



# REGULATORY GUIDE

## REGULATORY GUIDE 1.127

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# CRITERIA AND DESIGN FEATURES FOR INSPECTION OF WATER CONTROL STRUCTURES ASSOCIATED WITH NUCLEAR POWER PLANTS

## A. INTRODUCTION

### Purpose

This regulatory guide (RG) describes a method that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for designing water control structures (e.g., dams, slopes, canals, reservoirs, and associated conveyance facilities) such that periodic inspections may be performed. In addition, this guide describes an acceptable inspection and monitoring program for water control structures. Water control structures include those used in the emergency cooling water system and those relied upon for flood protection.

### Applicable Rules and Regulations

- General Design Criterion (GDC) 45, “Inspection of Cooling Water System,” of Appendix A, “General Design Criteria for Nuclear Power Plants,” to Title 10 of the *Code of Federal Regulations*, Part 50, “Domestic Licensing of Production and Utilization Facilities” (10 CFR Part 50) (Ref. 1), requires, in part, that the cooling water system be designed to permit the appropriate periodic inspection of important components to ensure the integrity and capability of the system.
- Regulations in 10 CFR 50.34(a)(4) and 50.34(b)(4) require, in part, that each applicant for a nuclear power plant construction permit or operating license provide an analysis and evaluation of the design and performance of structures, systems, and components (SSCs) of the facility for the purpose of assessing the risk to public health and safety resulting from the operation of the facility.
- Multiple sections of 10 CFR Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants” (Ref. 2), including 10 CFR 52.47(a)(2), 52.79(a)(4), and 52.137(a)(3), state, in part, that the GDC in Appendix A to 10 CFR Part 50 establish the minimum requirements for the principal design criteria for water-cooled nuclear power plants. The regulations at 10 CFR 52.79(a)(29) state, in part, that an application for a combined license must contain a final safety analysis report that includes plans for the conduct of normal operations, including maintenance, surveillance, and periodic testing of SSCs.

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- Portions of 10 CFR 50.65, “Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants,” require that holders of an operating license of a nuclear power plant shall monitor the performance or condition of structures, systems, and components against licensee established goals in a manner sufficient to provide reasonable assurance that the SSCs are capable of fulfilling their intended functions.

### **Related Guidance**

- Regulatory Guide 3.11, “Design, Construction, and Inspection of Embankment Retention Systems at Uranium Recovery Facilities,” (Ref. 3) contains guidance for the design and construction of water control structures that may be useful in the development of design and inspection criteria for water control structures at nuclear power plants.
- NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” Section 2.5.4, “Stability of Subsurface Materials and Foundations,” provides general information concerning the stability of the subsurface of materials and foundations. Section 2.5.5, “Stability of Slopes,” of NUREG-0800 discusses the analysis procedures to evaluate the stability of slopes (Ref. 4).
- An ad hoc Interagency Committee on Dam Safety issued a report in 1979 titled “Federal Guidelines for Dam Safety” (currently identified as the Federal Emergency Management Agency (FEMA) publication 93, “Federal Guidelines for Dam Safety: Hazard Potential Classification System for Dams,” (Ref. 5) containing recommended safety guidelines for dam owners. This report undergoes periodic updating and some of the guidance in the report is applicable to the water control structures discussed in this RG.
- A facility’s technical specifications, as required by 10 CFR 50.36, “Technical Specifications,” may contain requirements for the inspection and monitoring of water control structures.
- The following NRC Inspection Procedures (IP) are identified to provide applicants and licensees useful insights when designing water control structures and developing inspection and monitoring programs. These NRC IPs contain guidance on NRC inspections of specific performance issues of risk-significant or safety related heat exchangers, heat sinks, dams, canals, embankments, intake and pump house structures, and other containment devices for the ultimate heat sink (UHS) that are directly or indirectly connected to service water systems.
  - NRC IP 71111.01, “Adverse Weather Protection,” (Ref. 6),
  - NRC IP 71111.06, “Flood Protection Measures” (Ref. 7),
  - NRC IP 71111.07, “Heat Sink Performance” (Ref. 8), and
  - NRC IP 62002, “Inspection of Structures, Passive Components, and Civil Engineering Features at Nuclear Power Plants” (Ref. 9).

### **Purpose of Regulatory Guides**

The NRC issues RGs to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency’s regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions that differ from those set forth in RGs will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

## **Paperwork Reduction Act**

This RG contains information collection requirements covered by 10 CFR Part 50 and 10 CFR Part 52 that the Office of Management and Budget (OMB) approved under OMB control numbers 3150-0011 and 3150-0151, respectively. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

## **B. DISCUSSION**

### **Reason for Revision**

Since the release of revision 1 of RG 1.127 in March 1978 the Federal guidelines for safety and inspection of dams and other water control structures have undergone significant revision. This RG is being updated to provide applicants and licensees with the most current guidance and allow them the opportunity to use modern testing equipment and processes when developing an inservice inspection and surveillance program for dams, slopes, canals, and other water-control structures associated with emergency cooling water systems or flood protection of nuclear power plants.

### **Discussion**

Nuclear power plants use dams, slopes, canals, and other water control structures and associated facilities, to impound, retain, and divert water sources for the reliable operation of emergency cooling systems. Failure of the water control structures to perform their functions could trigger flooding or result in a failure of the emergency cooling systems. Therefore, a high degree of reliable performance is necessary for safe plant operation. Dams and other water control structures should be maintained in good working order throughout their lives. Inspection and monitoring should be conducted in such a manner that changes in structural, hydraulic, and foundation conditions of the dam or other water control structure can be detected promptly. In addition, the design of features used for inspecting and monitoring these structures should be such that these activities can be performed following a design basis event.

According to the Association of State Dam Safety Officials (Ref. 10), the most common causes of dam and other water control structure failures are:

1. Overtopping caused by flooding, inadequate spillway design, debris blockage of spillways, or settlement of the dam crest account for approximately 34 percent of all failures.
2. Foundation defects, including settlement and slope instability, cause about 30 percent of all failures.
3. Seepage around hydraulic structures, such as pipes and spillways, through animal burrows, around roots of woody vegetation, and through cracks in dams, levees, and water control structures account for 20 percent of the failures.
4. The remaining 16 percent are the result of a variety of issues including structural failure, improper materials used in construction, and inadequate or improper maintenance.

In many cases, periodic inspection and monitoring programs could have identified the precursor conditions in time to take corrective action and avert some of the failures.

Thorough physical examination is an essential part of the inspection and monitoring program. The optimal frequency of inspections depends on the size, age, and condition of the facilities; the character of the foundation; and the regional geological setting. The potential impact the failure of the water control structure would have on the nuclear power plant or the proximity of the structure to populated areas should also be considered when formulating inspection periodicity.

The search for superficial signs of distress such as longitudinal and transverse cracks is only one phase of an inspection and monitoring program. Possible internal degradation may be probed by various portable instruments such as soniscopes, hydrophones, television, and borehole cameras. It is important that these observations be correlated closely with measurements from embedded devices, if available.

Embankments placed against or covered by structures are particularly vulnerable areas that should be monitored. They may be susceptible to internal erosion at the planes of contact. Attention should also be focused on the slopes of the reservoir behind the dam or levee where unstable terrain may be a problem. Early stages of slope failure may be manifested in various ways, including buckling of concrete and asphaltic linings, leaning of trees and poles, and cracking and bulging of walls. Thorough surveillance of suspected unstable areas is essential when disturbance could jeopardize the safety of the dam or water control structure. These areas require careful and frequent inspection, sometimes supplemented by periodic measurement of precise level and triangulation nets, reading of slope indicators or tilt meters, and study of aerial photographs.

Before filling a reservoir, records of piezometric levels, ground elevations, and background seismicity at the site should be compiled so that a comparison can be made with the effects of water loading. As soon as filling begins, inspection and monitoring should be performed. These activities should include regular patrol of the dam, water control structures and abutments; monitoring for seepage flows, changes in piezometric levels, and structural and foundation movements. These readings should be plotted and correlated with concurrent water levels. An increase in seepage flow and turbidity is a common symptom of piping as a result of impounded water penetrating and flushing out foundation openings.

Although the most critical time in the life of a reservoir may be during its first filling when the design is checked against actual performance, several years may pass before the foundation and structures have fully adjusted to the loads. Thereafter, deformation will continue in response to cyclical load conditions. Attention should be focused on inspection and data collection during relatively rapid changes in reservoir water surface elevations. In addition, year-to-year conditions at high and low seasonal levels should be compared. Data should also be collected on changes occurring since project construction that may influence the safety and function of the facilities. It is important that abnormalities affecting facility safety be corrected in a timely manner.

The service water channels should be examined for any conditions such as channel bank erosion, aggradations, or degradations that may impose constraints on the function of the cooling system and present a potential hazard to the safety of the plant. Submerged dams and emergency canals (e.g., artificially dredged canals at the river bed or the bottom of the reservoir) should be examined for any conditions (e.g., blockage caused by sedimentation, debris, or slope instability) that may impair the function of the canals under extreme low-flow conditions.

### **Harmonization with International Standards**

The International Atomic Energy Agency (IAEA) has established a series of safety guides and standards constituting a high level of safety for protecting people and the environment. IAEA safety guides present international good practices and increasingly reflects best practices to help users striving to

achieve high levels of safety. The following three IAEA safety standards contain guidance similar to the guidance in this RG.

1. IAEA Safety Guide NS-G-2.6, “Maintenance, Surveillance and In-Service Inspections in Nuclear Power Plants,” issued August 2002; (Ref. 11)
2. IAEA Safety Standard SSG-18, “Meteorological and Hazards in Site Evaluation for Nuclear Installations,” issued November 2011 (Ref. 12); and
3. IAEA Safety Standard NS-G-1.5, “External Events Excluding Earthquakes in the Design of Nuclear Power Plants,” issued November 2003 (Ref. 13).

While this RG does not endorse the identified IAEA guides, each of these IAEA safety guides describe the need for nuclear power plants to include inservice inspection and surveillance programs of SSCs whose failure could adversely impact the safe operation of the facility. This RG incorporates similar inspection guidance and is consistent with the basic safety principles provided in the identified IAEA standards.

### **Documents Discussed in Staff Regulatory Guidance**

This RG endorses, in part, the use of one or more codes or standards developed by external organizations, and other third-party guidance documents. These codes, standards and third-party guidance documents may contain references to other codes, standards or third-party guidance documents (“secondary references”). If a secondary reference has itself been incorporated by reference into NRC regulations as a requirement, then licensees and applicants must comply with that standard as set forth in the regulation. If the secondary reference has been endorsed in an RG as an acceptable approach for meeting an NRC requirement, then the standard constitutes a method acceptable to the NRC staff for meeting that regulatory requirement as described in the specific RG. If the secondary reference has neither been incorporated by reference into NRC regulations nor endorsed in an RG, then the secondary reference is neither a legally-binding requirement nor a “generic” NRC approved acceptable approach for meeting an NRC requirement. However, licensees and applicants may consider and use the information in the secondary reference, if appropriately justified, consistent with current regulatory practice, and consistent with applicable NRC requirements.

## **C. STAFF REGULATORY GUIDANCE**

This RG applies to onsite and offsite water control structures (e.g., dams, slopes, canals, reservoirs and associated conveyance facilities) the failure of which could cause nuclear power plant flooding, failure of the plant's emergency cooling systems, or otherwise endanger the plant.

Embankments and other appurtenant structures associated with, or part of, a water control structure addressed by this RG are those typically built to provide or protect the ultimate heat sink (UHS). Water control structures include those owned, operated, or regulated by others, and relied upon or taken credit for by the licensee or applicant.

The NRC staff may consider the recommendations of this guide fulfilled if the water control structure is regulated by another Federal or State agency that enforces an inspection program comparable to that described in this RG (e.g., a hydroelectric pumped-storage project built as part of a nuclear power plant and regulated by the Federal Energy Regulatory Commission.) For offsite water control structures not regulated by another Federal or State agency, the licensee or applicant should ensure inspections of

such structures are performed consistent with the guidelines specified in Section C.5 of this RG. Such an approach has been approved by the NRC for license renewal applicants as stated in Nuclear Energy Institute (NEI) Report 95-10, "Industry Guideline for Implementing the Requirements of 10 CFR Part 54—The License Renewal Rule," dated March 2001, (Ref. 14) as endorsed in RG 1.188, "Standard Format and Content for Applications to Renew Nuclear Power Plant Licenses" (Ref. 15).

Normal inspection and monitoring programs are performed at periodic intervals during the life of the facility to check the condition of the dam or other water control structure and evaluate their structural safety and operational adequacy. The water control structures and the associated inspection and monitoring program should include the features and items described below.

### **1. Design Features**

In accordance with GDC 45, the water control structures shall be designed and instrumented to facilitate the inspection and monitoring program discussed below. The features and instrumentation should be designed to withstand the same design basis as the water control structure itself.

### **2. Inspection of Inaccessible Areas**

The inspection and monitoring program should address detection of aging effects for inaccessible, below-grade, and submerged concrete structural elements. For plants with non-aggressive raw water and ground water/soil (pH > 5.5, chlorides < 500 parts per million (ppm) and sulfates < 1,500 ppm), the program should require: (a) evaluation of the acceptability of inaccessible areas when conditions exist in accessible areas that could indicate the presence of, or result in, degradation to such inaccessible areas and (b) examination of representative samples of the exposed portions of the below-grade concrete when excavated for any reason. Submerged concrete structures should be inspected during periods of low tide or when dewatered and accessible.

For plants with aggressive ground water/soil (pH < 5.5, chlorides > 500 ppm, or sulfates > 1,500 ppm), a program should be implemented to manage concrete aging. The program should include focused inspections of below-grade, inaccessible concrete structural elements exposed to aggressive groundwater/soil, on an interval not to exceed 5 years.

### **3. Inspectors**

Engineers experienced in the investigation, design, construction, and operation of water control structures should direct the inspection and monitoring program. The field inspection team should include engineers, engineering geologists, or other specialists who can recognize and assess signs of possible distress (e.g., structural joint movement, piezometric fluctuations, seepage variations, settlement and horizontal misalignments, slope movement, cracking of concrete, erosion, and corrosion of equipment and conduits) and recommend appropriate mitigating measures.

#### 4. Engineering Data Compilation

To facilitate the inspections and monitoring, the following engineering data related to the design, construction, and operation of the water control structures should be assembled and, to the extent practicable, included in the initial inspection report.<sup>1</sup> This data should include the following items, where available and appropriate:

a. General Project Data

- (1) a regional vicinity map showing the project location and the upstream and downstream drainage areas;
- (2) as-built drawings of important project features, including details such as instrumentation, internal drainage, transition zones, or relief wells; and
- (3) construction progress and as-built photographs of excavation, backfill, and concrete surfaces, points of contact between structures or between structures and earth embankments, and foundation conditions.

b. Hydrologic and Hydraulic Data

- (1) drainage area and basin characteristics;
- (2) storage and surcharge capacities, including dead storage;
- (3) elevation of the maximum design pool and freeboard height;
- (4) spillway characteristics (location, type, width, and crest length and elevation); and
- (5) location and description of flashboards, fuse plugs, and emergency spillways.

c. Other Types of Data

- (1) foundation data and regional geological features, including boring logs, geological maps, profiles and cross-sections, and reports of foundation treatment;
- (2) properties of embankment and foundation materials, including the results of laboratory tests, field tests, construction control tests, and assumed design material properties;
- (3) concrete properties, including the source and type of aggregate, the cement used, mix design data, and test results during construction;
- (4) electrical and mechanical equipment type; the rating of normal and emergency power supplies, hoists, cranes, valves, and valve operators; and control and alarm systems that could affect the safe operation of the water control structure;
- (5) pertinent construction records, including construction sequence, problems, alterations, modifications, and maintenance repairs;
- (6) a water control plan, including a regulation plan under normal conditions and during flood events or other emergency conditions;

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<sup>1</sup> Most engineering data are presented in preliminary and final safety analysis reports. To aid the inspectors, the initial inspection report should either incorporate this information or reference in detail its location in the safety analysis reports.

- (7) an earthquake history, including a summary of significant earthquakes in the vicinity; and
- (8) principal design assumptions and analyses, including hydrologic and hydraulic analyses, stability and stress analyses, and seepage and settlement analyses.

## 5. Onsite Inspection Program

The onsite inspection and monitoring program of water control structures should be established and conducted systematically to minimize the possibility of overlooking significant features. A detailed checklist should be developed to document the inspection of structural and hydraulic features, including electrical and mechanical control equipment. Particular attention should be given to evidence of leakage, erosion, seepage, slope instability, undue settlement, displacement, tilting, cracking, deterioration, and the improper functioning of drains and relief wells; to verifying the adequacy and quality of maintenance and operating procedures; and to post-construction changes.

The use of photographs and surveys for comparison of previous and present conditions and the documentation of new or progressive problems is encouraged. The inspection program should include a review of previous inspection records. The inspection should include appropriate features and items, including, but not limited to, the following:

### a. Concrete Structures in General

Concrete structures should be examined for the following:

- (1) Deterioration of concrete surfaces: The condition of the concrete surfaces should be examined to evaluate the deterioration and continuing serviceability of the concrete. Both American Concrete Institute (ACI) Report 349.3R-02, "Evaluation of Existing Nuclear Safety-Related Concrete Structures" issued June 2002 (and reapproved 2010) (Ref. 16) and ACI Report 201.1R-08 "Guide for Conducting a Visual Inspection of Concrete in Service" issued July 2008 (Ref. 17) contain guidance on the methodology and procedures for concrete inspections as well as descriptions of typical problems. This RG endorses the appendix in ACI 201.1R-08 as an acceptable standard form for the visual inspection of concrete structures.
- (2) Structural cracking: Concrete structures should be examined for structural cracking resulting from overstress caused by applied loads, shrinkage and temperature effects, or differential movements.
- (3) Movement – horizontal and vertical alignment: Concrete structures should be examined for evidence of any abnormal or differential settlements, heaving, tilting, deflections, or lateral movements.
- (4) Condition of the junctions: The conditions at the junctions of the structure with abutments or embankments should be determined.
- (5) Performance of drains – foundation, joint, and face: All drains should be examined to ensure that they can perform their design function.
- (6) Deterioration of water passages: All water passages and other concrete surfaces subject to running water should be examined for erosion, cavitation, obstructions, leakage, or significant structural cracks.

- (7) Seepage or leakage: The faces, abutments, and toes of the concrete structures should be examined for evidence of seepage or abnormal leakage, and records of the flow of downstream springs should be reviewed for unusual variation with the reservoir pool level. The sources of seepage should be determined, if possible.
- (8) Deterioration of monolithic joints-construction joints: All monolithic construction joints should be examined to determine the condition of the joint and filler material, any movement of joints, or any indication of distress or leakage.
- (9) Deterioration of foundation: The foundation should be visually examined to the extent possible for damage or for the possible undermining of the downstream toe.
- (10) Condition of abutments: The abutments should be examined for signs of instability or excessive weathering.

b. Embankment Structures

The American Society of Civil Engineers (ASCE), U.S. Army Corps of Engineers (USACE), Federal Emergency Management Agency (FEMA), and similar standards development organizations and regulatory agencies have published guidelines for the inspection of embankments and dams. These guidelines may aid with the development of an inspection and monitoring program. Dams and other water control structures should be inspected according to intervals specified by the regulatory agency under normal conditions and after unusual events (such as extreme rainfall and earthquakes). Such inspections will provide the best opportunity for the early detection of potential problems, including the following:

- (1) Settlement: The embankments and downstream toe areas should be examined for any evidence of unusual localized or overall settlement, depressions, or sink holes. Trending of survey data may help identify settlement over long time periods.
- (2) Slope stability: Embankment slopes should be examined for irregularities in alignment and variances from originally constructed slopes, unusual changes from original crest alignment and elevation, evidence of movement at or beyond the toe, and surface cracks that indicate movement.
- (3) Seepage: The downstream face of abutments, embankment slopes and toes, contacts between the embankment and structure, and the downstream valley areas should be examined for evidence of existing or past seepage. The sources of seepage should be investigated to determine cause and potential severity affecting dam safety under operating conditions. The presence on slopes of animal burrows and vegetative growth that might cause detrimental seepage or piping should be examined.
- (4) Clogging of, and inappropriate materials in, drainage systems: All drainage systems should be examined to determine whether the systems can freely pass discharge and ensure that the discharge water is not carrying embankment or foundation material. Systems used to monitor drainage should be examined to ensure that they are operational and functioning properly.
- (5) Gullies and notches in slope: The slope protection should be examined for erosion-formed gullies and wave-formed notches and benches that have reduced the embankment cross-section or exposed less wave-resistant materials. The adequacy of

slope protection against waves, currents, and surface runoff that may occur at the site should be evaluated. The condition of vegetative or any other protective covers should be evaluated, where pertinent.

c. Spillway Structures and Outlet Works

The inspection and monitoring program for the spillway should cover the structures and features, including bulkheads and flashboards, of service and auxiliary spillways for conditions that may impose operational constraints on the spillway. The outlet works inspection and monitoring program should include structures and features designed to release reservoir water below the spillway crest through or around the dam. The following spillway structures and outlet works should be examined:

- (1) Control gates and operating machinery: The structural members, connections, hoists, cables, and operating machinery and the adequacy of normal and emergency equipment should be examined and tested to determine the structural integrity and verify the operational adequacy of the equipment. In areas where cranes will be used for handling gates and bulkheads, the capacity and operating condition of the cranes and lifting beams should be verified. Operability of control systems and protective and alarm devices such as limit switches, sump high-water alarms, and drainage should be verified.
- (2) Unlined saddle spillways: If unlined saddle spillways are used, they should be examined for evidence of erosion and conditions that may impose constraints on the functioning of the spillway.
- (3) Approach and outlet channels: The approach and outlet channels should be examined for conditions that may impose constraints on the functioning of the spillway and the outlet works.
- (4) Stilling basin (energy dissipators): Stilling basins, including baffles, flip buckets, or other energy dissipators, should be examined for conditions that may impose constraints on the ability of the stilling basin to prevent downstream scour or erosion that may create or present a potential hazard to the safety of the dam. The condition of the channel downstream of the stilling basin should be examined.
- (5) Intake structure: The intake structure and features should be examined for conditions that may impose operational constraints on the outlet works. Entrances to the intake structure should be examined for conditions such as silt or debris accumulation that may reduce the discharge capabilities of the outlet works.
- (6) Conduits, sluices, and water passages: The interior surfaces of conduits should be examined for erosion, corrosion, cavitation, cracks, joint separation, and leakage at cracks or joints.
- (7) Drawdown facilities: Facilities provided for the drawdown of the water level should be examined for conditions that may impose constraints on their proper functioning.

d. Reservoirs

The inspection and monitoring program for the reservoir should include inspections for conditions that may impose operational constraints on the cooling system or that may be

hazardous to the safety of the dam or other water control structures. This program should include:

- (1) Shoreline: The landforms around the reservoir should be examined for indications of major active or inactive landslide areas and for their susceptibility to landslides of sufficient magnitude to significantly reduce reservoir capacity or create waves that might overtop the dam.
- (2) Sedimentation: The reservoir and drainage area should be examined for excessive sedimentation or recent developments in the drainage basin that could cause a sudden increase in sediment load, thereby reducing the reservoir capacity with an attendant increase in the maximum outflow and maximum pool elevation.
- (3) Potential upstream hazard areas: The reservoir area should be examined for changes with a potential for hazardous backwater flooding.
- (4) Watershed runoff potential: The drainage basin should be examined for any extensive recent alterations to the surface of the drainage basin such as changed agricultural practices, timber clearing, railroad or highway construction, or real estate developments that might adversely affect the runoff characteristics. Upstream projects that could have an impact on the safety of the dam should be identified.

e. Cooling-Water Channels and Canals and Intake and Discharge Structures

The cooling-water channels and canals and intake and discharge structures should be inspected as follows:

- (1) Channels and canals: The water conveyance channels and canals should be inspected for channel bank erosion, bed aggradation or degradation and siltation, undesirable vegetation, or any unusual or inadequate operational behavior.
- (2) Intake and discharge structures: The structures and all features should be inspected for any conditions that may impose operational constraints on the cooling facilities, such as silt or debris accumulation at the water intake or discharge.

f. Safety and Performance Instrumentation

The functionality and accuracy of both remote monitoring and local instrumentation installed to measure/monitor the behavior of the structures should be examined and tested. This should include remote alarms and displays if installed. The available records and readings of installed instruments should be reviewed to detect any unusual performance or distress of the structure. The adequacy of the installed instrumentation to measure the performance and safety of the dam and other water control structures should be evaluated. Records of the following instrumentation (if available) should be examined to determine any potential problems:

- (1) Headwater and tailwater gauges: The existing records of the headwater and tailwater gauge measurements should be examined to determine the relationship between these and other instrumentation measurements such as streamflow, uplift pressures, alignment, and drainage system discharge with the upper and lower water surface elevations.

- (2) Horizontal and vertical alignment instrumentation (concrete structures): The existing records of alignment and elevation surveys and measurements from inclinometers, inverted plumb bobs, gauge points across cracks and joints, or other devices should be examined to determine any change from the original position of the structures.
- (3) Horizontal and vertical movement, consolidation, and pore water pressure instrumentation (embankment structures): The existing records of measurements from settlement plates or gauges, surface reference marks, slope indicators, and other devices should be examined to determine the movement history of the embankment. Existing piezometer measurements should be examined to determine if the pore water pressures in the embankment and foundation would, under given conditions, impair the safety of the structure. Survey methods should also be used to monitor the magnitude and rate of horizontal and vertical movements of the surface monuments at the toes of embankment dams.
- (4) Uplift instrumentation: The existing records of uplift measurements should be examined to determine if the uplift pressures for the maximum pool would impair the safety of the structure.
- (5) Drainage system instrumentation: The existing records of measurements of the drainage system flow should be examined to confirm the normal relationship between pool elevations and discharge quantities or to detect any changes that have occurred in this relationship.
- (6) Seismic instrumentation: The existing records of seismic instrumentation should be examined to determine the seismic activity in the area and the response of the structures to recent earthquakes.
- (7) Remote-Monitoring Instrumentation: The existing records should be examined to confirm that remote-monitoring instruments (when installed) properly communicate with, and agree with, the local instrument records. Installed instrumentation with remote monitoring capabilities should be examined to verify the functionality and accuracy of the instruments and remote monitoring output.

g. Operation and Maintenance Features

The following operation and maintenance features should be examined:

- (1) Reservoir regulation plan: The actual practices in regulating the reservoir and discharges under normal and emergency conditions should be examined to determine if these practices comply with the designed reservoir regulation plan.
- (2) Maintenance: The maintenance of the operating facilities and features that pertain to the safety of the water control structure should be examined to determine the adequacy and quality of the maintenance procedures for keeping the facilities in a safe operating condition.

h. Post-Construction Changes

Baseline inspection data on the construction changes of water control structures should be collected during and after the construction phases, where the safety of the structures could be adversely affected.

**6. Technical Evaluation**

When findings of the engineering data review or the inspection and monitoring program indicate that changes outside normal/expected variations occur, an evaluation of the existing conditions of the water control structure should be made as discussed below. The evaluation should include the assessment of the hydraulic and hydrologic capacities and the structural stability based on the changes.

a. Hydraulic and Hydrologic Design Capacities

Hydraulic and hydrologic design capacities should be evaluated in accordance with applicable portions of RG 1.59, “Design-Basis Floods for Nuclear Power Plants” (Ref. 18), RG 1.102, “Flood Protection for Nuclear Power Plants” (Ref. 19) and RG 1.27, “Ultimate Heat Sink for Nuclear Power Plants” (Ref. 20). The evaluation should consider constraints on water control such as blocked entrances, restrictions on the operation of spillway and outlet works, inadequate energy dissipators, restrictive channel conditions, and reduction in reservoir capacity by sedimentation and other factors.

b. Sustainability Assessments

Sustainability assessments should use in-situ properties of the structures, including foundation and pertinent geologic, geotechnical and seismic information, to determine the existence of changes to or the continuation of conditions that are or could become hazardous over time and to formulate recommendations pertaining to the need for additional investigations, analyses, or remedial measures.

The probability of soil liquefaction after a seismic event is another important aspect of the stability of embankments that should be assessed. Regulatory Guide 1.208, “A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion” (Ref. 21) and RG 3.11, “Design, Construction, and Inspection of Embankment Retention Systems at Uranium Recovery Facilities” (Ref. 22) as well as FEMA Publication 93 should be used for conducting post-earthquake stability assessments using the residual strength of the soils composing the embankments. Post-earthquake stability assessments should be performed following a seismic event considered important for the water control structure (e.g., an earthquake that meets or exceeds the design basis for the structure or component).

**7. Operating Experience**

Inspection and monitoring programs of water control structures should be established commensurate with safety, and should also take into account industrywide operating experience.

## **8. Special Provisions for Dams**

In addition to the guidance contained herein, instrumentation, monitoring, and inspection of dams should meet the guidance in the Federal Guidelines for Dam Safety (see Ref. 5). This should include incorporating the appropriate design provisions to conduct the inspection and monitoring programs.

## **9. Frequency of Inspections**

The inspection intervals discussed below should be used in developing projected inspection schedules. These intervals in no way preclude more frequent inspections if deemed necessary or less frequent inspections (with a minimum frequency of every 5 years) for those structures in which conditions or structural integrity warrant such relaxation.

NOTE: In some cases, plant-specific licensing documents govern the frequency of inspections.

### **a. Initial Inspection**

The first general onsite inspection should be carried out shortly after topping out for new earth and rockfill dams or water control structures and before the impoundment of reservoir water for new concrete structures. For existing facilities that are now in operation, inspection and monitoring programs should be implemented as soon as practicable if no prior inspections comparable to those described in this guide have been performed.

### **b. Subsequent Inspections**

The second inspection of earth and rockfill dams or water control structures should be performed at a reasonable stage of reservoir filling but in no case later than at the attainment of the normal operating pool level. The second inspection of concrete structures should be performed when the reservoir water attains the normal operating pool level but in no case later than 1 year after initial impoundment has begun. Subsequent inspections should be performed at 1-year intervals for the next 4 years and at 2-year intervals for the following 4 years; these inspections may then be extended to every 5 years if the results of the previous inspections warrant this extension.

### **c. Special Inspections**

Special inspections of dams and other water control structures should be performed as soon as practical after the structure has passed unusually large floods or after the occurrence of unusual events such as earthquakes, hurricanes, tornadoes, intense local rainfalls, etc. For earthquakes, inspections should be performed following a seismic event considered important for the water control structure (e.g., an earthquake that meets or exceeds the design basis for the structure or component). Such inspections should be followed by an engineering evaluation of the structural stability of the structure using the appropriate (possibly degraded) material properties of the structure, the results of the evaluation should be communicated to the appropriate regulatory authorities.

For water control structures owned, operated or regulated by others, and relied upon or taken credit for by the licensee, the licensee or applicant should verify with the owner of such structures that the occurrence of such unusual events did not impact the structure's ability to perform its intended safety function.

## **10. Inspection Report**

In addition to the information identified in Section C.4, "Engineering Data Compilation" of this RG, a technical report should be prepared containing the results of each general inspection. These documents should be kept at the project site for reference purposes; should be available for inspection by regulatory authorities; and should be retired only on termination of the project. Any abnormal hazardous conditions observed during the inspection should be reported to the NRC in accordance with the Commission's regulations, and as required by the plant technical specifications.

The content of the reports is described below.

### **a. Initial Report**

In addition to a general description of water control structures, major elements of the report should include the following:

- (1) results of the visual inspection of each project feature, including photographs, where appropriate;
- (2) results of the instrumentation observations;
- (3) an evaluation of the operational adequacy of the reservoir regulation plan and the maintenance of the structure and operating facilities, including the warning system;
- (4) a technical assessment of the causes of distress or abnormal conditions and an evaluation of the behavior, movement, deformation, or loading of the structure; and
- (5) conclusions and recommendations for additional investigations, remedial measures, or future inspections, where appropriate.

### **b. Subsequent Reports**

These reports should include information, as described in items 10a(1)-(5) above, relative to changes or to the continuation of an abnormality in conditions noted since the previous inspection. The reports should also include any extreme events that have occurred since the last inspection, such as floods or seismic events.

## D. IMPLEMENTATION

The purpose of this section is to provide information on how applicants and licensees<sup>2</sup> may use this guide and information about the NRC's plans for using this RG. In addition, it describes how the NRC staff complies with 10 CFR 50.109, "Backfitting" and any applicable finality provisions in 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

### Use by Applicants and Licensees

Applicants and licensees may voluntarily<sup>3</sup> use the guidance in this document to demonstrate compliance with the underlying NRC regulations. Methods or solutions that differ from those described in this RG may be deemed acceptable if they provide sufficient basis and information for the NRC staff to verify that the proposed alternative demonstrates compliance with the appropriate NRC regulations. Current licensees may continue to use guidance the NRC found acceptable for complying with the identified regulations as long as their current licensing basis remains unchanged.

Licensees may use the information in this RG for actions that do not require NRC review and approval such as changes to a facility design under 10 CFR 50.59, "Changes, Tests, and Experiments." Licensees may use the information in this RG or applicable parts to resolve regulatory or inspection issues.

### Use by NRC Staff

The NRC staff does not intend or approve any imposition or backfitting of the guidance in this RG. The NRC staff does not expect any existing licensee to use or commit to using the guidance in this RG, unless the licensee makes a change to its licensing basis. The NRC staff does not expect or plan to request licensees to voluntarily adopt this RG to resolve a generic regulatory issue. The NRC staff does not expect or plan to initiate NRC regulatory action which would require the use of this RG. Examples of such unplanned NRC regulatory actions include issuance of an order requiring the use of the RG, requests for information under 10 CFR 50.54(f) as to whether a licensee intends to commit to use of this RG, generic communication, or promulgation of a rule requiring the use of this RG without further backfit consideration.

During regulatory discussions on plant specific operational issues, the staff may discuss with licensees various actions consistent with staff positions in this RG, as one acceptable means of meeting the underlying NRC regulatory requirement. Such discussions would not ordinarily be considered backfitting even if prior versions of this RG are part of the licensing basis of the facility. However, unless this RG is part of the licensing basis for a facility, the staff may not represent to the licensee that the licensee's failure to comply with the positions in this RG constitutes a violation.

If an existing licensee voluntarily seeks a license amendment or change and (1) the NRC staff's consideration of the request involves a regulatory issue directly relevant to this new or revised RG and (2) the specific subject matter of this RG is an essential consideration in the staff's determination of the acceptability of the licensee's request, then the staff may request that the licensee either follow the

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2 In this section, "licensees" refers to licensees of nuclear power plants under 10 CFR Parts 50 and 52; and "applicants" refers to applicants for licenses and permits for (or relating to) nuclear power plants under 10 CFR Parts 50 and 52, and applicants for standard design approvals and standard design certifications under 10 CFR Part 52.

3 In this section, "voluntary" and "voluntarily" mean that the licensee is seeking the action of its own accord, without the force of a legally binding requirement or an NRC representation of further licensing or enforcement action.

guidance in this RG or provide an equivalent alternative process that demonstrates compliance with the underlying NRC regulatory requirements. This is not considered backfitting as defined in 10 CFR 50.109(a)(1) or a violation of any of the issue finality provisions in 10 CFR Part 52.

Additionally, an existing applicant may be required to comply with new rules, orders, or guidance if 10 CFR 50.109(a)(3) applies.

If a licensee believes that the NRC is either using this RG or requesting or requiring the licensee to implement the methods or processes in this RG in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfit appeal with the NRC in accordance with the guidance in NUREG-1409, "Backfitting Guidelines," (Ref. 23) and NRC MD 8.4, "Management of Facility-Specific Backfitting and Information Collection" (Ref. 24).

## REFERENCES<sup>4</sup>

1. *U. S. Code of Federal Regulations (CFR) “Domestic Licensing of Production and Utilization Facilities,”* Part 50, Chapter 1, Title 10, “Energy.”
2. CFR, “Licenses, Certifications, and Approvals for Nuclear Power Plants,” Part 52, Chapter 1, Title 10, “Energy.”
3. U.S. Nuclear Regulatory Commission (NRC), Regulatory Guide (RG) 3.11, “Design, Construction, and Inspection of Embankment Retention Systems at Uranium Recovery Facilities,” Washington, DC.
4. NRC, NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” Washington, DC.
5. Federal Emergency Management Agency (FEMA) 93CD, “Federal Guidelines for Dam Safety: Hazard Potential Classification System for Dams,” compact disk containing all the Federal guidelines for dam safety (FEMA 64, FEMA 65, FEMA 93, FEMA 94, FEMA 148, and FEMA 333), FEMA, Hyattsville, MD, September 2005.<sup>5</sup>
6. NRC, Inspection Procedure (IP) 71111.01, “Adverse Weather Protection,” Washington, DC.
7. NRC, IP 71111.06, “Flood Protection Measures,” Washington, DC.
8. NRC, IP 71111.07, “NRC, “Heat Sink Performance,” Washington, DC.
9. NRC, IP 62002, “Inspection of Structures, Passive Components, and Civil Engineering Features at Nuclear Power Plants,” Washington, DC.
10. Association of State Dam Safety Officials (ASDSO), *Dam Failures and Incidents*, <http://www.damsafety.org/news/?p=412f29c8-3fd8-4529-b5c9-8d47364c1f3e>, accessed December 11, 2013.<sup>6</sup>

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4 All NRC documents that are publicly available may be accessed through the NRC Library on the NRC’s public Web site at: <http://www.nrc.gov/reading-rm/doc-collections/>. The documents can also be viewed online or printed for a fee in the NRC’s Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone 301-415-4737 or 800-397-4209; fax 301-415-3548; and e-mail [pdr.resource@nrc.gov](mailto:pdr.resource@nrc.gov).

5 FEMA documents may be obtained from the agency’s Web site (<http://www.fema.gov/>); or by mail at Federal Emergency Management Agency, P.O. Box 10055, Hyattsville, MD 20782; telephone 800-745-0243; fax 800-827-8112.

6 Documents and information from the Association of State Dam Safety Officials are available online at <http://www.damsafety.org/>; by e-mail to [Info@DamSafety.org](mailto:Info@DamSafety.org); by contacting their headquarters at 450 Old Vine St., Lexington, KY 40507; or by telephone at 859-550-2788.

11. International Atomic Energy Agency (IAEA) Safety Guide NS-G-2.6, "Maintenance, Surveillance and In-Service Inspections in Nuclear Power Plants," Vienna, Austria, August 2002.<sup>7</sup>
12. IAEA, "Metrological and Hydrological Hazards in Site Evaluation for Nuclear Installations," Safety Standard SSG-18, Vienna, Austria, November 2011.
13. IAEA, "External Events Excluding Earthquakes in the Design of Nuclear Power Plants," Safety Standard NS-G-1.5, Vienna, Austria, November 2003.
14. Nuclear Energy Institute (NEI) Report 95-10, "Industry Guideline for Implementing the Requirements of 10 CFR Part 54 – The License Renewal Rule," March 2001, (ADAMS Accession No. ML011020144).
15. NRC, RG 1.188, "Standard Format and Content for Applications to Renew Nuclear Power Plant Licenses," Washington, DC.
16. American Concrete Institute (ACI) Report 349.3R-02, "Evaluation of Existing Nuclear Safety Related Concrete Structures," issued June 2002 (Reapproved 2010).<sup>8</sup>
17. ACI, Report 201.1R-08, "Guide for Conducting a Visual Inspection of Concrete in Service," issued July 2008.
18. NRC, RG 1.59, "Design-Basis Floods for Nuclear Power Plants," Washington, DC.
19. NRC, RG 1.102, "Flood Protection for Nuclear Power Plants," Washington DC.
20. NRC, RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants," Washington, DC.
21. NRC, RG 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," Washington, DC.
22. NRC, RG 3.11, "Design, Construction, and Inspection of Embankment Retention Systems at Uranium Recovery Facilities" Washington, DC.
23. NRC, NUREG-1409, "Backfitting Guidelines," Washington DC. (ADAMS Accession No. ML032230247)
24. NRC, Management Directive (MD) 8.4, "Management of Facility-Specific Backfitting and Information Collection," Washington, DC.

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7 Copies of International Atomic Energy Agency (IAEA) documents may be obtained through their Web site: [WWW.IAEA.Org/](http://WWW.IAEA.Org/) or by writing the International Atomic Energy Agency P.O. Box 100 Wagramer Strasse 5, A-1400 Vienna, Austria. Telephone (+431) 2600-0, Fax (+431) 2600-7, or E-Mail at [Official.Mail@IAEA.Org](mailto:Official.Mail@IAEA.Org)

8 Documents from the American Concrete Institute (ACI) are available from the ACI bookstore Web site (<http://www.concrete.org/BookstoreNet/bookstore.htm>); or by contacting the corporate office at ACI, P.O. Box 9094, Farmington Hills, MI 48333; telephone 248-848-3700, fax 248-848-3701.

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