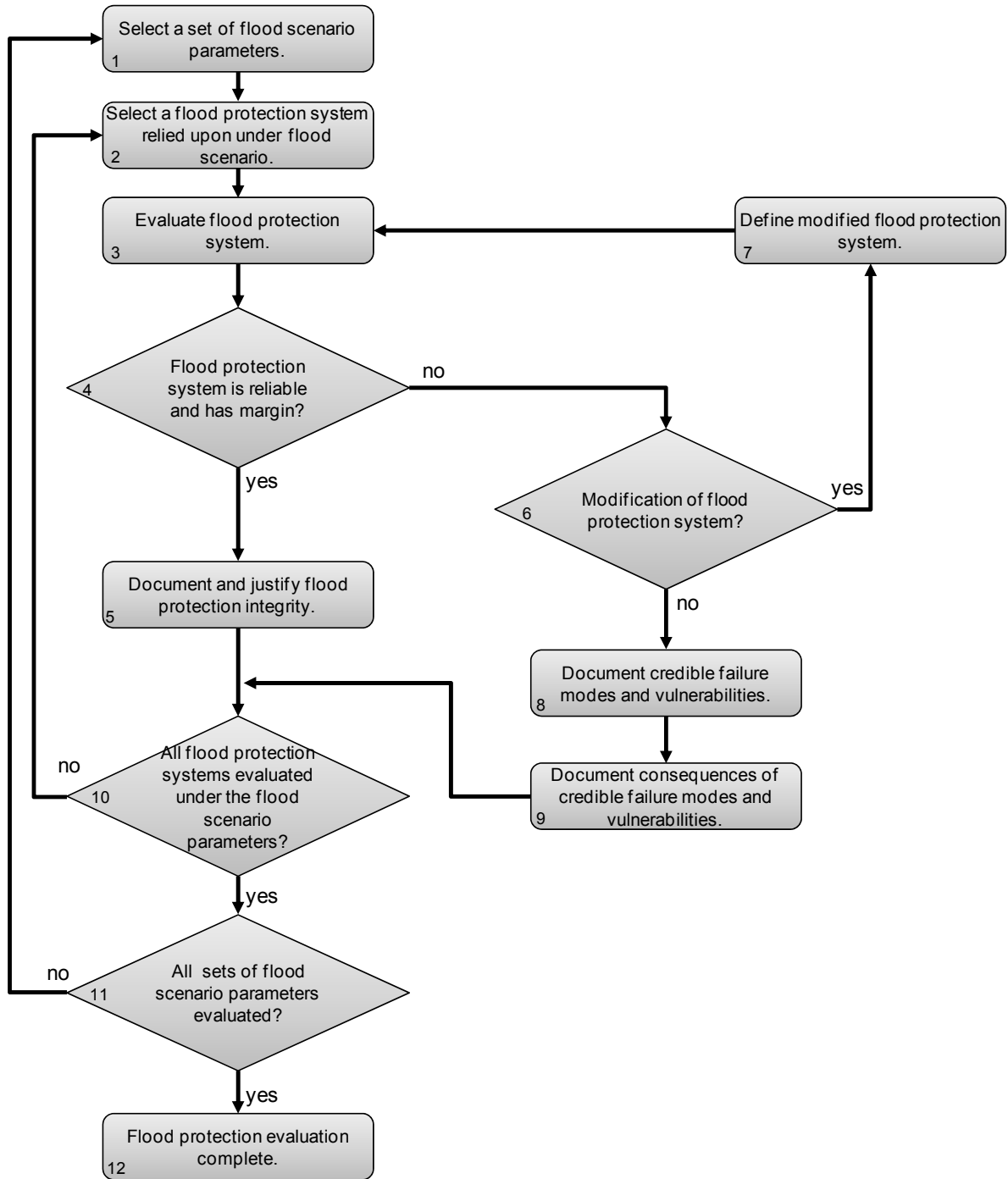


Figure 3: Flood protection evaluation process flowchart

7. Evaluation of Mitigation Capability

Mitigation capability refers to the capability of the plant to maintain key safety functions¹⁵ in the event that a flood protection system(s) fails or that a site does not have flood protection under the flood scenario parameters.

An evaluation of mitigation capability is required for sites that have not demonstrated that the flood protection systems are reliable and have margin. Mitigation capability should be evaluated for credible flood protection failure modes, including concurrent failures, identified based on the evaluation described in Section 6. For each scenario involving the compromise of flood protection under the flood scenario parameters, the mitigation capability of the plant should be evaluated for the entire flood event duration considering all available resources.

In addition, as described in Section 3.1, sites that allow water to enter buildings or other areas with SSCs important to safety by procedure or design (and resulting in the potential compromise of those SSCs) should evaluate mitigation capability.

7.1 Process Overview

The licensee may demonstrate the mitigation capability of a plant using one of three potential methods, depending on site characteristics and information needed for decisions:

- scenario-based evaluation
- margins-type evaluation
- full PRA

The scenario-based approach is intended to be a systematic, rigorous, and conservative, (although primarily qualitative) evaluation used to demonstrate that there is high confidence that key safety functions can be maintained for the specific purposes to which this ISG is intended. A margins-type evaluation is quantitative and uses conditional core damage probability (CCDP) and conditional large early release probability (CLERP) as figures of merit. The margins-type assessment will be more realistic than a scenario-based evaluation, but more conservative than a PRA. Moreover, a margins-type evaluation will typically use logic models that are more complex than a scenario-based evaluation but simpler than models used as part of a full PRA. The full PRA evaluation uses a conventional PRA-based approach to evaluate the mitigation capability of the plant. Each of these methods is described further below.

A margins-type evaluation and a full PRA are acceptable for evaluating mitigation capability at all sites. However, licensees may opt to perform a scenario-based evaluation, or to use a scenario-based evaluation as a starting point before proceeding to a margins-type evaluation or full PRA. When using a scenario-based evaluation to assess mitigation capability, the licensee is responsible for justifying that the scenario-based evaluation provides sufficient detail and supporting information (e.g., captures dependencies, interactions, and total flood effect) to demonstrate that there is high confidence that key safety functions can be maintained. For example, if the logic structure developed under a scenario-based evaluation becomes too complex, it would become apparent that a

¹⁵ See Section 9 for the definition of key safety functions.

scenario-based evaluation is not capable of reaching a justifiable conclusion and a margins-type evaluation or full PRA would be necessary. As another example, if the use of conservative, deterministic engineering evaluations, logic structures, and conservative performance criteria using a scenario-based approach do not demonstrate that there is high confidence that key safety functions can be maintained, the licensee may choose to make modifications (e.g., to the plant or procedures) or proceed to an evaluation of mitigation capability using a margins-type evaluation. The margins-type evaluation can account for more complicated interactions and dependencies. In addition, the margins-type evaluation quantitatively evaluates the reliability of manual actions and active components. If a more refined evaluation is needed than is possible in a margins-type evaluation, an external flood PRA is appropriate.

7.2 Scenario-Based Evaluation of Mitigation Capability

The scenario-based evaluation is used to demonstrate that there is high confidence that key safety functions can be maintained using qualitative and quantitative information and insights. Although the scenario-based evaluation does not require the computation of risk-based metrics (e.g., CCDP and CLERP), it should use a systematic, rigorous, and conservative approach to demonstrate that key safety functions can be maintained with high confidence under the flood scenario parameters. A scenario-based evaluation must include the following key elements:

- a detailed description of the scenario and its key components
- a description of the approach(es) used for mitigation
- a timeline showing necessary manual actions, including cues, indications, and notifications
- an evaluation of the reliability of active components
- an evaluation of manual actions
- the development of logic structures (i.e., event and fault trees) that include each SSC that must change state and each manual action, to capture dependencies between SSCs as well as manual actions. The logic structures should show necessary support systems for each SSC that changes state (e.g., AC or DC power, cooling water, fuel, equipment required for activation)
- a conclusion of the overall reliability of the approach(es) used for mitigation

Additional details on these key elements are provided below.

Figure 4 provides a flowchart that depicts the process for a scenario-based evaluation of mitigation capability. The evaluation begins by defining the scenario to be evaluated (boxes 1-4 of Figure 4), which consists of specifying:

- the flood scenario parameters
- the credible flood protection failure mode(s)¹⁶
- all direct consequences of flood protection failure (e.g., particular rooms inundated)

¹⁶ Under a scenario-based evaluation flood protection is assumed to fail in credible ways (i.e., the probability of flood protection failure is 1.0). Credible failure modes of flood protection systems for a given set of flood scenario parameters are identified as part of the evaluation of flood protection systems (see Section 6 and Appendix A to this guidance). Concurrent failures of multiple flood protection systems (along with associated consequences) should be considered if the flood scenario parameters could adversely affect multiple flood protection systems.

- the plant conditions (e.g., identification of whether onsite power and offsite power are available) and all equipment affected by the consequences of flood protection failure

Typically, inundation of equipment will cause failure. However, associated flood effects (e.g., debris, dynamic loads) may also adversely affect equipment; therefore, the evaluation should consider these effects as well. The scenario-based evaluation should concurrently consider all failures of flood protection features and equipment that could result from the flood scenario parameters.

Once the scenario has been defined, the licensee should perform the following:

- Define the key safety functions that must be maintained (Box 5 in Figure 4).
- Specify equipment available for use in maintaining key safety functions (Box 6 in Figure 4) and describe in detail the approach(es) used for mitigation.
- Perform an evaluation of mitigation capability using available resources (Box 7 in Figure 4) to demonstrate whether there is high confidence that key safety functions can be maintained, as described below.

In demonstrating that there is high confidence that key safety functions can be maintained, the evaluation should:

- Demonstrate that any credited equipment will be functional, available, and accessible when needed (e.g., that it is located above the flood elevation or is protected by flood protection that is reliable and has margin), throughout the entire flood event duration, and that it can be deployed when necessary.
- Justify the availability and reliability of each active component as described in Section A.1.2.1 of Appendix A to this guidance.
- Evaluate whether manual actions are feasible and reliable as described in Appendix C to this guidance, including justification and documentation as described in Section C.6 of Appendix C to this guidance.
- Qualitatively assess operational requirements such as surveillance, inspection, design control, maintenance, procurement, and testing (e.g., whether or not equipment is included in established plant equipment reliability programs).
- Demonstrate that all credited equipment and features (e.g., engineered structures, pumps, and other components) are capable of performing their design function and that they have the appropriate factors of safety.
- Demonstrate sufficient consumables (e.g., fuel) on site and their continued accessibility.
- Demonstrate redundancy and diversity in approach(es) used for mitigation.
- Evaluate the differences between modes of operation relative to the identification and maintenance of key safety functions.
- Consider other quantitative and qualitative attributes that provide confidence in the reliability of equipment, availability of resources, and feasibility and reliability of any credited actions.

To capture interactions, dependencies, and overall flooding effect, the licensee should use logic tools (i.e., event trees and fault trees) and timelines to structure and document the scenario-based evaluation. The following provides guidance on the development of logic models and timelines:

- Logic structures should be developed in sufficient detail to demonstrate that there is high confidence that key safety functions can be maintained.
- The scenario-based evaluation should be conservative and simplifications made in logic models should result in bounding analyses.
- Diversity, redundancy, and other considerations that support the robustness of approaches used to mitigate the event (e.g., robustness against single failures) provide increased confidence that key safety functions can be maintained.
- Failure branches of event trees should be shown, but need not be fully developed if not required to justify the conclusions of the assessment.
- Timelines should illustrate all required actions and should capture dependencies such as actions that must be performed in series or in parallel and actions that depend on the availability of resources or site access.

If the scenario-based evaluation can demonstrate that there is high confidence that key safety functions can be maintained, the results must be documented and justified. If the evaluation cannot demonstrate with high confidence that key safety functions can be maintained, then either: (1) a scenario-based evaluation is not sufficient and a margins-type evaluation or PRA is necessary, or (2) modifications should be made to the plant to improve flood protection or mitigation capability such that there is high confidence that key safety functions can be maintained.

The evaluation should be repeated until all flood protection failure modes and sets of flood scenario parameters have been evaluated (as directed by Boxes 11 and 12 in Figure 4).

7.3 Margins-Type Evaluation of Mitigation Capability

The margins-type assessment evaluates mitigation capability given set(s) of flood scenario parameters and credible flood protection failures(s).¹⁷ A margins-type evaluation is quantitative and uses CCDP and CLERP as figures of merit.

Figure 5 illustrates the margins-type method used for evaluating mitigation capability. Like the scenario-based mitigation evaluation, the margins-type mitigation evaluation begins by specifying the following:

- the flood scenario parameters
- the credible flood protection failure mode(s)¹⁸
- all direct consequences of flood protection failure (e.g., particular rooms inundated)
- the plant conditions (e.g., identification of whether onsite and offsite power are available) and all equipment affected by the consequences of flood protection failure

Typically, inundation of equipment will cause failure. However, associated flood effects (e.g., debris, dynamic loads) may also adversely affect equipment and should be considered.

¹⁷ The licensee should perform a margins-type assessment for flood protection features or flood protection feature combinations that are not judged to be reliable or have margin.

¹⁸ Credible failure modes of flood protection systems for a given set of flood scenario parameters are identified as part of the evaluation of flood protection systems (see Section 6). Concurrent failures of multiple flood protection systems (along with associated consequences) should be considered if the flood scenario parameters could adversely affect multiple flood protection systems.

If crediting the probability of flood protection failure(s) as part of a margins-type assessment, all credible flood protection failure modes must be considered along with their probability of occurrence. In logic models, both failures and non-failures associated with flood protection must be tracked. Moreover, it is not acceptable to utilize the probability of flood protection failure to justify that an evaluation of mitigation capability is not necessary (i.e., regardless of the probability of flood protection failure, it is necessary to perform an evaluation of mitigation capability).¹⁹

In some cases, licensees may consider a bounding flood protection failure mode (i.e., a failure mode that bounds lesser failure modes) to reduce the number of failure modes considered under the margins-type evaluation. In this case, the failure of flood protection should be assumed to occur (i.e., the probability of flood protection failure is 1.0).²⁰ Licensees should consider bounding failure modes only if the associated approaches for mitigation are the same and the effects of timing or other factors of the mitigation approach are similar.

Once the evaluation has specified the plant conditions along with equipment affected by the flood protection failure, plant system models should be updated, enhanced, or developed to reflect the current plant state and available equipment. The internal events PRA model, with appropriate modifications, can be used to model plant systems. Basic failure events are added to the internal events PRA model for evaluating the mitigation capability of the plant during a flood event. Alternatively, it is acceptable to develop a system model(s) specifically intended to compute CCDP and CLERP under the flood scenario parameters and flood protection failure mode(s) being analyzed rather than adapting the existing internal events PRA model. If such a model is developed, it should be consistent with the internal events systems model with respect to plant response. In updating or developing system models, the evaluation should do the following:

- Consider equipment failures caused directly by the flood event and consider all random failures of remaining plant equipment (e.g., failure to start and failure to run).
- Quantitatively evaluate the reliability of active components based on operating experience, testing, and other available information by using traditional PRA or statistical techniques.
- Quantify the reliability of credited human actions by using human factors engineering and human reliability concepts and approaches. The process described in Appendix C to this guidance should be used to develop the bases for HRA quantification. The evaluation should include the considerations described in Appendix C, including:
 - identification and definition of human actions as well as development of a human failure event narrative (see Section C.2 of Appendix C);

¹⁹ The mitigation evaluation should be used if (1) flood protection cannot be shown to be reliable and have margin by comparison against appropriate performance criteria (as described in Section 6), or (2) flood protection does not exist for the flood scenario under consideration. Therefore, it is not acceptable to use the probability of failure to justify the evaluation of mitigation capability is not necessary. It is also noted that, as described in Section 3.2.2, flood frequencies should not be used to justify that the evaluation of mitigation capability is not necessary.

²⁰ As an alternative to assuming a failure probability of 1.0 when considering a bounding flood protection failure mode, it is acceptable to assign a probability to the bounding failure mode that is equal to the sum of the probabilities of all credible flood protection failure modes.

- evaluation of applicable performance shaping factors (Section C.3.1) ;
- a detailed timing analysis including computation of time margin and consideration of uncertainties (Section C.3.2); and
- evaluation of sufficiency of available time margin (Section C.4).

In addition, the evaluation should do the following for all resources and actions credited in the margins-type evaluation:

- Demonstrate that any credited equipment will be functional, available, and accessible (e.g., that it is located above the flood elevation or is protected by flood protection that is reliable and has margin) when needed, throughout the entire flood event duration, and can be deployed when necessary.
- Provide a timeline showing necessary manual actions, including cues, indications, and notifications.
- Qualitatively assess operational requirements such as surveillance, inspection, design control, maintenance (e.g., document whether a component is covered by established plant equipment reliability programs), procurement, and testing.
- Demonstrate that sufficient consumables (e.g., fuel) are on site and are accessible.
- Consider other quantitative and qualitative attributes that provide confidence in the reliability of equipment, availability of resources, and feasibility and reliability of any credited actions.

Using plant system models, the licensee should calculate CCDP and CLERP. The evaluation of mitigation capability should be repeated until all flood protection failure modes and sets of flood scenario parameters have been evaluated.

If the licensee proposes modifications to the plant, it should evaluate the effectiveness of the modification on mitigation capability as described above.

7.4 Use of PRA to Evaluate Total Plant Response, Including Mitigation Capability

If a PRA is used to assess total plant response, including the mitigation capability of a plant, the evaluation should be consistent with guidance contained in Section 8 of Reference 8, as well as Reference 9. However, it is noted that Section 8 of Reference 8 establishes technical requirements when a reactor is at power. As part of the integrated assessment, it is necessary to consider mitigation capability during other modes of operation. References used by staff in the review of lowpower and shutdown PRAs for advanced reactor designs may provide useful insight for addressing these other modes of operation. For example, Chapter 19 of the Standard Review Plan (Ref. 10) has been used for the evaluation of shutdown PRAs for advanced reactor designs and Regulatory Guide 1.200 (Ref. 9) provides information on the scope and technical attributes for low-power and shutdown PRAs for internal events.

If modifications to the plant are proposed, the effectiveness of the modification on mitigation capability should be evaluated as described above.

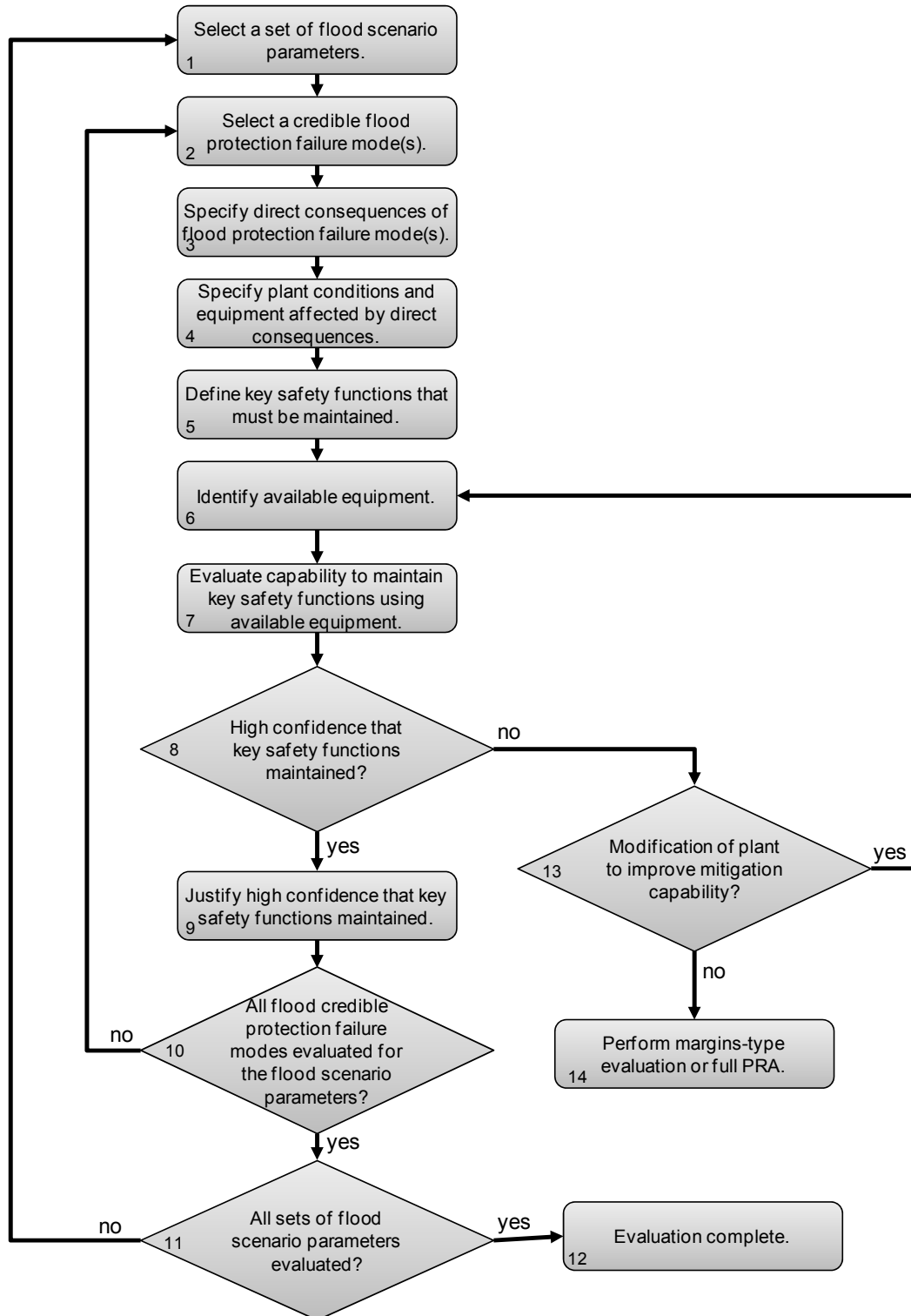


Figure 4: Scenario-based mitigation evaluation flowchart

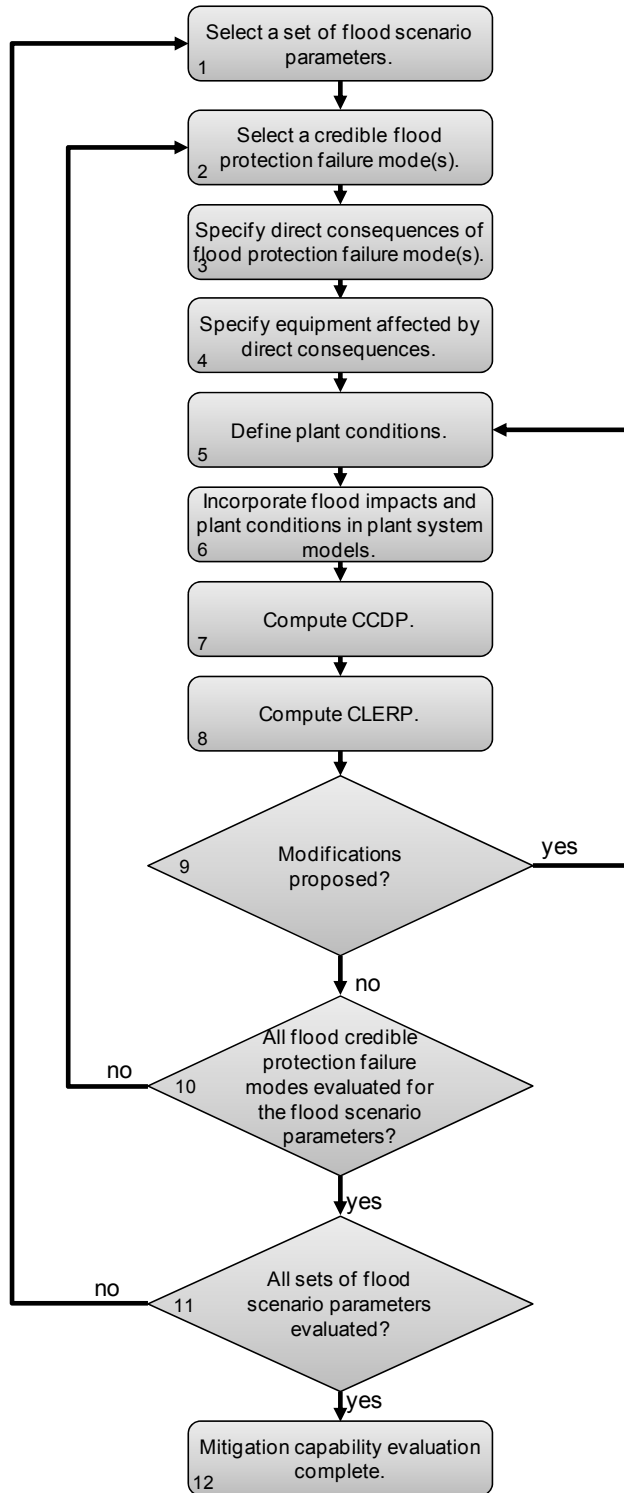


Figure 5: Margins-based mitigation evaluation flowchart

8. Documentation

As described in the March 12, 2012, 10 CFR 50.54(f) letter, the integrated assessment submittal should provide the following (Ref. 11, Encl. 2, p. 8-9):

- a) Description of the integrated procedure used to evaluate integrity of the plant for the entire duration of flood conditions at the site.
- b) Results of the plant evaluations describing the controlling flood mechanisms and its effects, and how the available or planned measures will provide effective protection and mitigation. Discuss whether there is margin beyond the postulated scenarios.
- c) Description of any additional protection and/or mitigation features that were installed or are planned, including those installed during course of reevaluating the hazard. The description should include the specific features and their functions.
- d) Identify other actions that have been taken or are planned to address plant-specific vulnerabilities.

Additional details on documentation of items (a) through (d) are provided in Sections 8.1 through 8.4.

8.1 Integrated Assessment Procedure

Consistent with item (a) above, the integrated assessment submittal should do the following to describe the integrated assessment procedure used to evaluate the integrity of the plant for the entire duration of flood conditions at the site:

- Describe the methodologies used to demonstrate the effectiveness of:
 - flood protection features and systems; and
 - approach(es) used for mitigation.
- Describe any plant system models, including modifications made to existing internal event model(s), for the evaluation of the plant's flood protection and mitigation capability.

8.2 Plant Evaluation Results

Consistent with item (b) above, the integrated assessment submittal should include the plant evaluation results describing the controlling flood mechanisms and their effects and explaining how the available or planned measures will provide effective protection and mitigation and should discuss whether margin exists beyond the postulated scenarios.

8.2.1 Controlling Flood Mechanism(s)

The submittal should discuss the applicable flood mechanism(s) and the flood scenario parameters, including flood height and the associated effects, that the integrated assessment evaluated. In addition, the submittal should discuss the site conditions during the entire duration of the flood event for each set of flood scenario parameters, including the following:

- the plant mode(s), including the duration of time the plant is expected to remain in each mode;

- the availability and quality of cues, indications and notifications, including water gauges, meteorological gauges, weather and tsunami forecasting tools, or similar instrumentation and communication mechanisms, as well as any durable agreements in place to ensure notification from offsite entities;
- the basis for action by plant operators in response to onsite cues and indications or notification from offsite entities (e.g., plant response to notification of an upstream dam failure);
- the availability of and access to onsite and offsite resources and consumables;
- accessibility considerations to and from the site and around the site that may impact protective and mitigating actions;
- the condition and access to the ultimate heat sink;
- availability of offsite power;
- structures and systems important to safety affected by the flood scenario parameters; and
- availability of staff and accessibility to and from the site for staff augmentation.

To aid understanding the flood scenario parameters, the submittal may describe the conservatisms associated with the flooding analysis that led to the scenario flood parameters; however, this step is optional.

8.2.2 Evaluation of Flood Protection

The submittal should do the following to provide information on the evaluation of flood protection:

- Describe all site flood protection systems, including all manual actions necessary for the implementation of flood protection; the number of staff necessary to implement flood protection procedures, any necessary qualifications and training; and the ability of offsite staff to return to the site under the anticipated conditions.
- Describe performance criteria used to evaluate flood protection, including any codes or standards used in the evaluation.
- Provide technical justification for all assumptions (including the failure modes considered) used to demonstrate the effectiveness of flood protection features.
- For each set of flood scenario parameters and flood protection system, document and submit the following information:
 - credible flood protection modes identified and the justification for any flood protection modes that were deemed not credible;
 - the condition of flood protection features;
 - results of quantitative engineering evaluations, including:
 - justification of the structural adequacy of features;
 - expected leakage through barriers; and
 - implications of identified deficiencies.
 - results of evaluations of whether the performance, characteristics, and configuration of the flood protection feature(s) conforms to accepted practices and is sufficiently robust, including a detailed description of the results of the following:
 - comparison to appropriate, present-day design codes and standards;
 - comparison against Standard Review Plan Sections 3.4.1 and 3.4.2, Refs. 6 and 7);
 - assessment of exterior and incorporated flood protection features as described in Section A.1.1 of Appendix A to this guidance;

- justification and quantification (if applicable) of the reliability of active features as described in Section A.1.2 of Appendix A; and
 - assessment of temporary features as described in Section A.1.3 of Appendix A to this guidance.
- description of operational requirements applicable to flood protection features (e.g., surveillance, inspection, design control, maintenance, procurement, and testing);
 - justification of whether the capacity of pumping or drainage systems is sufficient to handle any inflow through flood protection features for the entire flood event duration;
 - results of evaluations of manual actions against the criteria contained in Appendix C to this guidance, including all documentation requirements described in Section C.6 of Appendix C to this guidance;
 - timeline showing all necessary manual actions, including cues, indications, and notifications;
 - the availability and accessibility of necessary consumables for the entire flood event duration; and
 - results of system-level evaluations performed on flood protection systems, including justification.
 - results of sensitivity studies, if appropriate
- Provide a discussion of any defense-in-depth considerations that are maintained under each set of flood scenario parameters.
 - Discuss any additional margin beyond the postulated scenarios for the flood protection system(s). Characterize margin with respect to:
 - physical barrier dimensions;
 - structural and other performance capacity; and
 - time and staffing associated with the performance of manual actions.
 - If flood protection features are not shown to be reliable and have margin, document and describe at what flood height and under what associated effects, the flood protection feature or system is able to reliably accommodate a flood.
 - Provide a summary list of any flood protection features or systems determined not to be capable of performing its intended safety function under the reevaluated hazard.
 - If modifications are proposed, provide justification that the modified flood protection is reliable and has margin through comparison against established performance criteria or quantification of reliability.

8.2.3 Evaluation of Mitigation Capability

The submittal should do the following to provide information on the evaluation of mitigation capability:

- Summarize the approach used for mitigation
- Describe the equipment and manual actions, if applicable, associated with the mitigation capability of the plant
- Describe the performance criteria used to evaluate the mitigation capability of the plant
- Document conclusions (including sensitivity studies, if appropriate) on the effectiveness of the total mitigation capability
- Discuss any defense-in-depth considerations that are maintained under each set of flood scenario parameters

- Discuss any additional margin beyond the postulated scenarios for the mitigation capability of the plant. Characterize margin with respect to physical barrier dimensions, structural and other performance capacity, and time and staffing associated with the performance of manual actions

Document and submit the following information for each scenario if a scenario-based evaluation of mitigation capability is used:

- A detailed description of the scenario and its key components, including the following:
 - the flood scenario parameters;
 - the flood protection failure modes considered;
 - all direct consequences of flood protection failure;
 - plant conditions and all equipment affected by the consequences of flood protection failure; and
 - key safety functions that must be maintained.
- Justification that the scenario-based evaluation provides sufficient detail and supporting information to demonstrate that there is high confidence that key safety functions can be maintained.
- Description (including figures) of logic structures and timelines developed to support the scenario-based evaluation, including the following:
 - a timeline showing all necessary manual actions, including cues, indications, and notifications; and
 - the logic structures (i.e. event and fault trees) that include each SSC that must change state and each manual action to capture dependencies between SSCs and manual actions. The logic structures should show necessary support systems for each SSC that changes state.
- Demonstration that key safety functions can be maintained with high confidence under each scenario, including the following:
 - demonstration that any credited equipment will be functional, available, and accessible when needed, throughout the entire flood event duration, and can that it be deployed when necessary;
 - justification of the availability and reliability of each active component as described in Section A.1.2.1 of Appendix A to this guidance;
 - results of evaluations of manual actions against the criteria contained in Appendix C of this guidance, including all documentation requirements described in Section C.6 of Appendix C of this guidance;
 - a description of operational requirements applicable to mitigation equipment (e.g., surveillance, inspection, design control, maintenance, procurement, and testing);
 - a demonstration that sufficient consumables are on site and that that these consumables are accessible;
 - description of redundancy and diversity in approach(es) used for mitigation; and
 - other quantitative and qualitative attributes that provide confidence in the reliability of equipment, availability of resources, and feasibility and reliability of any credited manual actions.

Document and submit the following for each scenario, if a margins-based evaluation of mitigation capability is used:

- A detailed description of the scenario and its key components, including the following:
 - the flood scenario parameters;
 - the flood protection failure modes considered;
 - all direct consequences of flood protection failure; and
 - plant conditions and all equipment affected by the consequences of flood protection failure.
- A summary of system models developed specifically for evaluation of mitigation capability or modifications made to existing PRA models.
- A timeline showing all necessary manual actions, including cues, indications, and notifications.
- Justification for equipment, actions, and resources credited for mitigation, including the following:
 - justification of the reliability of active components as described in Section A.1.2.1 of Appendix A to this guidance and justification for and results of the quantification of the reliability of active components;
 - results of evaluation of the reliability of manual actions, including a detailed description of the method used to assess the reliability of manual actions:
 - identification and definition of human actions;
 - the human failure event narrative;
 - evaluation of applicable performance shaping factors;
 - a detailed timing analysis including computation of time margin and consideration of uncertainties; and
 - evaluation of the sufficiency of available time margin.
 - a demonstration that any credited equipment will be functional, available, and accessible when needed, throughout the entire flood event duration and can that is can be deployed when necessary;
 - a description of operational requirements applicable to mitigation equipment (surveillance, inspection, design control, maintenance, procurement, and testing);
 - demonstration that sufficient consumables are on site and that these consumables are accessible; and
 - other quantitative and qualitative attributes that provide confidence in the reliability of equipment, availability of resources, and feasibility and reliability of any credited manual actions.
- The CCDP and CLERP calculated for each scenario.
- Dominant sequences and CCDP and CLERP contributors identified.

If a PRA is performed, describe and document the analysis and results as outlined in Reference 8 and include appropriate additional considerations to account for all modes of operation considered as part of the integrated assessment.

8.2.4 Peer Review

The submittal should include the peer review documentation as described in Section B.3 of Appendix B to this guidance.

8.3 Additional Protection and Mitigation Features

Consistent with item (c) above, the submittal should describe any additional protection or mitigation features or both that the licensee has installed or is planning to install, including

those that it installed during the course of reevaluating the hazard. The submittal should do the following in its inclusion of the specific features and their functions:

- Describe any flood protection or mitigation capabilities discussed Section 8.2 that are credited in the plant's current licensing basis but that were modified during the course of the hazard reevaluation or integrated assessment. Include specific features and their functions in the description.
- Describe any flood protection or mitigation capabilities discussed in Section 8.2 that are not credited in the plant's current licensing basis. Include specific features and their functions in the description.
- Describe any flood protection or mitigation capabilities discussed in Section 8.2 that are planned and have not yet been installed. Include specific features and their functions in the description.
- Provide a timeline for the completion of all planned actions that were credited as part of the integrated assessment.
- Describe any interim actions that are in place until planned actions are completed.

8.4 Other Actions Involving Plant-Specific Vulnerabilities

Consistent with item (d) above, the submittal should do the following to identify other actions that the licensee has taken or is planning to take in an effort to address plant-specific vulnerabilities:

- Describe any vulnerabilities (see the definition in Section 9) that the review identified, including the key safety functions that may be affected.
- Describe any actions that the licensee has taken to address these plant-specific vulnerabilities.
- Separately, describe any planned actions to address these plant-specific vulnerabilities.

9. Terms and Definitions

Active (flood protection) feature: An incorporated, exterior, or temporary flood protection feature that requires the change of a component's state in order for it to perform as intended. Examples include sump pumps, portable pumps, isolation and check valves, flood detection devices (e.g., level switches), and flood doors (e.g., watertight doors).

Available Physical Margin (APM): A margin that describes the flood margin available for applicable flood protection features at a site (not all flood protection features have APMs). The APM for each applicable flood protection feature is the difference between the licensing basis flood protection height and the flood height at which water could affect an SSC important to safety. A determination of APM for local intense precipitation may not be possible. Section 3.13 of the flooding design basis walkdown guidance, NEI 12-07 (Ref. 2) provides additional details.

Cliff-edge: An elevation at which safety consequences of a flood event may increase sharply with a small increase in the flood height and the associated effects.

Critical elevation: The elevation at which a piece or group of equipment will fail to function, or a transient will be induced, due to flood height and associated effects.

Current Licensing Basis: The current licensing basis is the set of NRC requirements applicable to a specific plant, plus a licensee's docketed and currently effective written commitments for ensuring compliance with, and operation within, applicable NRC requirements and the plant-specific design basis, including all modifications and additions to such commitments over the life of the facility operating license. The current licensing basis also includes the plant-specific design basis information, defined by 10 CFR 50.2, as documented in the most recent updated final safety analysis report in accordance with 10 CFR 50.71. The set of NRC requirements applicable to a specified plant's current licensing basis includes the following:

- the requirements in, and the appendices to, the following NRC regulations:
 - 10 CFR Part 2, "Agency Rules of Practice and Procedure"
 - 10 CFR Part 19, "Notices, Instructions, and Reports to Workers: Inspection and Investigations"
 - 10 CFR Part 20, "Standards for Protection against Radiation"
 - 10 CFR Part 21, "Reporting of Defects and Noncompliance"
 - 10 CFR Part 26, "Fitness for Duty Programs"
 - 10 CFR Part 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material"
 - 10 CFR Part 40, "Domestic Licensing of Source Material"
 - 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities"
 - 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions"
 - 10 CFR Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants"
 - 10 CFR Part 55, "Operator's Licenses"
 - 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material"

- 10 CFR Part 72, “Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste”
 - 10 CFR Part 73, “Physical Protection of Plants and Materials”
 - 10 CFR Part 100, “Reactor Site Criteria”
- Commission orders
 - license conditions
 - exemptions
 - technical specifications
 - plant-specific design basis information defined in 10 CFR 50.2 and documented in the most recent updated final safety analysis report (as required by 10 CFR 50.71)
 - licensee commitments remaining in effect that were made in docketed licensing correspondence (such as licensee responses to NRC bulletins, license event reports, generic letters and enforcement actions)
 - licensee commitments documented in NRC safety evaluations (Ref. 2)

Design bases: As defined by 10 CFR 50.2, the information that identifies the specific functions that an SSC of a facility must perform, and the specific values or ranges of values chosen for controlling parameters as reference bounds for design. These values may be: (1) restraints derived from generally accepted "state of the art" practices for achieving functional goals, or (2) requirements derived from an analysis (based on calculation or experiments or both) of the effects of a postulated accident for which an SSC must meet its functional goals (Ref. 2).

Event tree: A logic diagram that begins with an initiating event or condition and progresses through a series of branches that represent expected system or human performance that either succeeds or fails and arrives at either a successful or failed end state (Ref. 8).

Exterior (flood protection) feature: An engineered passive or active flood protection feature that is external to the immediate plant area and credited to protect safety-related SSCs from inundation and static/dynamic effects of external floods. Examples of such features include levees, dikes, floodwalls, flap gates, sluice gates, duckbill valves and pump stations (Ref. 2).

Failure modes and effects analysis: A process for identifying failure modes of specific components and for evaluating their effects on other components, subsystems, and systems (Ref. 8).

Fault tree: A deductive logic diagram that depicts how a particular undesired event can occur as a logical combination of other undesired events (Ref. 8).

Feasible manual action: A manual action that is analyzed and that is demonstrated as being able to be performed within an available time to avoid a defined undesirable outcome. As compared to a reliable manual action (see definition), an action is considered feasible if it is shown that it can be performed within the available time (considering relevant uncertainties in estimating the time available); but it does not necessarily demonstrate that the action is reliable. For instance, performing an action successfully one time out of three attempts within the available time shows that the action is *feasible*, but not necessarily reliable (Ref. 12).

Flood event duration: The length of time in which the flood event affects the site, beginning with conditions being met for entry into a flood procedure or notification of an impending

flood (e.g., a flood forecast or notification of dam failure), including preparation for the flood and the period of inundation, and ending when water has receded from the site and the plant has reached a safe and stable state that can be maintained indefinitely. Figure 6 illustrates flood event duration.

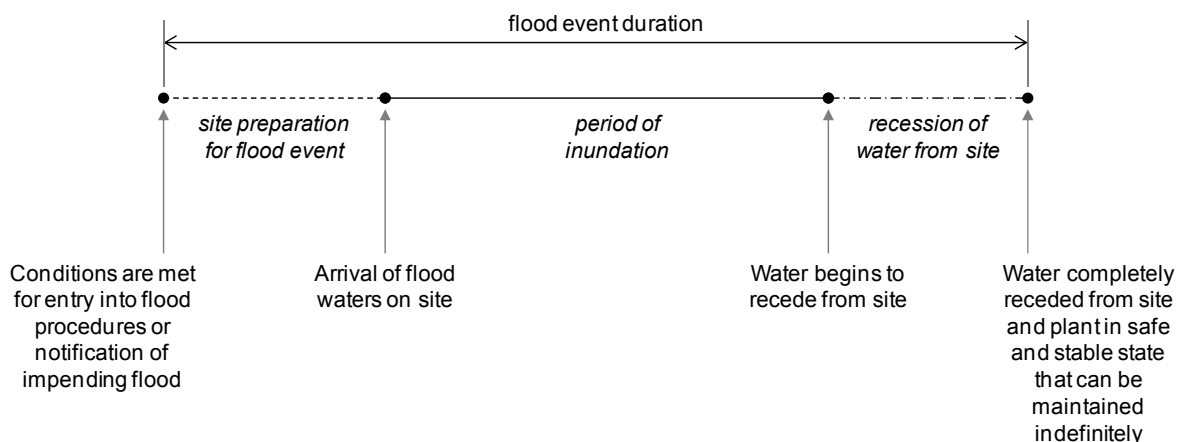


Figure 6: Illustration of flood event duration

Flood height and associated effects: The maximum stillwater surface elevation plus the following factors:

- wind waves and run-up effects;
- hydrodynamic loading, including debris;
- effects caused by sediment deposition and erosion;
- concurrent site conditions, including adverse weather conditions;
- groundwater ingress; and
- other pertinent factors.

Flood scenario parameters: A set(s) of flood parameters that the integrated assessment should consider. (see Section 5.2 for additional details).

Flood protection feature: An incorporated, exterior or temporary structure SSC (e.g., barrier), or an associated procedure that protects safety-related SSCs against the effects of external floods, including flood height and associated effects.

Flood protection system: In the context of the integrated assessment, a flood protection system is a set of flood protection features that are intended to protect a specific SSC or group of SSCs (e.g., features used to protect the intake structure) or the entire plant (e.g., a levee around an entire site) and that are primarily separate and independent from the flood protection features that are used to protect other SSCs.

Human reliability analysis (HRA): A structured approach used to identify potential human failure events and to systematically estimate the probability of those events using data, models, or expert judgment (Ref. 8). In the context of the integrated assessment, HRA approaches and concepts are used to evaluate whether manual actions are feasible and reliable (see Appendix C to this guidance).

Incorporated (flood protection) feature: An engineered passive or active flood protection feature that is permanently installed in the plant to protect safety-related SSCs from inundation and static/dynamic effects of external flooding. Examples include pumps, seals, valves, and gates that are permanently incorporated into a plant structure (Ref. 2).

Important to safety: A phrase that encompasses the broad scope of equipment covered by Appendix A to 10 CFR Part 50, the General Design Criteria (Ref. 14). In accordance with Appendix A, “General Design Criteria for Nuclear Power Plants,” to 10 CFR Part 50, the phrase, “structures, systems, and components (SSCs) important to safety,” refers to SSCs that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public. The phrase encompasses the broad class of plant features, covered (not necessarily explicitly) in the General Design Criteria, that contribute in important way to safe operation and protection of the public in all phases and aspects of facility operation (i.e., normal operation and transient control as well as accident mitigation). The phrase “important to safety” includes safety-grade (or safety-related) as a subset (Ref. 15).

Key safety functions: The minimum set of safety functions that a plant must maintain to prevent core damage and large early release. These functions include reactivity control, reactor pressure control, reactor coolant inventory control, decay heat removal, and containment integrity in appropriate combinations to prevent core damage and large early release. (Ref. 8).

Manual action (for flooding): Proceduralized activity that plant personnel carry out to prepare for or respond to an external flood event.

Mitigation capability: In the context of the integrated assessment, mitigation capability refers to the capability of the plant to maintain key safety functions in the event that a flood protection system(s) fails (or is otherwise not available).

Passive (flood protection) feature: An incorporated, exterior, or temporary flood protection feature that does *not* require the change of state of a component in order for it to perform as intended. Examples include dikes, berms, sumps, drains, basins, yard drainage systems, walls, removable wall and roof panels, floors, structures, penetration seals, temporary watertight barriers, barriers exterior to the immediate plant area that is under licensee control, and cork seals.

Performance criteria (for flood protection): In the context of the integrated assessment, performance criteria refer to criteria or standards that are used, in part, to demonstrate that a flood protection feature is reliable and has margin.

Performance shaping factor (PSF): A factor that influences human performance and human error probabilities (definition adapted from Reference 13). The integrated assessment considers the following performance shaping factors:

- indications or cues;
- complexity;
- special equipment;
- human-system interface;
- procedures;
- training;
- workload, pressure, and stress;

- environmental factors;
- special fitness issues;
- staffing;
- communications;
- accessibility; and
- other scenario-specific performance shaping factors.

Plant-specific vulnerability: Reference 11 defines plant-specific vulnerabilities as “those features important to safety that when subject to an increased demand due to the newly calculated hazard evaluation have not been shown to be capable of performing their intended safety functions.”

Reasonable simulation: A walkthrough of a procedure or activity to verify the procedure or activity can be executed as specified/written. This simulation requires verification that:

- 1) All resources needed to complete the actions will be available. (Note that staffing assumptions must be consistent with site access assumptions in emergency planning procedures.);
- 2) Any credited time dependent activities can be completed in the time required considering the time required for detection, recognition and communication to initiate action for the applicable flood hazard;
- 3) Specified equipment/tools are properly staged and in good working condition.
- 4) Connection/installation points are accessible;
- 5) The execution of the activity will not be impeded by the event it is intended to mitigate or prevent (for example, access to the site and movement around it can be accomplished during the flood); and
- 6) The execution of the activity will not be impeded by other adverse conditions that could reasonably be expected to simultaneously occur (for example, winds, lightning, and extreme air temperatures) (Ref. 2).

Reliable manual action: A feasible manual action that is analyzed and demonstrated as being dependably repeatable within an available time to avoid a defined adverse consequence, while considering varying conditions that could affect the available time or the time to perform the action or both. As compared to an action that is only feasible (see definition), an action is considered to be reliable as well if it is shown that it can be dependably and repeatedly performed within the available time, by different crews, under somewhat varying conditions that typify uncertainties in the available time and the time to perform the action, with a high success rate. All reliable actions need to be feasible, but not all feasible actions will be reliable (Ref. 12).

Temporary (flood protection) feature: A passive or active flood protection feature within the immediate plant area that protects safety-related SSCs from inundation and static/dynamic effects of external flooding and that is temporary in nature (i.e., their installation must be done prior to the advent of the external flood). Examples include portable pumps, sandbags, plastic sheeting, and portable panels (Ref. 2).

Total plant response: The capability of the plant: (1) to protect against flood events (considering diverse flood protection features); and (2) to mitigate consequences, if the flood protection system is compromised (or otherwise not available), by maintaining key safety functions using all credited resources.

Unavailability: The probability that a system or component is not capable of supporting its function including, but not limited to, the time it is disabled for test or maintenance (Ref. 8).

Variety of site conditions: The site conditions considered by the integrated assessment should be all modes of operation (e.g., full power operations, startup, shutdown, and refueling) and adverse weather conditions that could reasonably be expected to occur concurrently with a flood event.

Vulnerability: See definition for *plant-specific vulnerability*.

10. References

1. American Nuclear Society, "Determining Design Basis Flooding at Power Reactor Sites," ANS/ANSI 2.8-1992, 1992.
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12. U.S. Nuclear Regulatory Commission, "Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire," NUREG-1852, October 2007, ADAMS Accession No. ML073020676.
13. D. Gertman et al., "The SPAR-H Human Reliability Analysis Method," NUREG/CR-6883, August 2005.
14. U.S. Nuclear Regulatory Commission, Generic Letter 84-01, Subject: NRC Use of the Terms, "Important to Safety" and "Safety Related," January 5, 1984, ADAMS Accession No. ML031150515.
15. U.S. Nuclear Regulatory Commission, Memorandum to Staff, Subject: Standard Definitions for Commonly-used Safety Classification Terms, November 20, 1981.

APPENDIX A: Evaluation of Flood Protection

The goal of this appendix is to provide guidance on the evaluation of flood protection. Section A.1 provides guidance on evaluating individual features of a flood protection system. Section A.2 provides guidance on evaluating a complete flood protection system.

A.1 Individual Flood Protection Features

This section provides guidance on evaluating individual features comprising flood protection systems. Section A.1.1 of this appendix provides guidance on the evaluation of exterior and incorporated flood protection features that are passive and permanent. Section A.1.2 provides guidance on the evaluation of active flood protection features. Section A.1.3 provides guidance on the evaluation of temporary protective measures. Section A.1.4 provides guidance on evaluation of equipment required for manual actions.

A.1.1 Exterior and Incorporated Flood Protection Features

The following steps should be considered in the assessment of exterior and incorporated flood protection features that are permanent and passive:

- analysis of potential failure modes
- evaluation of capacities
- comparison against present-day codes and standards
- evaluation of operational requirements
- sensitivity studies, as appropriate, to capture uncertainties

Section 6.2 of this interim staff guidance (ISG) describes high-level performance criteria applicable to all types of flood protection, including exterior and incorporated flood protection features that are permanent and passive. The following sections provide points to consider in evaluating individual exterior and incorporated flood protection features that are permanent and passive, such as:

- earthen embankments (e.g., earth dams, levees and dikes) (Section A.1.1.1)
- floodwalls (Section A.1.1.2)
- seawalls (Section A.1.1.3)
- concrete barriers (Section A.1.1.4)
- plugs and penetration seals (Section A.1.1.5)
- storm drainage systems (Section A.1.1.6)

In evaluating these types of features, licensees should refer to the guidance in this appendix, as well as appropriate codes and standards, to assess whether in place or planned features conform to accepted engineering practices. If an assessment and evaluation of plant features reveals deficiencies and shortcomings in their capability to perform adequately as a flood barrier because they do not conform to accepted engineering practice, the implications of the deficiencies should be summarized. Planned actions to mitigate and improve the features to function as a flood barrier should be discussed. Moreover, licensees should identify flood protection features not meeting the implied expectations associated with the points of consideration provided in this appendix and provide a technical judgment of the capability and robustness of the feature.

A.1.1.1 Earthen Embankments (Earth Dams, Levees and Dikes)

Earthen dikes and embankments come in a variety of configurations. There are differences in design and construction details between earthen dams, levees, and dikes. However, since earthen dams, levees, and dikes are subsets of an “earthen embankment,” this appendix will use that term. This section provides points of considerations for evaluating earthen embankments, including the following:

- potential failure modes of earthen embankments
- considerations that should be evaluated to determine whether appropriate factors are considered in the embankment design
- material characterization
- maintenance and inspection

Potential failure modes of earthen embankments that should be considered for applicability include the following:

- seepage, internal erosion, and piping
- erosion-induced breaching
- shear failure
- surface sloughing
- excessive deformation
- seismically-induced liquefaction
- other types of slope movement

The foundation and subsurface design of an embankment, levee, or berm should be evaluated to determine whether the following factors are appropriately considered in its design:

- foundation stability
- positive control of seepage
- minimum adverse deformation via good contact between flood protection structure and foundation
- use of cut off walls and drainage systems to control seepage paths through foundation

The stability of embankments should be evaluated utilizing pertinent geologic information and in situ engineering properties of soil and rock materials. The geologic information and site characteristics that should be considered include the following:

- groundwater and seepage conditions
- lithology, stratigraphy, and geologic details disclosed by borings and geologic interpretations
- maximum past overburden at the site as deduced from geological evidence
- structure, including bedding, folding, and faulting
- alteration of materials by faulting
- joints and joint systems
- weathering
- cementation
- slickensides

- field evidence relating to slides, earthquake activity, movement along existing faults, and tension jointing

The materials used in construction of the embankment should be evaluated to determine whether the following factors are appropriately considered in its design:

- use of filter materials to preclude migration of soil materials through the embankment and foundation
- erosion control against surface runoff, wave action, hydrodynamic forces, and debris

In evaluating engineering properties of soil and rock materials used in construction of the embankment, the licensee should consider the following:

- possible variation in natural deposits or borrow materials
- natural water contents of the materials
- climatic conditions
- possible variations in rate and methods of fill placement
- variations in placement water contents and compacted densities that must be expected with normal control of fill construction

The maintenance and inspection regime of the embankment should be evaluated to assess whether the following is true:

- The embankment is inspected at regular intervals.
- Written procedures are in place for proper maintenance.
- Personnel responsible for inspecting the structure have been trained in inspection techniques, implementing preventative and compensatory measures, and correcting or repairing deterioration.
- Suitable instrumentation is used to obtain information on the performance and condition of the structure.

A.1.1.2 Floodwalls

A retaining wall is any wall that retains material to maintain a change in elevation, whereas the principal function of a floodwall is to prevent flooding (inundation) of adjacent land. A floodwall is subject to water force on one side, which is usually greater than any resisting earth force on the opposite side. A wall may be a retaining wall for one loading condition and a floodwall for another loading condition. The flood loading (e.g., surge tide, river flood) may be from the same or the opposite direction as the higher earth elevation.

For inverted T-type floodwalls, the crossbar of the T serves as a base and the stem serves as the water barrier. In evaluating T-type floodwalls, potential failure modes for T-walls that should be considered include the following:

- seepage
- wall stability

Planning and design procedure considerations for floodwall projects are described in References A1 and A2.

An I-wall is a slender cantilever wall, embedded in the ground or in an embankment that rotates when loaded and is thereby stabilized by reactive lateral earth pressures. The licensee should consider the following potential failure modes of I-walls:

- depth of piling
- deep seated (global failure)
- rotational failure caused by inadequate pile penetration
- seepage

Reference A3 provides information on I-Walls, as they relate to hydrostatic loads, static and dynamic water (wave) loads, seepage and piping, I-wall deflections, and determination of safety factors.

A.1.1.3 Seawalls

Seawalls are onshore structures with the principal function of preventing or alleviating overtopping and flooding of the land and the structures behind them caused by storm surges and waves. The licensee should consider potential failure modes of seawalls, including instability due to erosion of the seabed at the toe of the structure and increase in wave impact, runup, and overtopping. References (A4-A6) provide additional information on seawalls.

A.1.1.4 Concrete Barriers

In assessing whether other concrete barriers can support flood loads, the licensee should evaluate the foundation and subsurface design of the barrier to determine whether the following factors were appropriately considered in design of the structure:

- static loads from stillwater elevation
- hydrodynamic loading from wave effects and debris
- foundation design and treatment, including good contact between the flood protection structure and foundation
- removal of problem soils
- increasing seepage paths through the foundation by use of deep cut off walls, if necessary

The licensee should evaluate the material properties of the concrete barrier (using available documentation and current condition) to assess whether the following is true:

- There was a competent investigation of material sources.
- Adequate testing was performed of materials in accordance with accepted standards.
- Proper proportioning of concrete was performed to improve strength and durability.

The licensee should evaluate the design of the concrete barrier to ensure it is safe against overturning and sliding without exceeding the allowable stress of the foundation and concrete for the loading conditions imposed by the flood and all associated flood effects

The licensee should evaluate the maintenance and inspection regime of the concrete barrier to assess whether the following is true:

- The barrier is inspected at regular intervals.

- Written procedures are in place for proper maintenance.
- Personnel responsible for inspecting flood control structures have been trained in inspection techniques, implementing preventative and compensatory measures, and correcting or repairing deterioration.
- Suitable instrumentation is being used to obtain information on the performance and condition of the structure (e.g., assessing settlement and tilting of foundations, condition of the concrete including degradation mechanisms, seepage).

A.1.1.5 Plugs and Penetration Seals

In assessing whether plugs and penetration seals are watertight and support applied loads the evaluation should demonstrate the following:

- the ability to withstand the flood height and associated effects (including static and dynamic loads) associated with the flood scenario parameters, including the following considerations:
 - all sizes tested to withstand hydrostatic seal pressures for the anticipated water pressures
 - adequate design for the effects of hydrodynamic and debris loading from floods
- leakage restricted to amount within the capacity of drainage or pumping systems
- the ability to withstand anticipated temperatures
- suitability for applications in water - above ground and direct burial and ability to provide the electrical insulation where cathodic protection is required
- adequate resistance to fires, corrosive fluids, ultraviolet and radiation, as applicable
- appropriate qualitative evaluation of operational requirements such as surveillance, inspection, design control, procurement, maintenance, and testing to provide confidence in the reliability of plugs and penetration seals

A.1.1.6 Storm Drainage Systems

If credited, the licensee should evaluate the storm drainage systems to demonstrate they are capable of passing sufficient flow to accommodate the reevaluated flood flow rate while maintaining the flood height not greater than the allowable value.¹ The evaluation should consider all effects associated with the flood (e.g., scour). Performance should be compared against appropriate present-day codes and standards, including Section 2.4.2, Revision 4, "Floods," of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR [light-water reactor] Edition" (Ref. A7). Storm drainage systems should also be evaluated to demonstrate that they are in satisfactory condition. Qualitative evaluation of operational requirements, such as surveillance, inspection, design control, procurement, maintenance, and testing is appropriate (e.g., a walkdown procedure should be provided for verifying that the system is clear of debris and objects that could impede flow). If drainage systems are associated with active components, active components should be evaluated using considerations described in Section A.1.2.

¹ If storm drainage is not capable of handling the reevaluated flood, flood protection should be provided and evaluated.

A.1.2 Active Features

A.1.2.1 Active Components

The availability and reliability of active components (e.g., pumps, valves) should be justified using:

- operational data
- performance criteria (e.g., see Table A1)
- consideration of operational requirements:
 - surveillance
 - inspection
 - design control
 - maintenance
 - procurement
 - testing and test control

If applicable, licensees should further use the following to justify the availability and reliability of active components and features:

- incorporation of equipment in plant programs (e.g., whether the component is included in established plant equipment reliability programs or subject to 10 CFR Part 50, Appendix B)
- conformance to consensus standard developed for similar uses, including emergency uses (e.g., standards developed by the National Fire Protection Association for fire protection equipment)

In addition, when information is available, the reliability of active components (e.g., failure to start on demand and failure to run once started) should be quantitatively evaluated and documented based on operating experience, testing, and other available information using traditional probabilistic risk assessment or statistical techniques. In some cases, this information may not be available. In this case, tests or analyses may be appropriate to support quantification of reliability. If information is not available and testing is not feasible, the integrated assessment submittal should: (1) describe why quantification of equipment reliability is not possible or necessary; and (2) justify why the equipment can be reasonably credited despite these limitations.

A.1.2.2 Flood Doors and Hatches

In assessing whether watertight doors (flood doors and hatches) perform their intended functions, the following factors should be considered:

- Hydrostatic force resistance – flood barriers should conform to the criteria for resisting lateral forces due to hydrostatic pressure from freestanding water.
- Hydrodynamic force resistance – flood barriers should conform to the criteria for resisting lateral forces due to moving flood waters.
- Debris impact force resistance – flood barriers should conform to the criteria for resisting debris objects at stated velocities.

A.1.3 Temporary Features

Standards, codes, and guidance documents (e.g., References A8 and A9) should be consulted to determine whether the configuration of the temporary barrier (e.g., configuration of a sandbag wall) conforms to accepted engineering practices. Justification of feature reliability may require laboratory- or field-testing (e.g., Reference A10), analytical modeling, or demonstrations. If an assessment and evaluation of temporary features reveals deficiencies and shortcomings in their capability to perform adequately as a flood barrier because they do not conform to accepted engineering practice, the implications of the deficiencies should be summarized.

Moreover, it should be demonstrated that temporary features can be moved to the location where needed and installed. The licensee should use Appendix C to this guidance to evaluate manual actions associated with construction or installation of temporary protective measures.

A.1.4 Equipment Necessary to Perform Human Actions

The licensee should use Appendix C to this guidance to evaluate human actions associated with flood protection features.

Equipment necessary to facilitate performance of manual actions should be functional, available, and accessible when required. The availability of special equipment required for the performance of protective or mitigating actions should be considered. In crediting the availability of equipment for use by personnel, the licensee should consider the following criteria:

- Equipment should not be damaged or otherwise adversely effected by the flood event (e.g., direct inundation, excessive humidity, hydrodynamic forces, or debris) or adverse environmental conditions.
- Equipment should not be located in an area exposed to the flood (including any associated effects), unless a strong justification exists for the continued functionality of the equipment.
- All “needs” of the equipment should be met, including, for example, supporting electrical power, cooling, and ventilation.
- Equipment should be easily located and all aids should be readily available.
- Physical access and manipulation constraints should be considered in evaluating whether equipment is available for use.

Plant personnel should be able to find and reach the equipment and should be able to perform the required actions using the equipment. Credit should only be given if the equipment is functional, available, and accessible to personnel. Therefore, if any of the above criteria are not met, the operation of the equipment should be considered infeasible.

The licensee should consider special and portable equipment that may be required to facilitate performance of required actions. Special equipment may include keys to open locked doors (doors may “fail closed” in the event of a loss of power), ladders, and special purpose tools (e.g., equipment required to fill sandbags, portable generators, tools to manipulate equipment manually) and equipment necessary to cope with environmental conditions (e.g., flashlights and personal protective equipment such as personal floatation devices). Equipment should be easily located and readily available so as not to impede or delay the performance of required actions. Equipment should be controlled and routinely

verified. Personnel should be trained to locate and use the required equipment. The licensee should consider any delays associated with acquisition and use of portable equipment.

A.2 Flood Protection Systems

Section A.1 provides guidance of the evaluation of individual flood protection features (i.e., evaluation at the component level). Some flood protection systems involve multiple features or components. This section describes the evaluation of flood protection systems as a whole (i.e., at the system-level) as directed by Section 6 of this ISG. System evaluation should begin with defining the flood scenario parameter to which the system is subjected. Next, criteria defining failure of the flood protection system should be identified. In the context of the integrated assessment, failure may be defined as loss of barrier integrity, a leakage rate into a room exceeding a specified threshold, or other effects. Failure modes and effects analysis (FMEA) is a common tool for systematically identifying possible failure modes of a structure, system, and component (SSC) and evaluating the effects of the failure on other SSCs and is applicable to the integrated assessment. Once failure criteria have been defined, individual flood protection barriers within the flood protection system should be evaluated at the component level under the loads resulting from the flood scenario parameters as described in Section A.1. Finally, the flood protection system should be evaluated, accounting for interactions and dependencies between components.

Following the above steps, the system evaluation should progress through the sequence of subsequent events that can ultimately lead to end states corresponding to failure (or damage) of the flood protection system and subsequent adverse consequences (e.g., leakage of water past a barrier or inundation of a room). Logic structures, such as event trees, provide a way to represent the various outcomes that can occur as a result of the flood scenario parameters. An event tree starts with the specification of the flood scenario parameters and develops sequences based on whether a feature (including a human action) succeeds or fails in performing the intended functions. The system level evaluation should account for factors such as the following:

- the duration of the flood event²
- the reliability of active components (e.g., pumps that are required to remove water that bypasses flood barriers)
- the effect of flood height and associated flood effects on the performance of barriers
- the robustness of barriers, particularly temporary barriers
- the feasibility and reliability of human actions that must be performed to install or construct barriers (e.g., flood gates, sandbag walls), including factors that can influence personnel performance, as described in Appendix C to this guidance

² For some hazards, flood conditions could persist for a significant amount of time. Extended inundation on or near the site could present concerns such as site and building access, travel around the site, equipment operating times, and supplies of consumables. The licensee should evaluate flood protection feature limitations based on flood duration. For example, if the duration of the design basis flood is 72 hours and a diesel driven pump is credited with removing water from an area, the total amount of fuel available for the pump and the operating time it represents should be determined and included in the assessment.

A.3 References

- A1. U.S. Army Corps of Engineers, "Engineering and Design - Retaining and Flood Walls," EM 1110-2-2502, 1989.
- A2. U.S. Army Corps of Engineers, "Engineering and Design – Waterstops and Other Preformed Joint Materials for Civil Works Structures," EM 1110-2-2102, 1995.
- A3. U.S. Army Corps of Engineers, "Design of Sheet Pile Walls," EM 1110-2-2504, 1994.
- A4. U.S. Army Corps of Engineers, "Engineering and Design-Design of Coastal Revetments, Seawalls and Bulkheads," EM 1110-2-1614, 1995.
- A5. U.S. Army Corps of Engineers, "Coastal Engineering Manual-Part VI, Introduction to Coastal Project Element Design," EM 1110-2-1100, 2002.
- A6. U.S. Army Corps of Engineers, "Coastal Engineering Manual- Part V, Planning and Design Process," EM-2-1100, 2002.
- A7. U.S. Nuclear Regulatory Commission, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," NUREG-0800, Section 2.4.2: "Floods," Revision 4, March 2007, ADAMS Accession No. ML070100647.
- A8. U.S. Army Corps of Engineers, Flood-Fight Handbook - Preparing for a Flood. 2009. Available at: http://www.mvp.usace.army.mil/docs/disaster_response/CEMVP_Flood-Fight_Handbook_2009.pdf.
- A9. U.S. Army Corps of Engineers, Sandbag Construction. [Online] [Cited: November 26, 2012.] Available at: http://www.mvp.usace.army.mil/docs/flood_fight2009/5Sandbag_Construction_2009_JR L.pdf.
- A10. U.S. Army Corps of Engineers, Laboratory Testing of Flood Fighting Products. Coastal and Hydraulics Laboratory. [Online] [Cited: August 23, 2012.] Available at: <http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=Projects;182>.

Table A1: Criteria for Evaluating Active Components

<p>Functional characteristics:</p>	<ol style="list-style-type: none"> 1. Equipment is capable of performing its required function (e.g., functional requirements such as pump flow rate, pump discharge pressure are met). 2. Equipment is in satisfactory condition. 3. Functionality of the equipment may be outside the manufacturer's specifications if a documented engineering evaluation justifies that the equipment will be functional when needed during the flood event duration. 4. There is an engineering basis for the functional requirements for the equipment which: <ol style="list-style-type: none"> a. is auditable and inspectable; b. is consistent with generally accepted engineering principles; c. defines incorporated functional margin; and d. is controlled within the configuration document control system.
<p>Operational characteristics</p>	<ol style="list-style-type: none"> 1. Equipment is covered by one of the following: <ol style="list-style-type: none"> a. existing quality assurance (QA) requirements in Appendix B of 10 CFR Part 50; b. existing fire protection QA programs; or c. a separate program that provides assurance that equipment is tested, maintained, and operated so that it will function as intended and that equipment reliability is achieved. 2. Testing (including surveillances) <ol style="list-style-type: none"> a. Equipment is initially tested or other reasonable means should be used to verify that its performance conforms to the limiting performance requirements. b. Periodic tests and test frequency are determined based upon equipment type and expected use. Testing is done to verify design requirements and basis are met. The basis is documented and deviations from vendor recommendations and applicable standards should be justified. c. Periodic inspections address storage and standby conditions as well as in-service conditions (if applicable). d. Equipment issues identified through testing are incorporated into the corrective action program and failures are included in the operating history of the component. 3. Preventive maintenance (including inspections) <ol style="list-style-type: none"> a. Preventive maintenance (including tasks and task intervals) is determined based upon equipment type and expected use. The basis is documented and deviations from vendor recommendations and applicable standards should be

	<p>justified.</p> <ul style="list-style-type: none"> b. Periodic testing addresses storage and standby conditions as well as in-service conditions (if applicable). c. Equipment issues identified through inspections are incorporated into the corrective action program and failures are included in the operating history of the component.
Unavailability characteristics	<ol style="list-style-type: none"> 1. The unavailability of equipment should be managed such that loss of capability is minimized. Appropriate and justifiable unavailability time limits are defined as well as remedial actions. A replacement would be for equipment that is expected to be unavailable in excess of this time limit or when a flood event is forecasted. 2. A spare parts strategy supports availability considerations. 3. The unavailability of installed plant equipment is controlled under existing plant processes such as technical specifications.
Equipment storage characteristics	<ol style="list-style-type: none"> 1. Portable equipment is stored and maintained to ensure that it does not degrade while being stored and that it is accessible for maintenance and testing. 2. Credited active equipment is protected from flooding. It is accessible during a flooding event. Alternatively, credited active equipment may be stored in locations that are neither protected from flooding nor accessible during a flood if adequate warning of an impending flood is available and equipment can be relocated prior to inundation. <ul style="list-style-type: none"> a. Consideration should be given to the transport from the storage area recognizing that flooding can result in obstacles restricting normal pathways for movement. b. Manual actions associated with relocation of equipment should be evaluated as feasible and reliable (see Appendix C to this guidance). 3. A technical basis is developed for equipment storage that provides the inputs, assumptions, and documented basis that the equipment will be protected from flood scenario parameters such that the equipment could be operated in place, if applicable, or moved to its deployment locations. This basis is auditable, consistent with generally accepted engineering principles, and controlled within the configuration document control system.

APPENDIX B: Peer Review

A peer review is an important element of the integrated assessment. The peer review increases confidence in the results of the integrated assessment and provides assurance that these results form a sound basis for regulatory decisions. Where feasible, the peer review can incorporate established licensee review procedures if compatible with the site-specific conditions and nonroutine nature of the integrated assessment. The following sections describe the peer reviewer attributes, attributes of an acceptable peer review, and required documentation of the peer review.

B.1 Peer Reviewer Attributes

The reviewers should have the following attributes:

- Peer reviewers should be independent of those who are performing the integrated assessment (i.e., the peer review team members should have neither performed nor directly supervised any work on the portions of the assessment they are reviewing).
- The number of peer reviewers is dictated by the scope of the integrated assessment. This number should include as many people as necessary for review by individuals with appropriate expertise. Collectively, peer reviewers should have expertise in all areas of importance to the integrated assessment. For example, reviewers should have combined experience in the following areas (as applicable): systems engineering, flood hazard assessment, flood protection engineering (e.g., structural and geotechnical engineering), human reliability analysis and evaluation of manual actions, and application of probabilistic risk assessment (PRA) methodologies.
- One of the peer reviewers should be designated as the peer review team leader. The team leader is responsible for the entire peer review process, including completion of the final peer review documentation. The team leader is expected to provide oversight related to the process, scope, and technical aspects of the peer review. The team leader will establish the initial scope of the peer review and assemble an appropriate review team. The team leader should have sufficient knowledge and experience to determine the scope of the review based on the above considerations. The peer review team leader should expand the scope of the review and add members to the team, if necessary, to ensure that all areas of review are appropriately covered.
- Peer reviewers may be selected from within the licensee's organization if the attributes described above are met. If reviewers with the above attributes cannot be assembled from within the licensee's organization (in whole or in part), then the licensee should assemble additional reviewers from outside the licensee's organization (i.e., external peer reviewers).

B.2 Peer Review Attributes

The peer review should have the following attributes:

- To facilitate an efficient and informative review, an in-process peer review is recommended, though a one-time peer review at the end of the integrated assessment is also acceptable. In other words, it is recommended that the peer review be performed contemporaneously with the integrated assessment and

observations made by the reviewers should be transmitted to the integrated assessment team as soon as possible.

- The peer review should be conducted as an assembled team. This is particularly important for critical items such as the following (if credited): (1) manual actions; (2) temporary protective measures; and (3) nonsafety-related equipment used for event mitigation. Reviewers should have the opportunity to interact with one another when performing the reviews, irrespective of the specific areas of review to which a team member is assigned.
- The reviewers should evaluate each of the following if they are a part of the integrated assessment and assess the rationale, if they are not:
 - methodologies used to evaluate capabilities for flood protection and mitigation
 - assumptions made and methods used to formulate and validate the methodologies
 - performance criteria applied
 - evaluations of the reliability of flood protection features and systems for which generally accepted codes and standards are either unavailable or inapplicable
 - evaluations of the feasibility and reliability of nonroutine or new human actions (i.e., actions that are not routinely performed or have not been previously evaluated under other processes)
 - judgments made regarding the mitigation capability and reliability of credited systems (applies to both margins-type and full PRA methods)
 - judgments made that there is high confidence that key safety functions will be maintained, including logic models and timelines (applies to scenario-based evaluation methods)
- Peer reviewers should pay particular attention to the following:
 - assumptions, particularly those that are not thoroughly developed and documented
 - justification for the use of novel models or methods, especially if those models or methods are inconsistent with current practices
 - technical judgments, especially those that are not supported by technical analyses, such as explicit calculation or appropriate data
 - judgments made regarding the reliability of protection or mitigation actions involving the use of equipment, personnel, or other resources in nontraditional ways
- Peer reviewers should evaluate the completeness, accuracy, and technical bases of the final integrated assessment report

B.3 Peer Review Documentation

The peer review process should be clearly documented in the integrated assessment submittal. Documentation of the peer review should be contained in a separate enclosure report as part of the licensee's integrated assessment submittal and should include the following:

- a description of the peer review process
- the names and credentials (e.g., training, experience, capabilities, and background) of the peer review team members and leader, as well as the areas on which each reviewer concentrated

- a description of how the assembled peer review team met the reviewer attributes (Section B.1)
- a discussion of the key findings and a discussion as to how the findings were addressed
- an assessment of the disposition of comments made by peer reviewers
- a review of the final integrated assessment report
- the conclusions of the peer review team as to the completeness, accuracy, and technical bases of the integrated assessment

APPENDIX C: Evaluation of Manual Actions

C.1 Overview

C.1.1 Purpose and Scope

This appendix provides guidance for evaluating manual actions associated with flooding based on concepts and approaches used in human factors engineering and human reliability analyses (HRA).¹ The purpose of the evaluation is to ensure, with high confidence, that manual actions required for flooding events are both feasible and reliable. An action is considered feasible if it has been analyzed and the licensee has shown that it can be performed correctly within an available time to avoid a defined undesirable outcome. A feasible action is reliable when it is shown to be dependably repeatable within an available time (while considering varying conditions that could affect the available time or the time required for performing the action or both). All reliable actions must be feasible, but not all feasible actions will be reliable (Ref. C1). Results of the evaluation process described in this appendix may show that an important human action is infeasible or cannot be performed reliably. In these instances, it may be possible to modify aspects of the task or the circumstances in which the action is performed to identify acceptable alternatives. Therefore, the evaluation process described in this appendix may be iterative.

Much of this appendix focuses on manual actions performed outside the main control room (MCR), including actions taken throughout the plant and around the site associated with both flood protection and mitigation. Nonetheless, some flooding scenarios may challenge the operating crew's ability to maintain situation awareness and command and control. Therefore, in addition to ex-MCR actions, the scope of this evaluation also comprises manual actions that are performed in the MCR during a flood scenario with the specific intent to affect plant operating conditions.²

C.1.2 Organization of the Appendix

This appendix is organized according to the process for evaluating the feasibility and reliability of flood-related manual actions for the integrated assessment, as described below:

- Section C.2 describes a process for identifying and defining important human actions
- Section C.3 discusses evaluating whether manual actions are feasible, including the following:
 - evaluating the impact of performance shaping factors (PSFs) on the action (Section C.3.1), and
 - conducting a timing analysis (Section C.3.2)

¹ Due to the nature of and variety of potential flooding events and responses, it is recognized that additional approaches may be used or developed to augment the guidance provided in this appendix.

² These include actions to reconfigure flow paths, to recover equipment important to safety, to change power level, and to switch sources of coolant inventory, among others. Because Emergency Operating Procedures (EOPs) have been validated during their development and subsequent change processes, it is expected that actions included in the existing EOPs are acceptable with little further evaluation, but only if they are applicable to the plant mode and effective under the conditions of the scenario (e.g., instrumentation and controls for the equipment is not degraded, power is available, no spurious alarms).

- Section C.4 provides a process for evaluating whether manual actions are reliable
- Section C.5 discusses adjustments of actions and associated context to improve feasibility or reliability
- Section C.6 describes documentation

C.2 Identify and Define the Human Actions

The first step in the evaluation is to identify the manual actions associated with flood protection or mitigation. This step also entails defining the actions at the appropriate level of detail to support qualitative analysis and quantification, if necessary. For each human action upon which flood protection or mitigation depends, the licensee should develop a timeline that “locates” the human action within the sequence of activities in the flooding scenario and provide a high-level description of it (i.e., an “operational story” or “human failure event (HFE) narrative,” as described in NUREG-1921, “EPRI/NRC-RES Fire Human Reliability Analysis Guidelines,” issued July 2012; see Reference C2). The narrative should include the following:

- the initiating event for the scenario, including flood scenario parameters and credible flood protection failure modes (if applicable)
- the sequence of events (preceding system and functional failures and successes) leading up to the human action
- description of the objective of the action (i.e., what the action is intended to achieve)
- description of the credentials and experience of personnel performing the action (e.g., licensed operators versus maintenance personnel)
- description of the cognitive (detection, diagnosis, and decisionmaking) and execution (actions, behaviors) aspects of the manual action
- timing information (as specified in Section C.3.2 of this appendix)
- scenario-specific procedural guidance
- availability of cues and other associated indications that may be needed to initiate necessary actions, as well as cues that might subsequently enable personnel to detect the need to correct an action that has been omitted or performed incorrectly
- any preceding human errors or successes in sequence (e.g., previous human errors modeled in the scenario)
- human action success criteria
- undesired human responses
- physical environment in which the action is performed
- a summary of the operating history of human errors (including both plant-level and industry experiences) associated with (1) establishing and maintaining the flood protection features and (2) structures, systems, and components (SSCs) involved in flood mitigation

Guidance for determining the level of detail at which to define the human actions to be evaluated is available from numerous sources (e.g., References C3, C4, and C5). Section 9.4 of NUREG-1624, “Technical Basis and Implementation Guidelines for A Technique for Human Event Analysis (ATHEANA),” issued May 2000 (Ref. C6), provides a framework and detailed guidance for defining HFEs and unsafe acts. As a rule of thumb, the action should be defined at a level of detail that supports evaluating the impact of the performance shaping factors (PSFs) listed in Section C.3.1 of this appendix. For example, describing some actions at the functional level, such as an action to “establish operating routines to service gasoline and diesel driven equipment,” will not support evaluating PSF impacts because there will be different locations at which servicing must occur and the locations

may vary in terms of accessibility and the environmental conditions to which personnel will be exposed, among other considerations. Conversely, decomposing an action into highly detailed steps (e.g., “hammer in the first of four nails”) would be unnecessary for the evaluation if the same PSFs would impact the performance of each step in the same way.

C.3 Determine Whether the Action is Feasible

A manual action is feasible if it can be accomplished in the context within which it will be performed and there is adequate time available to perform the action, considering any adverse contextual or personnel factors that may delay or degrade performance. This appendix presents a two-step process for determining feasibility.

The first step is to evaluate any performance shaping factors (PSFs) that may adversely affect the performance of the manual action in a flooding scenario. PSFs that may affect the performance of actions during flooding events are described in Section C.3.1. Each subsection (Sections C.3.1.1 to C.3.1.13) includes a general discussion of the PSF, as well as criteria for determining whether the PSF is expected to be either nominal or degraded.

The second step in determining whether an action is feasible is to conduct a timing analysis. This analysis (described in Section C.3.2) determines whether the time available to complete the action is greater than the time required when accounting for uncertainties in timing estimates (i.e., margin). If the time required to perform the action is greater than the time available, but there is insufficient margin to account for uncertainties, the action should be considered infeasible.

Detailed justification should be provided to support the determination that an action is feasible. The following should be considered when evaluating the feasibility of an action:

- whether the PSF associated with stress is categorized as nominal or moderate
- whether all other PSFs are categorized as nominal
- whether the timing analysis determines that the time available to perform the action is greater than the time required, when accounting for uncertainties.

If there are strong reasons to believe that an action can be performed despite the presence of degraded PSFs, the basis for determining that the action is feasible should be justified and documented in detail. In addition, a timing analysis should be conducted to: (1) account for the impact of the degraded PSF on the time required to perform the action; and (2) show that there is margin available to complete the action.

C.3.1 Performance Shaping Factors

The following PSFs are relevant to manual actions associated with flooding:

- *Cues and indications*—the availability and quality of information needed to initiate and perform the action
- *Complexity*—the ambiguity and mental effort associated with detection, diagnosis and decisionmaking and any complicated aspects associated with action execution, such as special sequencing, coordination between multiple individuals at different locations, or the need for sensitive and careful manipulations
- *Special equipment*—the availability and usability of any special equipment needed to perform the human action, including portable equipment as well as personal protective equipment (PPE)

- *Human-system interface*—the availability and usability of that part of a piece of equipment or system with which personnel interact to perform the action
- *Procedures*—the availability, accuracy, applicability, and usability of instructions for performing a human action
- *Training*—the availability and quality of training provided for performing the human action
- *Perceived workload, pressure and stress*—the extent to which a crew or individual experiences time pressure and stress from the need to perform the action in the available time along with their overall sense of being pressured and/or threatened in some way with respect to what they are trying to accomplish
- *Environmental factors*—the presence and severity of those factors that could negatively impact the ability to perform the human action, such as the presence of water, radiation, poor lighting, temperature extremes, humidity, noise, vibration, and electrical hazards
- *Special fitness issues*—the extent to which performance of the human action requires unusual levels of fitness or conditions create fitness concerns
- *Staffing*—the availability of sufficient numbers of qualified personnel to perform the action, considering concurrent activities and collateral duties
- *Communications*—the availability, accessibility, and functionality of communications equipment needed to perform the action and coordinate activities among personnel
- *Accessibility*—the ability of personnel and resources to move around the site as well as the ability of offsite personnel and resources to arrive onsite
- *Scenario-specific PSFs*—other task or contextual factors that have the potential to adversely affect performance of the action

As described previously, manual actions that are associated with PSFs that are not categorized as “nominal” should be considered infeasible, with the exception of the “perceived workload, pressure, and stress” PSF, for which a moderate categorization is acceptable. This PSF is excepted because, at a minimum, moderate levels of stress can be expected during flooding events.

The following subsections describe PSFs to be considered in evaluating whether manual actions are feasible.

C.3.1.1 Cues and Indications

Cues and indications serve the following three functions:

- 1) Enable personnel to determine that flood protection and mitigation actions are required or appropriate
- 2) Direct or guide personnel performing actions
- 3) Provide feedback on the success or failure of actions

In the context of flood protection, indications should be available to provide notification that a flood event is imminent if manual actions are required to provide protection against flooding. Examples of indications include river forecasts, dam condition reports, and river gauges. If durable agreements are not in place to ensure communication from offsite entities and the plant does not have an independent capability to obtain the same information onsite, any manual action initiated by the indication should be considered infeasible. Consideration should be given to the quality of the agreements in place between offsite entities and personnel at the nuclear power plant site, as well as the potential for the communication mechanisms to fail.

Cues and indications are also necessary (1) for determining whether and which flood protection manual actions are required, (2) to direct the performance of those actions, and (3) to evaluate whether the actions have achieved their objective. Particularly with respect to active flood protection features, cues and indications should be available to verify that the needed equipment is functioning as intended. The impact of other postulated conditions on the availability of cues and indications should also be considered (e.g., communication difficulties resulting from noise, difficulties in manipulating equipment, or verifying equipment status in the dark).

In the context of mitigation actions, indications should be available to alert personnel to the failure of flood protection features and the presence of water in locations that are intended to be kept dry or otherwise protected from flood effects. For cases in which indications are not available, the evaluation can consider compensatory measures (e.g., local observations). Evaluations of the adequacy of time should account for the frequency of manual checks in the absence of continuous monitoring. If cues or indications are not available, the mitigation actions should be considered infeasible.

For control room based actions, the presence and the salience of indicators and cues should be considered. Annunciators, alarms, computer logs, and position indicators may be more or less effective based on the context (e.g., it may not be feasible to expect an operator to attend to a single annunciator when 50 or 60 are in alarm coincidentally). Additionally, consideration should be given to whether spurious alarms resulting from flood effects are likely to cause unwanted operator responses that could make plant conditions worse instead of better. In addition to potential effects on cues and indications, some flooding scenarios may degrade or fail systems normally available to crews in the MCR for taking actions to control key safety functions. If local control actions are required, the evaluation should consider the communications burden on the operating crew for directing the action and verifying that the action has been successful. The evaluation should also pay attention to the accessibility of data or information in digital or computerized systems (e.g., if the computer is not functional because of the flood, many alarms and other information will be inaccessible to operators).

Based on the considerations described above, the PSF for cues and indications should be evaluated using the following categorization scheme:

- Nominal—Cues and indications are available and can be accessed in time to support diagnosis and decisionmaking before action execution is required, and the cues and indications are accurate.
- Degraded—Cues and indications are missing, difficult to obtain, or unreliable.

C.3.1.2 Complexity of the Required Action

Complexity refers to the nature of the situation that must be diagnosed, the decision to be made, or the action to be performed. High levels of complexity, particularly in the absence of training and practice, reduce the feasibility of manual actions. Sources of complexity that may affect the timeliness and effectiveness of cognition (i.e., detection, diagnosis, and decision-making) may include:

- diagnostic ambiguity from conflicting or difficult-to-interpret cues and indications
- unfamiliar circumstances that require mental effort and, perhaps consultation, to interpret
- ambiguity in the appropriate prioritization of competing goals

- the need to consider multiple variables simultaneously while implementing a proceduralized action

Sources of complexity that may affect the timeliness and effectiveness of action execution may include:

- the need for personnel to perform many unfamiliar steps in rapid succession;
- the need to perform multiple actions concurrently; and
- whether special sequencing or coordination is required for the action to be successful (especially if it involves multiple persons in different locations)

Actions that require concurrent diagnosis and execution or sensitive and careful manipulations are also likely to be complex.

Input from personnel should be obtained regarding their perceptions of whether the scenario is complex or simple. If rarely-used configurations will be necessary, the licensee should consider the possibilities of new single failures, interfacing loss-of-coolant accidents, inadvertent system interactions, and unrecognized drainage pathways for the reactor vessel or important storage tanks. In addition, to evaluate complexity, the following questions should be considered:

- Are there many alarms or indications to which the crew or operator must identify, evaluate, and respond?
- Will communication between several individuals at different locations be necessary?
- Will plant symptoms be difficult to ascertain because of instrumentation failures and spurious indications?
- Will component failures have multiple or propagated effects on systems, equipment, or other components?
- Will the action sequence include concurrent tasks that require specific timing to be successful?
- Will the situation include many distractions, crowds of people, or other factors that could divert attention from the required tasks?

Based on the considerations described above, the PSF for complexity should be evaluated for cognition and execution using the following categorization schemes:

Cognition

- Nominal—Detection, diagnosis, and decisionmaking associated with the action are simple, straightforward, and unambiguous or the crew or individual is highly familiar with and skilled in addressing the situation.
- Degraded—The available information is conflicting or difficult to interpret. Resolution of any ambiguity or response planning requires obtaining validating or convergent information, consideration of competing goals, multiple variables or consultation. Sources of distraction are present. Conditions require counter-intuitive responses or responses that conflict with highly trained responses to similar circumstances.

Execution

- Nominal—Execution of the action is simple and straightforward. Coordination requirements are minimal or highly practiced. Steps in the action sequence are performed at a single location, involve the concurrent management of one or very

few variables, and feedback on the effectiveness of the action is easily available and accurate.

- Degraded—Execution of the action is difficult. Execution requires rapid performance of multiple, complicated steps, the performance of steps by the same individual at multiple locations, coordination of steps between two or more individuals at multiple locations, or very sensitive and careful manipulations. Several variables may be involved in the action or there is ambiguity in how to perform the action.

C.3.1.3 Special Equipment

Manual actions associated with flooding may require special or portable equipment and PPE. Portable equipment may include keys (doors may “fail closed” in the event of a loss of power), ladders, hoses, torque devices, electrical breaker rackout tools, flashlights, portable pumps and meters, and rafts or boats, among other items. PPE may include protective clothing to enter high radiation areas or flood-specific protective clothing, such as life jackets, hip waders, or other special purpose gear. Section A.1.4 of Appendix A to this guidance discusses criteria for crediting the functionality, accessibility and availability of special equipment when needed to perform an action.

The use of special equipment itself may adversely affect action execution. Examples include increased opportunities for errors and delays from having to hold a flashlight or aim a headlamp when manipulations are required or from the time required to don PPE; movement restriction and careful performance to ensure that a raft or boat does not capsize; reduced vision from wearing face protection; reduced manual dexterity from wearing gloves; or reduced communications ability from wearing special purpose gear. In addition, personnel may not be familiar with and highly practiced in using some of the special equipment that may be required in flooding events, also resulting in discomfort, delay and an increased likelihood of errors.

Based on the considerations described above, the PSF for special equipment should be categorized using the following scheme:

- Nominal—The number and type of special equipment required is minimal and personnel are familiar with and practiced at using it.
- Degraded—Personnel are not familiar with and practiced using special equipment. The design of the equipment interferes with action performance, or the action requires use of multiple types of special equipment.

C.3.1.4 Human-System Interfaces

The availability, functionality, and usability of human-system interfaces (HSIs) will impact the performance of some manual actions. HSIs involved in flooding events include the controls and displays provided by portable and temporary equipment, control room HSIs, HSIs for local control stations, and any other hardware or software with which personnel must interact to obtain information or change the state of SSCs. NUREG-0700, Revision 2, “Human-System Interface Design Review Guidelines,” issued in 2002 (Reference C8 provides guidance for the evaluation of HSIs, including evaluation of conventional (non-computerized) HSIs).

HSI design may affect both the cognition and execution aspects of a manual action and will likely have a greater impact on local actions than actions in the MCR. For example, if the

decision to perform an action depends on readings from meters or gauges that are normally backlit but there is no backup power to maintain the lighting during a flooding event, the cognitive portion of an action will be delayed. Action execution may be delayed if time is required to travel from the location of a display to the equipment to be manipulated. Labeling of components may become particularly important for local actions that must be performed in the dark or extreme weather conditions.

Based on the considerations described above, the PSF for HSIs should be categorized using the following scheme:

- Nominal—HSIs required to perform the action are functional, accessible and their design supports human performance under anticipated flooding conditions.
- Degraded—HSIs are poorly designed (e.g., poor labeling, needed instrumentation cannot be seen from the location where control inputs are made, or there are poor computer interfaces), have been damaged, or are difficult to use under the expected conditions. The HSI fails to support diagnosis or post-diagnosis behavior, or the instrumentation is inaccurate (i.e., misleading). Required information is not available from any source (e.g., instrumentation is so unreliable that individuals ignore the instrument, even if it is registering correctly at the time).

C.3.1.5 Procedures

Procedures, or instructions for performing actions, improve human performance by doing the following:

- assisting personnel to diagnose the type of event that may be occurring and deciding on the required actions to respond to the event
- providing guidance for how to perform the required actions and verifying that they have been effective
- minimizing confusion that may result from conflicting signals, including spurious actuations, or other factors.

Written and maintained plant procedures must be available to cover all credited manual actions. Written procedures should describe what needs to be done (including interpretation of cues), how and where the actions should be performed, and what tools or equipment should be used.

If procedures are not available to guide a manual action, the action should be considered infeasible, except when a strong case can be made that performing the steps required to complete the manual action are “skill-of-the-craft.”³

In addition to being available, procedures should be technically accurate, comprehensive, explicit, easy to use, and validated. Personnel should be trained to implement the procedures. If the expected conditions in which the procedures will be used make it difficult or impossible to read the procedure, personnel should either be trained to perform the steps

³ “Skill of the craft” is a term describing those tasks in which it is assumed that the workers know certain aspects of the job and need no written instructions (e.g., a plumber replacing a washer in a faucet) (Ref. C11).

from memory or provisions should be made to communicate the procedure steps to the individuals performing them.

The PSF for procedures may affect both the cognition and execution portions of a manual action. Based on the considerations described above, the PSF for procedures should be categorized using the following scheme:

- Nominal – Procedures support performance of the action, in that they:
 - identify parameters to monitor and criteria that trigger action
 - are sufficiently comprehensive to apply to the range of circumstances associated with flooding events
 - are technically accurate and up to date
 - are written at a sufficient level of detail for the expected users
 - are accessible, easy to understand and easy to use in the circumstances of expected use, and
 - they have been validated
- Degraded – The procedures PSF should be considered degraded if:
 - procedures do not exist
 - procedures have been damaged or destroyed
 - procedures are not easily available
 - procedures are incomplete (e.g., precautions, warnings and notes are missing)
 - procedures have not been validated
 - procedures do not apply to the circumstances at hand
 - special equipment is needed to read or communicate the instructions
 - the level of detail assumes training that all potential users may not possess, or
 - aspects of formatting, terminology or sentence structure in the procedure make it difficult to comprehend

C.3.1.6 Training and Experience

Personnel performing required manual actions should have been trained in their individual responsibilities for performing the actions and had opportunities to practice. In evaluating the effectiveness of training, the following factors should be considered:

- Training should establish familiarity with procedures and required actions including operation of any special equipment.
- Training should engender familiarity with potential adverse conditions arising from a flood event (e.g., dangerous weather).
- Training should prepare personnel to handle departures from the expected sequence of events.
- Training should provide the opportunity to practice the skills required to accomplish the manual action (e.g., construction of barriers using special equipment).

Training and experience may take on added importance for flood protection actions because it may be necessary to call additional personnel to the site to establish flood protection features. These additional personnel may be unfamiliar with the layout of the site, as well as the rigor and procedural adherence expected of personnel in the nuclear industry.

Based on the considerations described above, the PSF for training and experience should be evaluated as follows for ex-control room actions:

- Nominal—Specific training has been provided on the affected SSCs and relevant indicators, procedures, tools and special equipment to be used in flooding events. Opportunities to practice the actions have been provided to ensure that individuals are proficient with the actions to be performed in a flooding event and have been exposed to abnormal conditions.
- Degraded (or low) —No specific training was provided before the flooding event on the affected SSCs and relevant indicators, procedures, tools, special equipment or action sequence. This level of training and experience does not ensure that individuals have the knowledge and skills required to adequately perform the required tasks; does not provide adequate practice in those tasks; or does not expose individuals to various abnormal conditions.

Based on the considerations described above, the PSF for training and experience should be evaluated as follows for in-control room actions:

- Nominal —Training is provided in accordance with licensed operator requalification program requirements as required by 10 CFR 55.59(c) and includes training for flooding scenarios.
- Degraded (or low) —Training should be considered degraded (low) if any of the following apply:
 - Training on the action or a specific topic of importance to the action is not provided.
 - Training content is incomplete, incorrect, out-of-date, or otherwise less than adequate.
 - The systems approach to training (e.g., job or task analysis, definition of knowledge, skills, and abilities, task qualification process) was not used to ensure that the worker could successfully perform the task in actual job conditions.
 - Assumptions about “skill-of-the-craft” appear to be incorrect (e.g., all operators do not have the experience assumed regarding the action being reviewed).
 - Simulator training is:
 - incomplete (e.g., it does not simulate the failure of a particular device, or include a particular scenario),
 - inaccurate (e.g., it does not match the actual plant or system response), or
 - the simulator is not used for training even though it is capable of being used.
 - Personnel are not familiar with the tools required to perform the action.

C.3.1.7 Perceived Workload, Pressure and Stress

Perceived workload, pressure and stress refer to the extent to which a crew or individual experiences time pressure from the need to perform the action in the available time along with their overall sense of being threatened in some way with respect to what they are trying to accomplish. Stress may also arise from existing or potential conditions that may affect an individual’s physical well-being (e.g., exposure to an unfamiliar hazard) or that of others

(e.g., family members possibly being in danger, the potential for radioactive release). High workload, time pressure, and stress are generally thought to have a negative impact on the performance of crews or individuals (particularly if the task being performed is considered to be complex).

The impact of these factors should be carefully considered in the context of the scenario and that of the other PSFs thought to be relevant. For example, if the scenario is familiar, procedures and training are very good, and the crews or individuals typically implement their procedures well within the available time, relatively high expected levels of workload, time pressure and stress may not have a significant impact on performance. Alternatively, if the scenario is unfamiliar, the procedures and training for the scenario are considered only adequate, and the time available to complete the action has been significantly shortened because of flooding, then workload, time pressure and stress may have a significant adverse impact on performance.

Several individuals or crews, as applicable, should be interviewed independently to estimate the extent to which workload, pressure and stress could affect performance of the action.

Based on the considerations described above, the PSF for workload, pressure and stress should be categorized using the following scheme:

- Nominal—A level which is conducive to good performance, or at least, is not disruptive.
- Moderate —Personnel experience unusual levels of workload, time pressure and stress that may cause them to narrow their focus or have difficulty focusing. Moderate levels of stress are more likely to occur when the onset of the event is sudden and unfamiliar or the situation persists for long periods. Stress will also increase if the individual or crew has previously made an error or believes that they made an error.
- Degraded—A level at which the performance of most people will deteriorate. This level may be associated with sudden onset and rapidly degrading conditions, as well as a feeling of threat to one's own life or to others' safety and well-being.

C.3.1.8 Environmental Factors

The environmental conditions at the location where an action is performed may affect an individual's physical or mental performance. As a result, an individual's capability to perform the required actions may be degraded or precluded. The expected environmental conditions should be considered at both the locations where the manual actions will be performed and along the access and egress routes. Personnel performance can be degraded, if not precluded, by adverse environmental conditions in reaching the location. In addition, personnel may be unable to perform the action in the conditions existing at the location. The environment along the egress route after completion of the action should also be considered to ensure personnel health and safety.

Environmental conditions associated with flooding events that could impair performance include the following:

- adverse weather (e.g., lightning, hail, wind, precipitation)
- temperatures (e.g., humidity, air and water temperatures, particularly if personnel must enter water)

- conditions hazardous to the health and safety of personnel (e.g., electrical hazards, hazards beneath the water surface, drowning, structural debris)
- lack of lighting
- radiation
- noise
- vibration

NUREG/CR-5680, “The Impact of Environmental Conditions of Human Performance,” issued in 1994 (Ref. C9) describes the impacts of temperature, lighting, noise and vibration on cognitive and physical performance and the levels at which these environmental factors cause performance degradations.

The licensee should consider the presence and severity of *each* of these environmental factors in evaluating the cognitive and execution elements of the manual action. For each environmental factor, the evaluation should categorize the factor using the following scheme:

- Nominal —The environmental factor is at a level unlikely to affect performance or personnel are highly familiar with and experienced in performing actions under the expected conditions.
- Degraded —The environmental factor is present and at a level likely to challenge successful performance; multiple adverse environmental factors co-exist at the location for performance; or, the conditions prevent performance of the action altogether. Environmental conditions that could prevent performance of an action include those that present a threat to life-safety or a significant risk to the health and safety of personnel performing the action.

Determine the appropriate overall category for environmental factors by using the worst case category among the individual factors.

C.3.1.9 Special Fitness Issues

Manual actions for flood protection or mitigation may require special types of fitness or involve fitness-for-duty issues related to fatigue. Special physical fitness requirements could include, for example, having the strength and agility to climb up or over equipment to reach a device because the flood has caused the ideal travel path to be blocked; needing the strength to move equipment and connect cables, especially if using a heavy or awkward tool; or having the stamina to use special purpose gear, which is physically demanding and hinders communication.

Fitness-for-duty issues related to fatigue include any personal factors that impair an individual’s ability to safely and competently perform the required manual actions. For example, fatigue may become problematic if workload prevents the management of acute fatigue or individuals accrue cumulative fatigue over extended periods of high work hours and limited sleep. Long and continuous work hours cause mental, as well as physical impairment. It is appropriate to determine how long a specific individual (worst-case and nominal schedules) could be on shift for the duration of the flood scenario under both the restrictions of the current fatigue management plan and under an exemption, if the licensee plans to request one.

For each special fitness issue identified, the licensee should determine whether it adversely affects cognition, execution, or both. Based on the considerations described above, the PSF for special fitness needs should be categorized using the following scheme:

- Nominal—Special fitness needs are not a barrier to performance of the action and sufficient personnel are available who are physically capable of performing the task.
- Degraded—Special fitness needs make the task difficult to perform, few or no personnel are physically capable of performing the task, or sources of impairment (e.g., acute or cumulative fatigue, illness) may adversely affect performance.

C.3.1.10 Staffing

In assessing the feasibility of a manual action, the persons performing the action should be qualified. In particular, the evaluation should consider whether the action requires a licensed operator or whether other special qualifications are required. The feasibility assessment should consider the availability of a sufficient number of trained personnel without collateral duties during a flood event such that the required manual action can be completed as needed. Required staff may be normally on site or available from offsite, if sufficient warning time is available and the flood event does not inhibit access to the site. Consideration should be given to whether task assignments (or task loads) subject one or more workers to excessive physical or mental stress or if concurrent tasks challenge the ability of the person to perform as required. Additional considerations include both normal staffing and minimum staff requirements associated with technical specifications. If there are insufficient qualified personnel to complete the action (considering actions that must be performed concurrently), the licensee should consider the action to be infeasible.

Based on the considerations described above, the PSF for staffing should be evaluated using the following categorization scheme:

- Nominal staffing —Sufficient qualified personnel to perform the required activities are either: 1) on site; or 2) available offsite with sufficient warning time to arrive on site and the event does not inhibit site access. The availability of qualified personnel to perform all concurrent (simultaneously) required activities is also taken into account.
- Degraded (insufficient) staffing —Insufficient qualified personnel are available to perform the required action.

C.3.1.11 Communications

Equipment (e.g., two-way radios) may be required to support communications between personnel to ensure the proper performance of manual actions (e.g., to support the performance of sequential actions, to verify procedural steps). In addition, because of the long durations of many flooding scenarios and because of the possible need of offsite support, communications with corporate and governmental organizations is important. Therefore, the evaluation should consider the flood's impact on offsite communications. Because there may be substantial warning time preceding some flood mechanisms, efficient communications may be less important when evaluating the feasibility of manual actions associated with preemptive protective measures. However, mitigation may require actions for which the time available to diagnose, perform, and confirm actions is short. Communication methods should be checked to ensure prevailing conditions do not challenge their effectiveness. The availability of alternate means of communications, if the planned communications system fails, should also be evaluated. Consideration should be

given to whether personnel are trained to operate the equipment that is planned to be used as well as alternatives and whether there is feedback in the control room to indicate that portions of communication systems may not be functional because of flooding or wind damage. Training should ensure effective communications and coordination during a flood event.

Based on the considerations described above, the PSF for communications should be evaluated using the following categorization scheme:

- Nominal—The flooding event does not adversely affect communications (both on site and off site).
- Degraded—The lack of, the poor quality of, or likely failures of the communications process or equipment negatively affect performance (e.g., too much static, insufficient number of radios or radiofrequencies to support the amount of work, no diversity and redundancy designed into the system).

C.3.1.12 Accessibility

Accessibility of the site and the locations in which manual actions must be performed are uniquely important for flood-related manual actions. Site accessibility for staff augmentation and replenishment of consumables should not be assumed in the evaluation of manual actions. For example, a rapid-onset flooding event on the backshift could require the establishment of temporary flood protection features or performance of manual actions associated with mitigation with only minimal staff available. Roads may become impassible. Severe weather conditions may impact the communications infrastructure causing significant delays in calling out any additional laborers needed. Site inaccessibility issues could also require sequestering personnel, which may create fitness-for-duty issues related to fatigue if conditions for sleeping and eating are uncomfortable or additional stress results from worry about personal property and family members.

The accessibility of locations at which actions must be performed is particularly important when evaluating manual actions that must be performed after the onset of flood conditions and throughout the duration of the flood event. The evaluation of accessibility requires the consideration of the travel path required for manual actions given the location of the flood waters and associated effects and how the flood might compromise such accessibility. Other accessibility issues include obstructions (e.g., charged fire hoses) and locked doors. In particular, the flood may cause electric security systems to fail locked. In this case, personnel will need to obtain keys for access. Doors that are normally locked should also be considered.

Inundation of an area and the equipment located there will create unique PSFs. Actions that must be performed in inundated areas or requiring personnel or equipment or both to travel through inundated areas, should be considered infeasible unless it can be shown that elevated pathways or other means are available to enable movement through the inundated areas and significant hazards to personnel (e.g., electrical hazards due to presence of water, low temperatures) are not present.

Based on the considerations described above, the PSF for accessibility should be evaluated using the following categorization scheme:

- Nominal—The location(s) can be reached easily and conditions are such that the action can be performed.

- Degraded (inaccessible) —Conditions reduce the accessibility of the site or the location at which the action is performed or one or more of the required actions is in a location that the personnel will not be able to reach because of the flood.

C.3.1.13 Scenario-Specific PSFs

In addition to the PSFs listed above, performance of a manual action may be affected by unique PSFs that are specific to the flood scenario in which the action is required. For example, safety culture issues may have a larger influence in some scenarios. Decisionmaking may be delayed if actions have high occupational safety, public health and safety, or economic consequences. This is particularly important if roles and responsibilities for these decisions have not been clearly defined in advance. On the other hand, weaknesses in the licensee's safety conscious work environment within some work groups could prevent individuals from raising concerns or offering information about a planned course of action that is necessary to ensure its success. Accessibility of locations, equipment, resources, and personnel will vary among scenarios, and is an important consideration. Scenario-specific PSFs should be added to the list of PSFs above and evaluated, as appropriate.

C.3.2 Timing Analysis

Figure C1 provides a framework for conducting a timing analysis of a manual action to evaluate whether the time available to perform the action is greater than the time required to complete it. The figure comprises several elements to capture the various aspects of timing during the period of time between when conditions exist that will require an action until the time at which the action is no longer beneficial.

C.3.2.1 Timing Elements

The following terms are associated with each timing element:

- T_0 = start time, or the point in time in a flooding scenario or HFE narrative at which the conditions exist that will require the human action (e.g., a weather forecast predicts excessive precipitation, a dam failure occurs, a levee onsite is overtopped, leakage develops)
- T_{delay} = time delay, or the duration of time it takes for the cue to become available that the action will be necessary (assumes that action will not be taken in the absence of a cue)
- T_{sw} = the time window within which the action must be performed to achieve its objective
- T_{avail} = the time available for action = $(T_{\text{sw}} - T_{\text{delay}})$
- T_{cog} = cognition time, consisting of detection, diagnosis, and decisionmaking
- T_{exe} = execution time including travel, collection of tools, donning of PPE, and manipulation of relevant equipment
- T_{reqd} = time required, or the time required for an individual or crew to accomplish the action = $(T_{\text{cog}} + T_{\text{exe}})$

C.3.2.2 Developing Timing Element Values

It is likely that some flooding scenarios that involve manual actions will not have been analyzed previously. As a result, it will be necessary to develop values for these timing elements based on the best available information.

The values used for T_{sw} , T_{delay} and T_{avail} should be established based on evaluations performed for other parts of the integrated assessment. Uncertainties in these values should be documented and the basis for the values used to perform the timing analysis should be justified.

Values for T_{reqd} ($T_{cog} + T_{exe}$) can be developed using several methods. Simulations of the action in the field will provide the most reliable baseline timing estimates. Individuals who would have to perform the action should perform the simulations and timing data should be collected from repeated simulations involving different individuals or crews to assess variability. Reasonable simulations performed under the flood walkdowns (See Section 9 for the definition of reasonable simulation) may also provide a useful source of information.

Prior experience with tasks or subtasks similar to the actions being evaluated may provide valuable insights for developing estimates of the time required to perform an action. For certain actions (e.g., actions performed in the MCR), information about manual actions may be available from the plant-specific Individual Plant Examination (IPE) and Individual Plant Examination of External Events (IPEEE), existing procedures, controlled system descriptions, and training documents. Plants that have a Time-critical Action Program (a configuration control program that validates and protects time-critical actions from inadvertent changes) may use timing information from that program when it is relevant to the scenario being evaluated. Timing data used from other analyses should be supplemented with information about the similarities and differences between those actions and the flooding manual action being evaluated.

Interviews with personnel who will perform the action can also be used to provide timing estimates. Maintenance personnel, operators, trainers, and other knowledgeable plant staff should be involved. Ideally, the licensee should interview those who would have to perform the action (or set of actions). More than one expert should be involved to obtain more than one opinion about the timing for the actions being examined in obtaining the estimate.

It may not be possible to collect actual baseline values for some actions because, for example, it is not safe or reasonable to place equipment in the expected condition (e.g., partially inundated) or expose personnel to anticipated hazards. In these cases, it may be possible to simulate the actions using mockups. Expert elicitation techniques may also be used to estimate timing values, as described in Appendix B to NUREG-1852, "Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire," issued October 2007 (Ref.C1), or other available guidance for performing HRA (e.g., NUREG-1880, "ATHEANA User's Guide," issued in 2007 (Ref. C10)).

Values for T_{reqd} should be increased above performance times required under nominal conditions to account for the impact of the perceived workload, time pressure and stress PSF, if it is categorized as having a moderate adverse effect on performance but does not meet the "degraded" criterion. The basis for the amount of time by which T_{reqd} is increased above performance time required under nominal conditions should be documented.

C.3.2.3 Account for Uncertainty and Human Performance Variability

Estimates of time available and time required should account for sources of uncertainty and human performance variability. The estimates should be bounding values such that:

- The estimated time available is the least amount of time available to perform the action, considering uncertainties and human performance variability.

- The time required is the greatest amount of time required to perform the action, considering uncertainties and human performance variability.

The following sources of uncertainty are inherent in estimating the time available for an action and the time required to complete it:

- Variations may occur in the nature of the flooding scenario and related plant conditions that were not specified in the scenario, but could affect the time estimates (e.g., fast energetic flooding that fails equipment quickly versus slowly developing flooding with few or no equipment failures for some time, or flooding in unanticipated locations).
- Factors that cannot be recreated in a simulation, or are not anticipated for an actual flooding situation could cause further delay in performing the actions (i.e., where the reasonable simulation may likely fall short of actual flooding situations), as in the following examples:
 - Personnel may need to recover from or respond to unexpected difficulties, such as problems with instruments or other equipment (e.g., locked doors, a stiff hand wheel, or difficulty with communication devices).
 - Environmental and other effects might exist that are not included as part of the simulation, such as:
 - radiation (e.g., the flood could reasonably damage equipment in a way such that radiation exposure could be an issue at the location in which the action needs to be taken, requiring personnel to don PPE, which takes extra time, but which may not be included in the demonstration)
 - effects of equipment inundation which are not likely to be actually simulated
 - increased noise levels from the flooding itself, the operation of pumps, and personnel shouting instructions
 - water in areas that may delay personnel movements
 - obstruction from charged hoses
 - too many people in one location provide obstacles to performance
 Though all of the above may not actually be simulated, they should be considered as possible (and perhaps even likely), when determining the time it may take to perform a human action in a real situation.
 - The simulation might be limited in its ability to account for (or envelop) all possible flooding locations where the actions are needed and for all the different travel paths and distances to where the actions are to be performed. A similar limitation is that the current location and activities of needed plant personnel when the flooding occurs could delay their participation in executing the human action. The intent of the evaluation is not to address temporary or infrequent situations but to account for those that are typical and may impact the timing of the action.
 - It may not be possible to execute relevant actions during the demonstration because of normal plant status and safety considerations while at power (e.g., personnel cannot actually operate the valve using the hand wheel, but can only simulate doing so).

- Typical and expected variability between individuals and crews may lead to variations in personnel performance (i.e., human-centered factors), as in the following examples:⁴
 - physical size and strength differences that may be important for the desired action
 - cognitive differences (e.g., memory ability, cognitive style differences)
 - different emotional responses to flooding (e.g., fear of water, concern for family and personal property)
 - different responses to wearing any PPE required
 - differences in individual sensitivities to “real-time” pressure
 - differences in team characteristics and dynamics

A tradeoff exists between the extent to which the feasibility assessment is realistic and the amount of uncertainty to be accounted for in the estimate of time required to perform an action. For instance, more realistic demonstrations of feasibility (e.g., systematic walkthroughs while simulating flood conditions) translate to less uncertainty with regard to justifying the time required to complete an action. Similarly, gathering information from a larger number of simulations with additional personnel can increase the confidence that estimated completion times bound expected variability in human performance.

C.3.2.4 Calculate Time Margin

The licensee should calculate the time margin available for the action using the values for time available and time required that have been developed for the analysis. Time margin is defined as the ratio of the difference between time available and time required ($T_{\text{cog}}+T_{\text{exe}}$) to the time required to perform the action and is calculated as follows:

$$\text{Time Margin} = \left[\frac{T_{\text{avail}} - T_{\text{reqd}}}{T_{\text{reqd}}} \right] \times 100\%$$

OR, as expanded:

$$\text{Time Margin} = \frac{[(T_{\text{sw}} - T_{\text{delay}}) - (T_{\text{cog}} + T_{\text{exe}})]}{(T_{\text{cog}} + T_{\text{exe}})} \times 100\%$$

C.3.2.5 Determine Whether the Time Margin Supports a Conclusion that the Manual Action is Feasible

For an action to be feasible, the time available must be greater than the time required when using bounding values that account for estimation uncertainty and human performance variability. This means that using the calculation under C.3.2.4, the margin must be a positive percent value for an action to be deemed feasible.

C.4 Determine Whether the Action is Reliable

For an action to be deemed reliable, sufficient margin should exist between the time available for the action and the time required to complete it. This margin should account for:

⁴ Given the likely experience and training of plant personnel performing the actions, it need not be assumed that these characteristics would lead to major delays in completing the actions, but their potential effects should be considered in the specific flood-related context of the actions being performed, to confirm this assumption.

(1) limitations of the analysis (e.g., failure to identify factors that may delay or complicate performance of the manual action); and (2) the potential for workload, time pressure and stress conditions to create a non-negligible likelihood for errors in task completion. One acceptable method for assessing the adequacy of the time margin is to establish that the time margin is equal to or greater than the maximum recovery time for any single credible human error. Event trees may be used to identify potential errors, error detection methods, and error recovery paths for the purpose of determining the adequacy of the margin. A simplified alternative criterion for determining if the margin is adequate to deem an action as reliable is to establish that the margin is not less than 100%. Such a margin may be justified when recovery from an error in performing the action could be accomplished by restarting the task from the beginning. The basis for the specific time margin used in the analysis should be justified and documented.

C.5 Adjustments

If the results of the feasibility and reliability evaluations indicate that a manual action cannot be performed or cannot be performed reliably, it may be possible to modify the nature of the task or aspects of the context in which it must be performed. Examples of adjustments could include changing the anticipated pathway by which personnel will move to the location at which the action must be performed, relocating equipment, adding resources stationed on site, developing procedures and providing training on them, or predetermining decision criteria and command and control authorities for actions with significant potential worker or economic consequences. The integrated assessment should document planned adjustments to ensure the feasibility and reliability of manual actions, as well as the basis and justification for a conclusion that the adjustments will lead to acceptable human performance.

C.6 Documentation

Documentation of the evaluation of human actions should include the following for each action:

- the HFE narrative (described in Section C.2 of this appendix).
- a description of the sources of information used for the evaluation and justification of their applicability to the action
- a detailed description justifying the categorization of all PSFs as well as a summary of the PSF evaluations, to be documented as shown in Table C1.
- a detailed description of the timing analysis including the following:
 - the calculated time margin for completing the action
 - the values used for each timing element in Figure C1 and justification for the values used
 - a description of how uncertainties in the values used for the timing analysis were addressed
 - a description of the methods (e.g., simulation, talkthroughs, walkthroughs, mockups, expert elicitation) used to develop and adjust the values for the timing elements in Figure C1 for each action, including the qualifications and experience levels of the subject matter experts involved in collecting or estimating the timing information, and the number of times each action was simulated to develop the timing estimates or the number of experts who provided independent estimates

- a detailed description of and justification for a conclusion that an action is feasible despite the presence of any degraded PSF and the timing analysis that demonstrates feasibility, if applicable.
- a detailed justification for the determination of whether an action is reliable, including:
 - a description of how available time margin accounts for: (1) limitations of the analysis; and (2) the potential for workload, time pressure and stress conditions to create a non-negligible likelihood for errors in task completion
 - the basis for the acceptability of the calculated margin
- a detailed description and analysis of planned adjustments to assure the feasibility and reliability of manual actions and the basis/justification for concluding the adjustment(s) will be effective.

C.7 References

- C1. U.S. Nuclear Regulatory Commission, "Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire," NUREG-1852, October 2007, ADAMS Accession No. ML073020676.
- C2. U.S. Nuclear Regulatory Commission, "EPRI/NRC-RES Fire Human Reliability Analysis Guidelines," NUREG-1921, July 2012, ADAMS Accession No. ML12216A104.
- C3. Electric Power Research Institute, "An Approach to the Analysis of Operator Actions in Probabilistic Risk Assessment," TR-100259, Palo Alto, CA, 1992.
- C4. Electric Power Research Institute, "Systematic Human Action Reliability Procedure (SHARP) Enhancement Project: SHARP 1 Methodology Report," TR-101711, Palo Alto, CA, 1992.
- C5. U.S. Nuclear Regulatory Commission, "Human Factors Engineering Program Review Model," NUREG-0711, Revision 2, February 2004.
- C6. U.S. Nuclear Regulatory Commission, "Technical Basis and Implementation Guidelines for A Technique for Human Event Analysis (ATHEANA)," NUREG-1624, Revision 1, May 2000, ADAMS Accession No. ML003719212.
- C7. U.S. Nuclear Regulatory Commission, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition - Severe Accidents," NUREG-0800, Section 19.0: Probabilistic Risk Assessment and Severe Accident Evaluation for New Reactors, Revision 2, June 2007.
- C8. U.S. Nuclear Regulatory Commission, "Human-System Interface Design Review Guidelines," NUREG-0700, Revision 2, May 2002, ADAMS Accession No. ML021700373.
- C9. D. Echeverria, et al., "The Impact of Environmental Conditions of Human Performance," NUREG/CR-5680, September 1994, ADAMS Accession No. ML071210164.
- C10. U.S. Nuclear Regulatory Commission, "ATHEANA User's Guide," NUREG-1880, June 2007, ADAMS Accession No. ML071770660.

C11. Swain, A.D., H.E. Guttmann, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications," NUREG/CR-1278, August 1983, ADAMS Accession No. ML071210299.

Table C1: Documentation of Performance Shaping Factors

PSFs	PSF categories	Applicable category	Summary of justification
Cues and indications	Nominal	<input type="checkbox"/>	
	Degraded	<input type="checkbox"/>	
Complexity	Nominal	<input type="checkbox"/>	
	Degraded	<input type="checkbox"/>	
Special equipment	Nominal	<input type="checkbox"/>	
	Degraded	<input type="checkbox"/>	
Human-system interfaces	Nominal	<input type="checkbox"/>	
	Degraded	<input type="checkbox"/>	
Procedures	Nominal	<input type="checkbox"/>	
	Degraded	<input type="checkbox"/>	
Training and experience	Nominal	<input type="checkbox"/>	
	Degraded (low)	<input type="checkbox"/>	
Workload, pressure, and stress	Nominal	<input type="checkbox"/>	
	Moderate	<input type="checkbox"/>	
	Degraded	<input type="checkbox"/>	
Environmental factors (may require multiple entries)	Nominal	<input type="checkbox"/>	
	Degraded	<input type="checkbox"/>	
Special fitness issues	Nominal	<input type="checkbox"/>	
	Degraded	<input type="checkbox"/>	
Staffing	Nominal	<input type="checkbox"/>	
	Degraded	<input type="checkbox"/>	
Communications	Nominal	<input type="checkbox"/>	
	Degraded	<input type="checkbox"/>	
Accessibility	Nominal	<input type="checkbox"/>	
	Degraded	<input type="checkbox"/>	
Scenario-specific PSFs	<i>added as appropriate</i>		

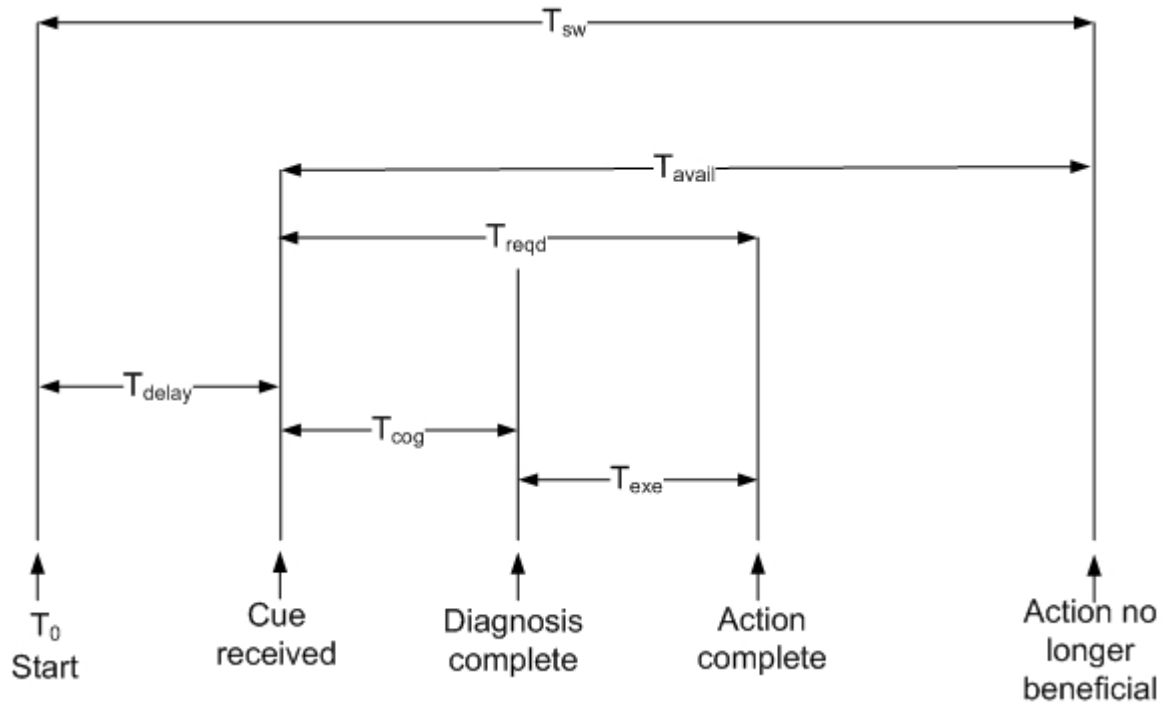


Figure C1: Framework for Conducting a Human Action Timing Analysis

APPENDIX D: Existing References and Resources

The goal of this appendix is to provide brief descriptions and discussions of existing assessments of external flood risk at nuclear power plants. These references may provide useful resources and insights for performance of certain aspects of the integrated assessment. However, the references provided here are for information only and this appendix does not necessarily endorse the specific approaches used in the external flood risk studies referenced here and these references do not supersede the guidance contained in this interim staff guidance.

D.1 Evaluations Performed under Task Action Plan A-45

The objectives of Task Action Plan (TAP) A-45 was initiated to evaluate the safety adequacy of decay heat removal systems in existing light water reactor nuclear power plants and to assess the value and impact of alternative measures for improving the overall reliability of the decay heat removal function. Probabilistic risk assessment (PRA) and deterministic evaluations were used to evaluate decay heat removal systems and support systems required to achieve hot standby and cold shutdown. The program analyzed the following six plants:

- Arkansas Nuclear One-1 (Ref. D1)
- Point Beach (Ref. D2)
- Quad Cities (Ref. D3)
- St. Lucie (Ref. D4)
- Turkey Point (Ref. C5)
- Cooper (Ref. D6)

It was beyond the scope of TAP A-45 to perform an in-depth PRA. The objective was to conduct an analysis that quantified the significant threats to the plant. The authors indicate that the analysis performed “embodies the basic philosophy of a full scope probabilistic risk assessment.” As such, in many cases, the scope of the TAP A-45 evaluations may be more limited than the evaluations required by the integrated assessment and TAP A-45 did not consider all facets pertaining to the integrated assessment.

To evaluate the frequency of plant damage due to external flooding, the following five tasks were performed:

- plant familiarization
- hazard analysis
- fragility analysis
- systems analysis
- risk quantification

There are necessary differences in the specific methodologies and techniques used to evaluate external flood risk at each site. The summary provided in this appendix is intended to provide a general overview of what was done at the sites and not all parts may be explicitly used at a given site.

The purpose of plant familiarization (Step 1) was to gather information on the occurrence of external hazards and the vulnerability of plant structures and equipment to flooding (e.g., plant location and flood hazard, plant design basis, and vulnerable structures and equipment). The hazard analysis (Step 2) was performed in two steps: (1) screening; and

(2) evaluation the frequency of occurrence. Because of the differences in flood hazard at each site, TAP A-45 used site-specific approaches to assessing flood hazard. Fragility analysis (Step 3) was performed for structures and equipment vulnerable to the effects of external flooding. A conservative approach was used in developing capacities of structures and equipment to resist external flood loads. An approach was used that is similar to that used in seismic applications. Fragility functions were typically computed with respect to hydrostatic loads and did not consider both flood height and associated effects, as required under the integrated assessment. Systems analysis (Step 4) involved evaluation of response of the plant to safety system failures. The systems analysis describes the component and system failures resulting from external flooding and associated effect on plant functions. Simple functional event trees were used to model the plant response to external flooding. Risk was quantified (Step 5) by determining core melt probability using system failure information and the functional event tree developed under step 4. The core melt frequency is determined by consideration of flood frequency and conditional core melt probability given an external flood event.

D.2 NUREG/CR-5042, Evaluation of External Hazards to Nuclear Power Plant in the United States

NUREG/CR-5042, "Evaluation of External Hazards to Nuclear Power Plants in the United States," December 1987 (Ref. D7) investigates the effect of external hazards on nuclear power plants in the United States. The objective of the work was to understand whether external initiators (internal fires, high winds and tornados, external flood and transportation accidents) are among the major potential accident initiators. NUREG/CR-5042 documents a review and evaluation of what was known (at the time) about the risk of core-damage accidents and potential for large radiological release as a result of external floods. The report uses two figures of merit as evaluation criteria: (1) mean core damage frequency less than 1×10^{-5} , and (2) frequency of large early release less than 1×10^{-6} . NUREG/CR-5042 provides a review of U.S. Nuclear Regulatory Commission's regulatory approach, the general design criteria found in Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities"; Appendix A, "Evaluation Factors for Stationary Power Reactor Site Applications Before January 10, 1997 and for Testing Reactors," to 10 CFR Part 100, "Reactor Site Criteria"; NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR [light-water reactor] Edition., regulatory guides, papers and reports, selected plant specific documents, and PRA literature on flooding a nuclear power plants. Reviewed literature includes the following sources:

- Indian Point probabilistic safety study, 1983
- probabilistic risk assessment, Limerick Generating Station, 1981
- severe accident risk assessment, Limerick Generating Station, 1983
- Millstone Unit 2 probabilistic safety study, 1983
- Probabilistic risk assessment of Oconee Unit 3, 1984
- Zion probabilistic safety study, 1982
- studies performed under TAP A-45, 1987 (see Section D.1)

NUREG/CR-5042 summarizes the above references and offers conclusions based on available literature. The report also describes a proposed approach for plant evaluation of external flood risk. The approach involves evaluation of the frequency of large flood events and contingent likelihood of an accident scenario given a large flood. Bounding analysis is

suggested as a mean to easily demonstrate that the figures of merit are met. If a probabilistic bounding assessment cannot demonstrate that risk is acceptably low (i.e., figures of merit are met) then a more extensive plant response analysis is required (e.g., through a full-scope PRA).

D.3 Individual Plant Examination of External Events Program

External flooding was evaluated under the Individual Plant Examination of External Events (IPEEE) Program. NUREG-1742, "Perspectives Gained from the Individual Plant Examination of External Events (IPEEE) Program," April 2002 (Ref. D8) documents the perspectives gained as a result of the review of the IPEEE submittals. The report observes that under the IPEEE program, 12 submittals reported the contribution of core damage frequency from external flooding. Typically, submittals treated external flooding as leading to a loss of offsite power (typically assumed unrecoverable) with additional random failures that could lead to core damage. Some submittals considered additional flood-induced damage (e.g., loss of intake structure, failures of diesel fuel oil transfer pumps, as well as failures of safety-related equipment in the diesel generator, auxiliary, and turbine buildings). The majority of sites used a qualitative screening rather than a PRA to evaluate external flooding under the IPEEE program (Ref. D8).

D.4 References

- D1. W.R. Cramond, et al., "Shutdown Decay Heat Removal Analysis of a Babcock and Wilcox Pressurized Water Reactor," NUREG/CR-4713, March 1987.
- D2. W. R. Cramond, et al., "Shutdown Decay Heat Removal Analysis of a Westinghouse 2-Loop Pressurized Water Reactor," NUREG/CR-4458, March 1987.
- D3. S.W. Hatch, et al., "Shutdown Decay Heat Removal Analysis of a General Electric BWR3/Mark I," NUREG/CR-4448, March 1987.
- D4. W.R. Cramond, et al., "Shutdown Decay Heat Removal Analysis of a Combustion Engineering 2-Loop Pressurized Water Reactor," NUREG/CR-4710, August 1987.
- D5. G.A. Sanders, et al., "Shutdown Decay Heat Removal Analysis of a Westinghouse 3-Loop Pressurized Water Reactor," NUREG/CR-4762, March 1987.
- D6. S.W. Hatch, et al., "Shutdown Decay Heat Removal Analysis of a General Electric BWR4/Mark I," NUREG/CR-4767, July 1987.
- D7. Kimura, C.Y., R.J. Budnitz, "Evaluation of External Hazards to Nuclear Power Plants in the United States," NUREG/CR-5042, December 1987.
- D8. U.S. Nuclear Regulatory Commission. "Perspectives Gained From the Individual Plant Examination of External Events (IPEEE) Program," NUREG-1742, April 2002, ADAMS Accession No. ML021270132.