BUREAU OF INDIAN AFFAIRS SAFETY OF DAMS PROGRAM HANDBOOK

55 IAM 1-H

Bureau of Indian Affairs
Office of Trust Services
Division of Water and Power, Safety of Dams Branch

#25-41, Issued: 5/28/25
Replaces #14-28, Issued: 8/22/14

FOREWORD

This handbook documents the procedures required to implement the Bureau of Indian Affairs' (BIA) Safety of Dams (SOD) Program policy, as set forth in Part 55 of the Indian Affairs Manual (IAM), specifically, 55 IAM 1. This handbook supersedes 55 IAM-H, Safety of Dams Handbook, issued 8/22/14.

The procedures and guidelines documented herein are intended to guide overall SOD activities for dams under the jurisdiction of BIA. Users of this handbook include, but are not limited to:

- SOD personnel in the BIA Division of Water and Power (DWP) Central Office and BIA regional offices.

- SOD dam operation and maintenance personnel, contractors, or Tribes operating through contracts issued pursuant to Public Law (P.L.) 93-638.

- State and federal agencies participating in BIA SOD activities.

- Consultants and water user associations under contract with SOD or Tribes.

This handbook is intended only to improve the internal management of BIA. It is not intended to, and does not create or affect any right, benefit, obligation, substantive or procedural, or trust responsibility enforceable at law or in equity by any party against the United States, the Department of the Interior (DOI), its officers, employees, or agents, or any other person. Although this guidance may inform the determination of the provisions of a contract or other agreement, this guidance does not replace, modify, or supersede any contract provisions, including the specifications, special provisions, and plans.

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Director, Bureau of Indian Affairs

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Chapter 1: Introduction

This handbook conveys the procedures and guidelines that apply to certain high- and significant-hazard potential dams located on Indian lands. The Bureau of Indian Affairs' (BIA) Safety of Dams (SOD) Program was established under the Indian Dams Safety Act (IDSA) of 1994, P.L. No. 103-302, 25 U.S.C. § 3801 et seq. Unless otherwise stated, this handbook does not address actions for low-hazard potential dams. SOD's principal authorities include, but are not limited to, 25 U.S.C. §§ 3801 – 3805, and the Federal Emergency Management Agency's (FEMA) Federal Guidelines for Dam Safety.[1]

Several internal guidance documents are referenced throughout this handbook. These guidance documents are updated frequently by SOD and are available upon request. Some of these guidance documents include:

- Flood Hydrology Guidelines
- Flood Inundation Mapping Standards
- Formal Evaluation Guidelines
- Guidelines for Hazard Potential Classification and Dam Failure Consequence Estimation

Additionally, references made throughout this handbook to documents prepared by other Federal Government agencies, such as FEMA, U.S. Army Corps of Engineers (USACE), the Department of Homeland Security (DHS), the Department of the Interior (DOI), and DOI's Bureau of Reclamation (BOR), can be found on those agency webpages, as well as through an internet search. Any updates or versions released after this handbook's publication date supersede the original references within this handbook.

BIA is committed to ensuring SOD dams are maintained in satisfactory condition on a long-term basis. SOD dams comprise a significant part of the water-resources infrastructure for numerous Indian reservations and Tribes.

SOD dams are managed using a risk-informed approach. The primary emphasis of the risk-informed decision making (RIDM) process is to protect downstream residents from undue risks and to prioritize risk reduction actions. Life safety is paramount. Continuous and periodic dam inspections and evaluations are critical to an effective dam safety program. The RIDM approach is a best practice adopted to develop balanced and informed assessments of the SOD dams and to evaluate, prioritize, and justify dam safety decisions.

Key SOD activities include, but are not limited to:

Risk Management and Risk Reduction: SOD uses a risk-informed management framework to ensure effective use of SOD resources, to prioritize dam safety assessments, to aid in decision

[1] FEMA P-93, Federal Guidelines for Dam Safety, 2023

making, to protect downstream populations from the potential adverse consequences of dam failure, to support justification for risk reduction actions where needed, and to prioritize funding for SOD projects. Risk reduction actions address static, seismic, and hydrologic potential failure modes (PFMs) through repairs and rehabilitation.

Emergency Management (EM): EM helps reduce the potential for life loss and damage to property from a dam failure. SOD develops, implements, and maintains Emergency Action Plans (EAPs), and conducts Tabletop and Functional Exercises of all EAPs on a periodic basis.

Early Warning System (EWS) sites: An EWS site provides automated remote environmental monitoring capabilities and alert messages to supplement onsite observations. SOD installs and maintains EWS sites on some SOD dams. EWS sites are prioritized for SOD dams that have life loss potential (i.e., high-hazard potential SOD dams). The site data is provided to authorized personnel through a secure website.

Inspections and Evaluations: These activities provide key information necessary to determine and document the overall condition of dams. SOD schedules annual inspections and formal inspections, including Periodic Reviews (PRs) and Comprehensive Reviews (CRs), on a recurring basis. Risk assessments integrate the analytical methods of risk analysis along with the sound professional judgment of engineers, scientists, subject matter experts, and review boards to determine reasonable actions that will minimize risk at SOD facilities.

Maintenance and Repairs: Recurring maintenance and repairs are performed to keep dams from deteriorating into an unsafe condition. Repairs are made on dams with the highest priority repair needs.

Security: Security assessments are performed to ensure adequate security for key dam facilities and structures against credible threats. SOD implements appropriate protective measures to address the potential threats.

The roles and responsibilities of employees involved in the SOD Program are defined in 55 IAM 1. SOD has a Central Office, led by the BIA SOD Officer, that oversees SOD activities for all dams administered by SOD. Regional SOD Officers are responsible for implementing SOD activities at the dams in their region.

1.1 SOD Dam Eligibility Requirements

For a dam to be eligible for administration under SOD, it must meet land status and size requirements. SOD will confer with the Tribe(s), BIA region, and BIA agency to determine a dam's eligibility and officially bring the dam under the administration of the SOD Program. Any dam thought to meet the eligibility requirements and not known to SOD should be brought to the attention of the Regional SOD Officer.

The term *SOD dam*, also known as SOD Program dam, as used in this handbook includes any dam meeting the requirements stated on the next page.

A. Land Status Requirements

IDSA states that the SOD Program is responsible for certain dams on Indian lands. As defined in 55 IAM 1 for SOD Program purposes, the term *Indian lands* means any land to which the title is held:

1) in trust by the United States for the benefit of an Indian Tribe or an individual Indian; or

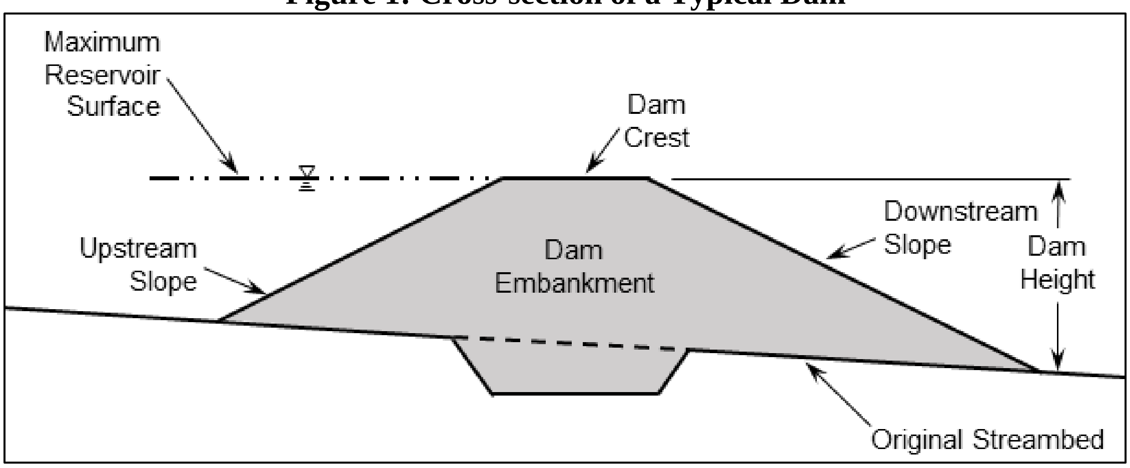
2) by an Indian Tribe or an individual Indian, subject to restriction against alienation under laws of the United States.

BIA will determine a dam's land status based on records maintained by BIA's Trust Asset Accounting Management System (TAAMS) or the regional Land Titles and Records Office (LTRO).

B. Dam Size Requirements

A typical dam configuration and physical parameters are illustrated in Figure 1 (below). The parameters include maximum reservoir surface, dam crest, upstream slope, dam embankment, downstream slope, dam height, and original streambed.

Figure 1: Cross-section of a Typical Dam



IDSA, 25 U.S.C. § 3802(2), requires BIA to use the following 33 U.S.C. § 467(3) definition of a *dam:*

> means any artificial barrier that has the ability to impound water, wastewater, or any liquid-borne material, for the purpose of storage or control of water, that—
>
> 1) is 25 feet or more in height from—
>   a. the natural bed of the stream channel or watercourse measured at the downstream toe of the barrier or,
>   b. if the barrier is not across a stream channel or watercourse, from the lowest elevation of the outside limit of the barrier to the maximum storage elevation; or

2) has a storage capacity of 50 acre-feet or greater at the reservoir maximum water surface elevation (typically equivalent to the dam crest).[2]

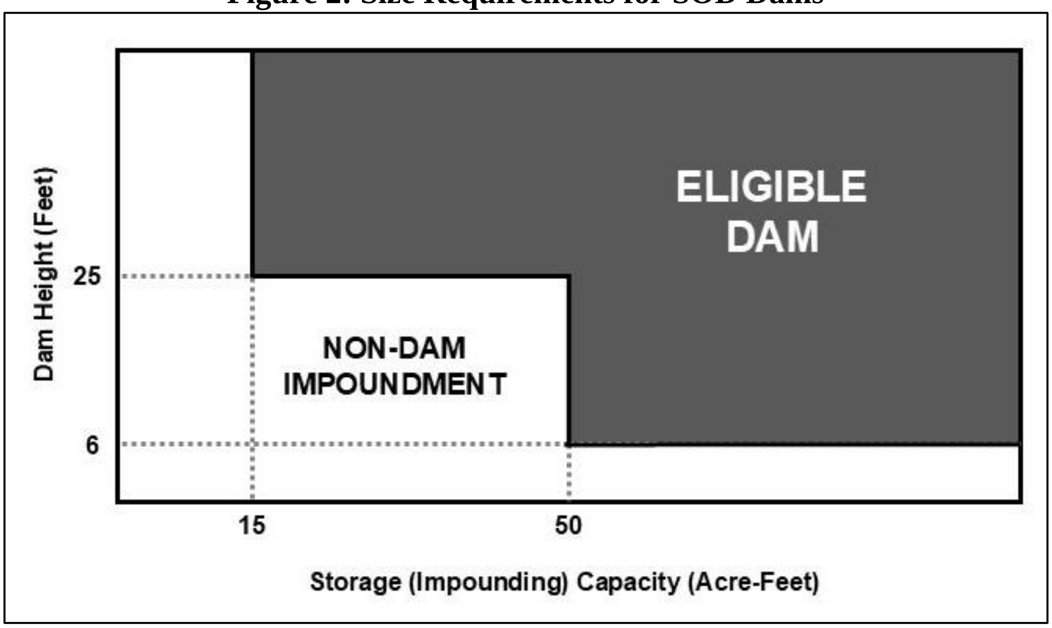
The 33 U.S.C. § 467(3) definition of *dam* does not include—

1) a levee; or
2) an artificial barrier that has the ability to impound water, wastewater, or liquid-borne material, for the purpose of storage or control of water that—
    a. is 6 feet or less in height regardless of storage capacity; or
    b. has a storage capacity at the maximum water storage elevation that is 15 acre-feet or less regardless of height;

unless the barrier, because of the location of the barrier or another physical characteristic of the barrier, is likely to pose a significant threat to human life or property if the barrier fails.

Figure 2 (below) illustrates the 33 U.S.C. § 467(3) definition of a *dam*. Artificial barriers that do not adhere to the above definition are not recognized as dams for SOD purposes and are called *non-dam impoundments*. The determination of dam eligibility will be evaluated by the BIA SOD Officer, in collaboration with the appropriate Regional SOD Officer. BIA may issue a waiver to add a barrier or impoundment of any height and storage capacity to the SOD Program if it meets the downstream hazard requirements for a high- or significant-hazard potential dam.

Figure 2: Size Requirements for SOD Dams



[2] According to the 2023 FEMA P-93, Federal Guidelines for Dam Safety, the definition of a dam should apply to dams that have a permanent reservoir or temporary storage of floodwaters. The impounding capacity at maximum water storage elevation includes storage of floodwaters above the normal full storage elevation.

C. Ineligible Dams

BIA considers the following dams ineligible for acceptance into the SOD Program:

- Dams under the jurisdiction of a state or Federal Government agency other than BIA.
- Dams the Secretary determines are not characteristic of IDSA.

1.2. Technical Assistance

Upon request, SOD will provide technical assistance to any Tribe during an emergency at any dam, barrier, or impoundment, regardless of whether it is a SOD dam or not. SOD can also provide technical assistance to Tribes for any dam, barrier, or impoundment safety issues. SOD will make every effort to assist Tribes during design and construction of new dams to minimize risks to people and property and promote development of sustainable infrastructure.

1.3 Hazard Potential Classification

The determination of the hazard potential classification of a dam is a critical component in the prioritization and administration of SOD dams. A dam's hazard potential classification is a categorization of the potential adverse consequences on downstream property and lives that directly result from the uncontrolled release of stored water, wastewater, or any liquid-borne material, due to failure of the dam or misoperation of the dam or appurtenant structures. Hazard potential classification does not indicate an assessment of any aspect of the structural integrity of the dam itself, but rather the effects if a failure or misoperation should occur.

SOD classifies dams in the following categories: *low-hazard potential*, *significant-hazard potential*, and *high-hazard potential*. This hazard potential classification system should be used with the understanding that the failure of any dam or water retaining structure, no matter how small, could represent a danger to downstream life and property. Whenever there is an uncontrolled release of stored water, the possibility exists that someone will be in its path, regardless of expectations and typical land uses.

SOD's hazard potential classification categories and descriptions are based primarily on FEMA P-333, Federal Guidelines for Dam Safety: Hazard Potential Classification System for Dams.[3] SOD's hazard potential classification system categorizes dams based on the probable loss of human life and impacts on economic, environmental, cultural, and lifeline interests (see Table 1, next page).

[3] In the Office of the Inspector General's (OIG) Report No. WR-EV-MOA-0002-2013, Recommendation No. 1 states, "Update BIA policies to align with the [FEMA 333] dam hazard classification." In accordance with OIG's recommendation and 753 Departmental Manual (DM) 2, BIA revised its hazard potential classifications. Consistent with FEMA 333, SOD dams are now classified as high-hazard potential if dam failure or misoperation will probably cause loss of human life. In addition, all SOD dams which were previously classified as significant-hazard potential (estimated life loss of one to six) are now classified as high-hazard potential.

Improbable loss of life exists where persons are only temporarily in the potential inundation area. For instance, this hazard potential classification system does not contemplate the improbable loss of life of the occasional recreational user of the river and downstream lands, passer-by, or non-overnight outdoor user of downstream lands. In any classification system, all possibilities cannot be defined. High-usage areas of any type should be considered appropriately. Judgment and common sense must ultimately be a part of any classification decision.

SOD dams are categorized into one of the following three categories, as illustrated in Table 1:

1. High-Hazard Potential

2. Significant-Hazard Potential

3. Low-Hazard Potential

Table 1: Hazard Potential Classification Definitions for SOD Dams

Hazard Potential Classification	Loss of Human Life	Economic, Environmental, Lifeline Losses
High-Hazard Potential	Probable loss of one or more lives expected	Yes (but not necessary for this classification)
Significant-Hazard Potential	None expected	Yes
Low-Hazard Potential	None expected	Low and generally limited

More information about classifying SOD dams is provided in SOD's Guidelines for Hazard Potential Classification and Dam Failure Consequence Estimation.

BIA prioritizes its rehabilitation funding to dams that are understood to be high-hazard potential at the time rehabilitation design is initiated. Rehabilitation funding for significant- and low-hazard potential dams is subject to the availability of appropriations or as approved by the BIA Director at the request of the SOD Program.

BIA has classified the hazard potential for many SOD dams. A key component of routine SOD dam inspections is to confirm the hazard potential classification for the dam remains appropriate. In accordance with the DOI's 753 DM 2: Dam Safety and Security Program – Program Requirements, the hazard classification of all SOD dams should be reassessed every five years to determine if a change in hazard classification is warranted. If at any time the Regional SOD Officer believes that land uses downstream of a SOD dam have substantially changed or otherwise has reason to question the hazard potential classification of an existing SOD dam, it must be reported to the BIA SOD Officer, who will initiate new analyses as appropriate.

Chapter 2: Risk-Informed Decision Making (RIDM)

RIDM, also known as risk management, is a management framework in which relative risks at a given dam and within a portfolio of dams can be compared to inform decisions regarding dam safety investments. RIDM uses the likelihood of hazards like floods and earthquakes ("loading"), system response given the loading, and consequences of failure, to estimate risk. SOD uses RIDM to manage its high- and significant-hazard potential dams.

Risk considerations help prioritize and inform all aspects of SOD activities and provide a measure of commonality that helps integrate the routine and non-routine SOD activities discussed in the remaining chapters of this handbook. These activities are introduced in this chapter and their essential roles are summarized. They are mutually dependent and should never be considered in isolation from the overall RIDM process. They help SOD achieve, demonstrate, and maintain an adequate level of safety for each dam. This approach is similar to processes used by other DOI organizations. However, it is tailored to address the unique needs of BIA's SOD Program.

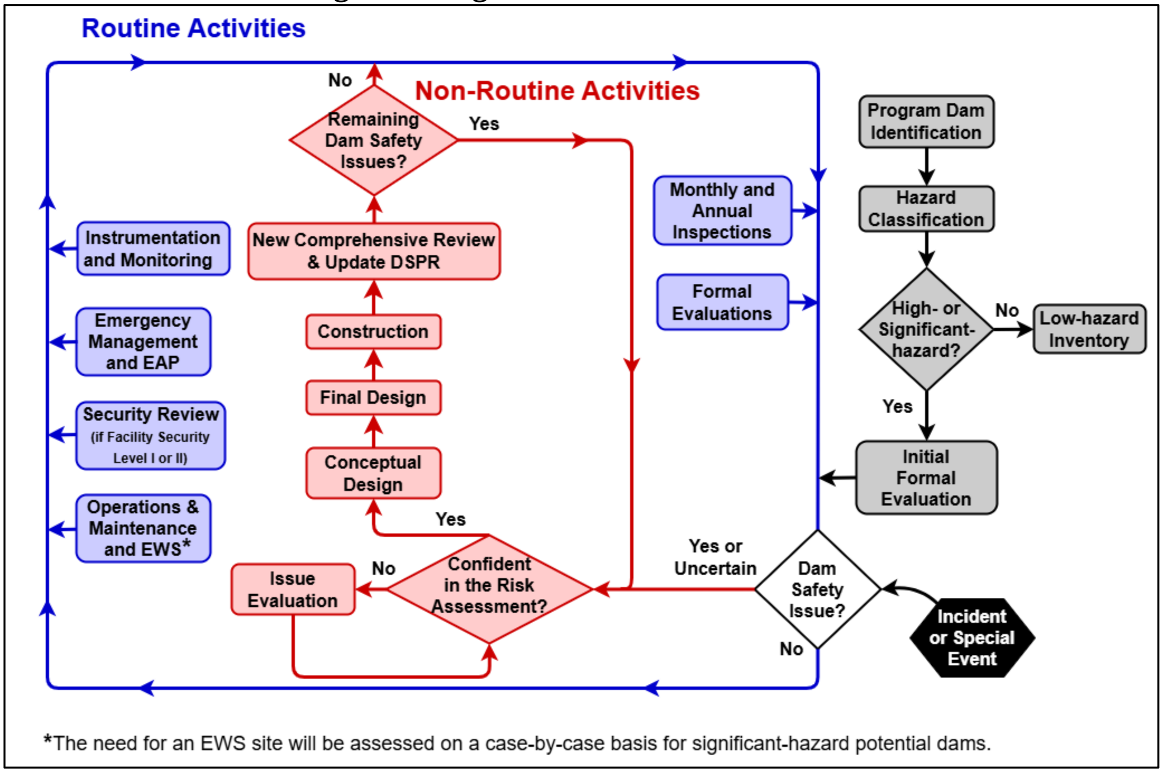
Whereas previous approaches typically relied solely on engineering analyses, the implementation of a RIDM process allows for decisions to be made based on the outcomes of risk assessments in addition to traditional engineering analyses. Emphasis is placed on *making the case* for dam safety decisions based on a review of the PFMs and estimated risks in relation to the SOD risk guidelines described herein.

For the purposes of evaluating risk at high-hazard potential dams, SOD considers the potential for life loss as the primary consequence of dam failure. For the purposes of evaluating risk at significant-hazard potential dams, SOD considers the main consequences of dam failure to be some combination of potential life loss, lifeline disruptions, cultural loss, environmental damage, and economic impacts, as determined on a case-by-case basis in accordance with SOD's Guidelines for Hazard Potential Classification and Dam Failure Consequence Estimation.

Once a dam has been determined to be a SOD dam and it has a high- or significant-hazard potential classification, then routine dam safety activities can begin. Routine activities include annual inspections, formal evaluations, Operations & Maintenance (O&M), EWS, EM, and monitoring instrumentation. These activities recur at established intervals and can facilitate the identification of potential dam safety issues. When potential issues are identified, non-routine activities may be initiated.

Non-routine activities include first evaluating the dam safety issues using investigations, engineering analyses, and risk assessments, and then addressing those issues through various risk reduction activities, including Issue Evaluations (IEs) and dam modification. This process is outlined in Figure 3 (next page) as a flowchart.

Figure 3: SOD Risk-Informed Decision Making Process for High- and Significant-Hazard Potential Dams[4,5]



2.1 Routine SOD Activities

Routine SOD activities that must occur at each high- and significant-hazard potential SOD dam include O&M, EM, EAP, annual inspections, and formal evaluations. High-hazard potential SOD dams will also receive EWS and Security Reviews (SRs). Significant-hazard potential SOD dams will not typically receive an EWS, SRs, or recurring CRs, but these can be provided when warranted.

A. O&M

Each high- and significant-hazard potential dam must have an O&M Manual that documents key operations, maintenance, and routine monitoring guidelines for the dam. Dam Operators/Dam Tenders are responsible for ensuring that the dam(s) under their charge are properly operated, maintained, and monitored in accordance with the O&M Manual. Chapter 6 of this handbook describes the O&M Manual requirements for SOD dams. In addition, most high-hazard potential SOD dams have an EWS, which requires regular maintenance. Chapter 8 of this handbook provides more information on SOD's EWS sites.

[4] This figure is an adaptation of the approach agreed upon by USACE, BOR, the Federal Energy Regulatory Commission (FERC), and the Tennessee Valley Authority (TVA) in the Federal Guidelines for Dam Safety Risk Management, Interagency Committee on Dam Safety (ICODS), 2013.
[5] The full dam modification process is outlined in Chapter 5 of this handbook.

B. EM and EAPs

EM at dams involves preparedness, response, and recovery associated with dam incidents, emergency events, and dam failures. Each SOD high- and significant-hazard potential dam has an EAP. SOD's EM procedures are described in Chapter 7 of this handbook.

C. SRs

SRs serve to reduce the potential for dam failure, or damage to dams due to malevolent attacks on dams and dam appurtenances, such as spillways and outlet works. Chapter 9 of this handbook provides more information on SOD's dam security procedures and requirements.

D. Instrumentation and Performance Monitoring

Each dam with significant instrumentation has a description of the instrumentation system (such as piezometers, inclinometers, or other performance monitoring sensors) included in the O&M Manual. The O&M Manual also contains detailed drawings, a data collection schedule, and instrumentation thresholds. Annual maintenance is typically performed on each instrumentation system.

E. Annual Inspections and Formal Evaluations

Dam safety inspections and evaluations are routinely performed for all SOD dams (that are not in an inactive status[6]).

Annual inspections are performed by personnel trained and experienced in dam safety examinations and assess all aspects of high- and significant-hazard potential SOD dams. Formal evaluations are performed for all high- and significant-hazard potential SOD dams on a five-year recurring cycle by highly qualified personnel with extensive experience performing dam safety examinations. All inspections and evaluations are documented in a written report, including photographs and descriptions of conditions. The formal evaluations also include recommendations for bureau actions to address concerns related to dam safety security, and O&M.

CRs and PRs are the primary types of formal evaluations performed for SOD dams. The Dam Safety Priority Rating (DSPR), used to inform prioritization of SOD funding for high-hazard potential dams, is developed during the CR process. More information on dam safety evaluations is provided in Chapter 3 of this handbook.

2.2 Non-Routine SOD Elements

Dam safety issues may also be identified as the result of an incident or unusual event, such as new signs of structural distress or the occurrence of a flood or an earthquake. When a potential dam safety issue is first identified, the need for intervention or interim risk reduction measures

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[6] Inactive status means that the dam is unable to impound or divert water for the purpose of storage or control of water. For example, the dam is breached, or the reservoir has been filled in by sediment.

(IRRMs) should be assessed and implemented as warranted. An IE may be used to better understand the severity of the dam safety deficiency and is described in more detail in section 3.3 of this handbook. When no additional intervention or IRRMs are warranted, the DSPR or risk priority assigned to the dam should be reevaluated and changed as appropriate.

Risk reduction alternatives should include: a no action alternative; structural and non-structural risk reduction measures; consideration of making IRRMs permanent; and decommissioning or replacing the structure.

Phasing or prioritizing incremental risk reduction actions at SOD dams can be an efficient and cost-effective approach to reducing overall SOD dam safety risks. If a decision has been made to modify the dam, a series of activities is initiated, which may include data collection, conceptual design, final design, and construction. The elements of the risk reduction and dam modification process are described in Chapter 5 of this handbook.

After completion of rehabilitation, a new CR is performed to assess the level of risk reduction achieved based on the implemented design criteria and SOD risk guidelines. It also serves to revise the DSPR or risk priority category as appropriate. Also, any IRRMs should be reviewed and modified as appropriate.

2.3 Dam Failures and Incidents

SOD generally defines a dam failure as a catastrophic event characterized by the initiation and complete progression of a dam failure mode that results in the sudden, rapid, uncontrolled, and unconstrained release of water impounded by the dam. Dam incidents are more common than dam failures, and dam failures typically begin as dam incidents. BIA classifies four primary types of dam incidents: 1) dam safety incidents; 2) high-flow incidents; 3) dam operational incidents; and 4) public safety incidents.

Dam safety incidents are defined as an adverse occurrence where a PFM initiates at a dam, or dam appurtenance, but does not progress to dam failure. Dam safety incidents can occur in numerous ways, however in all cases control of the water impounded by the dam is maintained, or the release of the reservoir is significantly constrained or prolonged, such that no adverse consequences occur in downstream areas. In some cases, a dam safety incident can develop into a dam failure if intervention efforts are unsuccessful and the sudden, rapid, uncontrolled release of the reservoir occurs.

High-flow incidents are characterized by the passage of natural flood events through the appurtenant structures of a dam that results in adverse downstream consequences. In these cases, the features of the dam are functioning in a manner consistent with their intended design to safeguard the integrity of the dam. The occurrence of these incidents typically involves an adverse or unusual event that results in adverse downstream consequences and can lead to the activation of the EAP, as described in Chapter 7 of this handbook.

Dam operational incidents are those where the controlled operation or misoperation of the features of a dam results in adverse consequences in the areas downstream or immediately upstream from the dam. These incidents are typically associated with the controllable appurtenances of a dam, such as the outlet works or gated spillway structures, and can be caused by operator error or component failure that does not result in a more extensive dam safety incident.

Public safety incidents occur when one or more people are harmed through their physical interaction with a dam, appurtenant structure, or reservoir. All dams demonstrate the potential to impact public safety, and appropriate location-specific protective measures and safety protocols are required at each facility. These incidents are often characterized by physical harm to a person or persons from the general public, or to an employee or employees from an agency or organization performing professional duties related to the dam.

The occurrence of most incident types will often require the activation of an EAP, intervention, significant monitoring, or emergency response such as evacuation. A dam incident is one way for potential dam safety issues to be identified, which could initiate the need for IRRMs.
Non-incident unusual events can also occur at dams, in which situations that have not been previously observed at the structure require additional attention, such as a spillway activating for the first time or elevated reservoir levels above those previously recorded. These events are not necessarily indicative of adverse conditions or the occurrence of an incident but may warrant increased observation.

Following the occurrence of an incident or failure at a dam that is classified as high- or significant-hazard potential, the Regional SOD Officer is required to complete an incident report[7] in accordance with relevant federal, DOI, and BIA-specific incident reporting requirements. Additional reporting after termination of dam incidents where the EAP has been activated is detailed in Chapter 7 of this handbook.

2.4 Dam Safety Risk

Risk is generally defined as the probability that some undesirable event may occur multiplied by the consequences of that occurrence. In the context of dam safety, the undesirable event is dam failure. Dam failures can lead to large-scale life loss, economic damage, environmental damage, or damage to cultural heritage sites. The consequences of a dam failure are an important measure of the severity of a dam failure. Therefore, dam safety risk is measured not only by the *probability* of dam failure, but also by the *estimated consequences* of dam failure. Of the different types of consequences that can result from dam failure, life loss is given the greatest emphasis in managing dam safety risk and in formulating dam safety risk reduction plans. It follows that the magnitude of estimated life loss is an important factor in evaluating dam safety risks and that unacceptable risks at high-hazard potential dams are generally addressed before risks at significant-hazard potential dams.

Dam safety risk management must seek to understand not only the *causes* of dam failure, but also the *factors* that determine the likelihood of failure occurrence and the magnitude of life loss and non-life loss consequences of a dam failure. Some non-life loss consequences of dam failure, such as damage to cultural heritage sites, are not readily quantifiable but they are nevertheless very important and should not be overlooked in dam safety decision making.

[7] The templates for the incident reports are maintained by SOD Central Office and can be provided upon request.

Dam safety risk analysis typically focuses on PFMs that will result in the sudden and uncontrolled release of water impounded by a dam. Even if a dam does not breach, a failing dam could include a malfunction or abnormality outside the design assumptions and parameters that could adversely affect the performance of a dam. All dams have multiple potential modes of failure. In addition to considering alternatives for reducing the likelihood of dam failure occurring, opportunities for reducing the magnitude of life loss, and cultural, environmental, and property damage in the event of dam failure should also be considered.

Incidents can lead to consequences like those following a dam failure. A dam safety risk analysis can also be used to evaluate the likelihood and potential severity of these non-breach risks.

2.5 Risk Assessment and Making the Dam Safety Case

Risk assessment provides the interpretive component of RIDM and relies on failure-mode-specific risk estimates and facility (dam)-specific total risk estimates to inform the prioritization of SOD activities. SOD follows the risk management guidelines detailed in FEMA's P-1025, Federal Guidelines for Dam Safety Risk Management and BOR's Public Protection Guidelines: A Risk-Informed Framework to Support Dam Safety Decision-Making. These guidelines are generally applied to all SOD high- and significant-hazard potential dams.

As stated in the Public Protection Guidelines, the basic unit in risk assessment is an individual reservoir or facility, which can include multiple dam and dike impoundments. Accordingly, risks are both tracked and managed at the level of the individual facility.

To best prioritize risk management activities, SOD uses the DSPR system detailed in BOR's Public Protection Guidelines, where facilities are assigned a single DSPR value to express the relative importance of identified dam safety needs. Additional information pertaining to the DSPR system, including the current description and supporting rational applicable to each of the DSPR categories, can be found in SOD's Formal Evaluation Guidelines.

To aid in communicating the relative severity of dam safety risks, SOD has generally adopted the same risk portrayal chart detailed in the Public Protection Guidelines (see Figure 4). A risk portrayal chart is created for each individual dam or facility. The chart contains distinct markers signifying the estimated Annualized Failure Probability (AFP) and life loss for each identified PFM, in addition to a marker used to identify the calculated total risk of the dam or facility. The chart also contains a visual representation of the threshold values for increasing or decreasing justification to reduce or better understand risks (referred to as the "visual guidelines"). As stated in the Public Protection Guidelines, a risk portrayal chart is designed to be "triaxial" in that any point on the chart can be interpreted as having either an AFP and life loss coordinate (as in the case of individual PFM estimates) or an AFP and Annualized Life Lose (ALL) coordinate (as in the case of the total risk estimates).

The risk portrayal chart contains three distinct segments representing the visual risk guidelines for high-hazard potential dams that are shown as grey dashed lines. The following is a general summary and description of each of these segments; more detailed descriptions of each are contained in the Public Protection Guidelines.

- Segment 1: An AFP of one in 10,000 (1×10^{-4})/year or less for an estimated life loss of 0 to 10 people. This segment is based on the idea that the risk associated with a dam plotting along or near this guideline would result in a relatively minor increase in risk exposure to a typical downstream inhabitant when compared to the average annual background risk of death among U.S. residents.

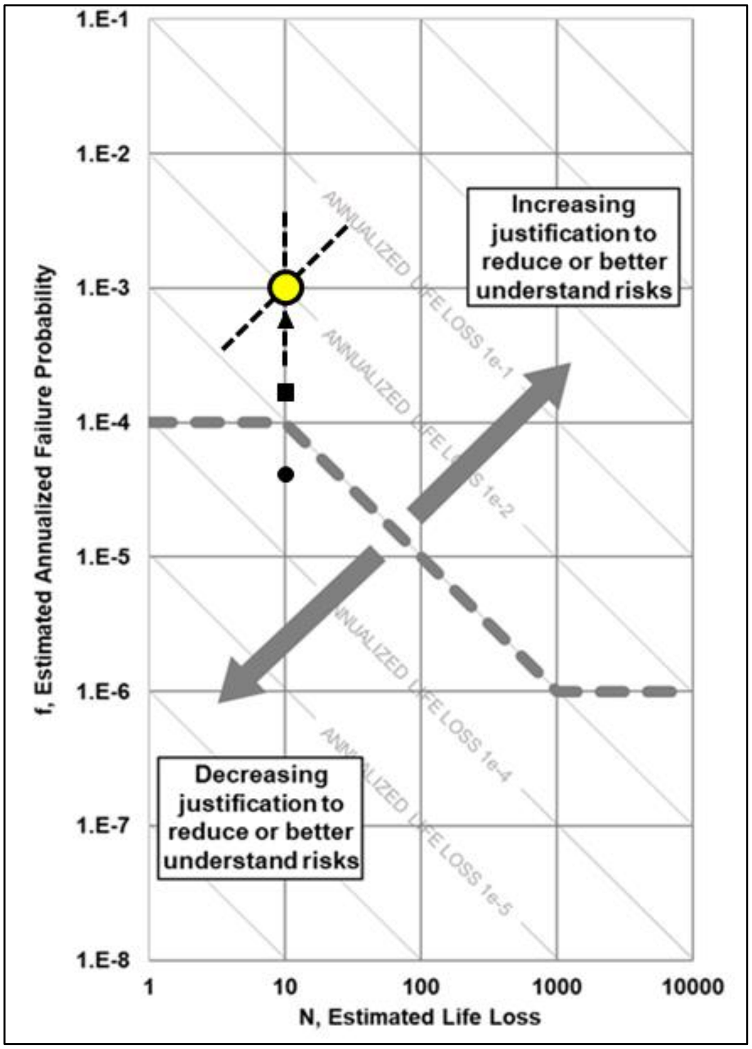
- Segment 2: An ALL of one in 1,000 (1×10^{-3}) lives/year or less for an estimated life loss of 10 to 1,000 people. This segment can be generally characterized as a reinforcement of the standards identified in Segment 1 by requiring the threshold AFP proportionally decreases with increasing potential life loss. This portion of the guideline is called the “societal risk” guidelines by some federal dam safety agencies and generally implies that dams whose failure has the potential to result in mass casualties are held to a higher standard of care.

- Segment 3: An AFP of one in 1,000,000 (1×10^{-6})/year or less for an estimated life loss of greater than 1,000 people. This guideline segment generally reflects a truncation of the Segment 2 guideline and signifies a point of diminishing returns for low-AFP, high-life-loss facilities where expenditures to better understand or reduce risks become very cost-intensive and may unreasonably dilute SOD’s generally limited economic resources away from dams with much higher risk of failure (and typically more straightforward risk reduction measures).

Figure 4 (next page) is an example of a typical risk portrayal chart with the risk guidelines for one high-hazard potential dam (or facility). AFP is on the vertical axis, estimated life loss is on the horizontal axis, and ALL is shown diagonally. For high-hazard potential dams, the best estimate AFP and estimated life loss for each individual PFM is plotted on a risk portrayal chart (indicated by the black circle, square, and triangle) and the overall AFP, ALL, and estimated life loss for all the significant PFMs combined are represented on the risk portrayal chart by a large circle. The uncertainties associated with the AFP and ALL are plotted on the chart as vertical and diagonal dashed lines, respectively, which are attached to the large circle. If the estimated risk for a high-hazard potential dam (the yellow dot) is above the visual risk guidelines (indicated by grey dashed lines), then there is an increasing justification to reduce or better understand the dam’s risks. If the estimated risk is below the risk guidelines, then there is a decreasing justification to reduce or better understand the dam’s risks.

Elements of SOD’s risk portrayal are occasionally updated, and the current version (or versions) can be found in SOD’s Formal Evaluation Guidelines.

Figure 4: Typical Risk Portrayal Chart Showing AFP and ALL SOD Risk Guidelines



Since significant-hazard potential dams do not have expected life loss, the risk guideline for significant-hazard potential dams is an AFP guideline, informed by an approximated recurrence probability resulting from FEMA's inflow design flood[8] and SOD's understanding of the appropriate standard of care for significant-hazard dams. This includes:

- An AFP of one in 3,000 (3.33×10^{-4})/year (corresponding to half an order of magnitude in log-scale greater than the AFP guideline used for high-hazard potential dams); or
- A lower AFP may be used when warranted by:
  - Potential for direct or indirect loss of life.
  - Potential for loss of critical infrastructure and/or life support systems.

[8] FEMA P-94, Selecting and Accommodating Inflow Design Floods for Dams, FEMA, 2013

- Potential for significant damage to cultural or environmental resources.
- Economic analysis.

Section 4.4 of this handbook explains the process for estimating AFP and ALL.

Substantial dam safety decisions must be: 1) supported by well-reasoned arguments and rationale; 2) informed by technical evidence and risk estimates; and 3) given consideration for attendant uncertainties and relevant non-technical factors. Decisions are risk-informed, not risk-based. Therefore, decision making is not automatically determined by numerical risk estimates. The urgency of actions, including funding, to reduce risks on an expedited basis in the short-term (interim risk reduction measures) or in the long-term (dam safety modifications) is commensurate with the level of risk based on current knowledge and uncertainties. This may involve first addressing only those PFMs that contribute significantly to the overall risk.

A key element in the RIDM process is to provide consistent rationale for non-routine dam safety decisions. *Making the case* should be the primary focus in the risk assessment process. Decisions and recommendations should be clearly supported with evidence, good engineering judgement, and adequately documented. The following items should be included in the decision summary document summarizing the findings of the RIDM process:

- Recommendations and justification for additional safety-related action, or alternatively, deciding that no additional safety-related action is required.
- Documentation of the:
  - Dam's existing condition and projected capability to withstand future loadings.
  - Numerical risk estimates and supporting investigations, analyses, and important considerations.
  - Consequences evaluation and supporting analyses.
  - Recommended actions.
- An evaluation of the sensitivity (uncertainty) to key parameters affecting the risk analyses and their effects on recommended actions.

Chapter 3: Dam Safety Evaluations

Dam safety evaluations are performed for all SOD dams (except those in inactive status) on a recurring basis as directed in DOI's 753 DM 2: Dam Safety and Security Program – Program Requirements. SOD dams are routinely inspected to identify deficiencies related to dam safety, public safety, security, and operations. Additional, special dam safety examinations are scheduled as warranted following dam incidents, to address specific SOD issues for normally inaccessible features, or after dam safety modifications have been completed. The dam safety examination schedule is updated each year. This schedule identifies each dam and the type of examinations that should be performed during that year.

SOD Program performs the following types of dam safety evaluations and inspections:

- Initial CR evaluations
- CR evaluations
- PR evaluations
- Issue Evaluations
- Annual inspections
- Routine monitoring and observation
- Special examinations
- Post-modification examinations

Table 2 (next page) shows the frequency of each evaluation type for SOD high- and significant-hazard potential dams. If a dam is undergoing rehabilitation or is in inactive status, then the CR/PR cycle may be paused until rehabilitation construction has been completed.

Table 2: Dam Safety Examination Frequency and Responsibility

Dam Examination Type	Applicable Hazard Classification	Frequency	Office Responsible	Inherently Federal Duty
Routine Monthly Inspection	High, Significant	Typically, monthly (schedule is developed specifically for each dam)	BIA agency/Tribe	No
Annual Dam Inspection	High, Significant	Yearly	Region	No
Periodic Review (PR) Evaluation	High	At least every 10 years (alternating with CRs)	SOD Central Office	Yes
Comprehensive Review (CR) Evaluation	High	At least every 10 years (alternating with PRs)	SOD Central Office	Yes
CR or PR Evaluation(1)	Significant	At least every 5 years	SOD Central Office	Yes
Issue Evaluation (IE)	High, Significant	As needed to determine severity of potential dam safety issues	SOD Central Office	Yes
Special Examinations	High, Significant	As needed when potential issues are identified at the dam	SOD Central Office	Yes
Examination of Normally Inaccessible Features	High, Significant	As specified within CR, typically performed in conjunction with a CR and/or PR examination; routine	SOD Central Office	No
Post-modification Examination	High, Significant	As needed after a dam modification	SOD Central Office	Yes

(1) The specific examination type will be determined on a case-by-case basis.

Typically, the Regional SOD Officer or other selected specialists perform annual inspections. Formal evaluations, such as CRs, PRs, IEs, and post-modification examinations are performed by SOD Central Office personnel or their assigned agents, with assistance from local, Tribal, or BIA regional personnel. Because CRs, PRs, and IEs directly impact the prioritization of dam safety activities and resources, including dam modifications, other risk reduction actions, and technical investigations, the Federal Government is inherently responsible for managing and conducting these formal evaluations.

Dam safety inspection reports provide field information on the condition and performance of the dam to support risk management and risk assessments as follows:

- Inspections provide documentation of the performance of the dam and appurtenant structures under the actual loading conditions. These conditions include: 1) seepage behavior under normal reservoir level; 2) hydraulic behavior of the spillway during or immediately after a flood; or 3) structural behavior of the dam and structures following a recent earthquake.

- Inspections provide evidence that may support an increase or decrease in the likelihood of occurrence of certain PFMs.

- Inspections identify areas requiring O&M improvements, such as control of burrowing animals, removal of woody vegetation on the embankment, and replacing deteriorated riprap.

- Formal evaluations facilitate review and update of PFMs, consequences, risk estimates, downstream hazard potential classifications, and EM activities.

- Post-modification evaluations facilitate an update of the pertinent data of the dam, PFMs, residual risk, and the EAP.

Each inspection and evaluation is documented in an examination report. The level of detail and information included in an examination report varies with the type of examination conducted. Examination reports serve: 1) as a valuable record of changing conditions at a dam; 2) to provide a review of PFMs; and 3) to identify evidence of PFM development.

General examination report guidelines for formal evaluations are contained in SOD's Formal Evaluation Guidelines. Depending on the type of evaluation performed, the examination report will likely contain the following information:

- A discussion of the pertinent features of the dam.

- Conditions on the day of the examination (e.g., reservoir level, outlet works, and spillway releases).

- Inspection checklist of site observations.

- Evaluation and discussion of observations that are related to PFMs.

- New SOD and O&M recommendations.

- Status of existing SOD and O&M recommendations.

- Color photographs of the observations with captions.

- Discussion of EM procedures and preparedness (including EAPs described in Chapter 7 of this handbook).

Completed dam safety evaluation reports are sent to BIA's Central SOD Office, regional SOD office, and BIA agency office, as appropriate.

Examination reports should be completed and distributed as timely as possible in accordance with SOD's schedule. Safety examinations should be performed in accordance with BOR's Safety Evaluation of Existing Dams Manual and SOD's Formal Evaluation Guidelines.

3.1 CR Evaluation

The CR is an intensive and comprehensive evaluation of all dam safety issues for a particular dam performed by a multidisciplinary team. It includes a thorough review of the design, construction, and performance records of the dam in addition to all previous investigations and engineering evaluations. The CR process also includes a site examination, identification of performance parameters, and review of all pertinent technical analyses. The findings of the examination are used to inform the Potential Failure Modes and Risk Analysis (PFMRA) that is part of each CR.

CR site examinations are performed by a team experienced in dam inspections, which includes an Examiner and Senior Engineer (both of whom are Professional Engineers (PEs) unless otherwise approved by the BIA SOD Officer), other appropriate BIA personnel, and appropriate Tribal personnel. A thorough inspection of all features of the dam and its appurtenant structures is performed.

The development of an updated facility-specific DSPR is one of the most important aspects of a CR. The DSPR provides a numeric score that is used by BIA to prioritize the findings, conclusions, and recommendations of each CR relative to other high- and significant-hazard potential dams under the administration of the SOD Program. The DSPR system is described in section 4.6 of this handbook.

For high-hazard potential dams, a CR is typically performed a minimum of once every 10 years for each dam. For significant-hazard potential dams, the type of formal examination performed at least every five years is determined on a case-by-case basis; it may be a CR evaluation if warranted.

The necessity for interim risk reduction measures or modifications to reduce dam safety risk is determined by the CR. Such actions may include: 1) temporary breaching; 2) providing additional spillway capacity; 3) instituting a reservoir storage restriction; 4) restricting potential population at risk (PAR) access to downstream areas (such as closing a campground); or 5) proceeding with an expedited dam modification. SOD, with Tribal input, will assess alternatives and decide the appropriate courses of action.

3.2 PR Evaluation

For high-hazard potential dams, a PR evaluation is performed every 10 years and alternates with CRs. For significant-hazard potential dams, the type of formal examination performed at least every five years is determined on a case-by-case basis; it may be a PR evaluation if a CR is not warranted. PR site examinations are performed by a team experienced in dam inspections, which includes an Examiner/Inspector and Senior Engineer (both of whom are PEs unless otherwise approved by the BIA SOD Officer), other appropriate BIA personnel, and appropriate Tribal personnel. Digital photographs are taken to document typical conditions, and special observations of the dam and the dam's appurtenant structures.

3.3 IE

An IE is an engineering evaluation and risk analysis process used to determine the nature and severity of a dam safety deficiency that needs to be addressed. IEs are typically initiated when there is a need for greater confidence in the current risk assessment, following an incident, discovery of an unusual condition, or an increase in potential consequences. The IE report can include or trigger the development of technical studies, such as geotechnical, hydrologic hazard, or seismic hazard analyses to better define the identified risks at a given dam. Phased investigations may provide a useful strategy to approach IEs in a cost-effective manner, especially when detailed investigations and analyses are needed to achieve an adequate level of confidence in the results and recommendations.

3.4 Other Examinations

The other types of dam safety evaluations and inspections performed by SOD are described below.

A. Annual Inspection

The Regional SOD Officer is responsible for ensuring that an inspection of each dam is performed annually in accordance with DOI's 753 DM 2: Dam Safety and Security Program – Program Requirements. Annual inspections are performed by personnel trained and experienced in dam safety examinations. The inspection should assess all aspects of the dam. Any concerns or issues found should be promptly reported to the BIA SOD Officer.

B. Routine Monitoring and Inspection

Routine monitoring and inspection of each dam is performed on a regular basis by the Dam Operator/Dam Tender or local BIA agency personnel. The schedule, inspection checklist, and reporting requirements for routine monitoring is developed specifically for each dam.

C. Special Examinations

Special examinations are performed on an as-needed basis to address specific issues observed at the dam. Examples of situations that may require a special examination include:

- Observations indicate that conditions exist which could potentially lead to the failure of the dam or unsafe operation of the dam. Examples of these conditions include: 1) potentially threatening seepage conditions either in the embankment or along an outlet works conduit, such as large seepage flows, or evidence of internal erosion; 2) potential embankment instability, including slumps, slides, or cracks; and 3) major equipment problems in the outlet works, which prevent control of the reservoir level.

- A recent earthquake near the dam.

- The reservoir has experienced a large flood event or other source of significant inflows, which result in large discharges through the spillway, maximum reservoir surfaces near the crest of the dam, or overtopping of the embankment.

Special dam safety examinations do not address all aspects of the dam and appurtenances. Instead, these examinations focus only on specific and readily observable concerns and issues. The personnel performing these examinations should have technical expertise commensurate with the nature of the issue. For example, a qualified Geotechnical Engineer should provide inspection of new seepage conditions. An Examination Report is prepared following the examination and is typically consistent with the format and content used in the PR report.

D. Examination of Normally Inaccessible Features

Some dams have features that are normally inaccessible for visual observation during a routine examination. These features include, but are not limited to:

- Outlet works intake structure under the reservoir

- Outlet works conduit that is too small for safe entry

- Toe drain conduit that is too small for entry

- Outlet works conduit that is underwater

- Outlet works gatehouse that is unsafe to enter

- Outlet works or spillway stilling basin that is normally underwater

Special examinations should be performed to inspect these normally inaccessible features on a regular basis in accordance with the specified frequency within SOD’s Formal Evaluation Guidelines.

Inspections of these features must be performed with proper safety provisions, such as confined space entry and lock-out tag-out procedures. For conduits less than 36 inches in diameter, it is recommended that conditions be surveyed using Closed Circuit Television (CCTV) equipment. If a reservoir drawdown is not practical, then underwater structures, like outlet works intake structures, will require a dive inspection. Outlet works or spillway stilling basins may need to be pumped before inspections are made. An Examination Report is prepared following the examination and is typically consistent with the format and content used in the PR report.

Chapter 4: Risk Management

Risk management is the framework that informs and prioritizes SOD dam safety decision making. At the highest level, risk management encompasses risk analysis, risk assessment, risk control, and risk communication to inform all aspects of dam safety administration. Risk management is used to inform both routine and non-routine activities and is applied to all high- and significant-hazard potential dams to help normalize the priority of actions throughout SOD.

As stated in FEMA P-1025, the components of SOD's dam safety risk management process are provided below.

1) **Risk analysis (risk estimation)**: Risk analysis is the portion of the risk management process in which PFMs, structural performance, and adverse consequences are identified through a qualitative or quantitative procedure. Risk analysis forms the quantitative component of the RIDM process implemented by SOD. The basic objectives of a risk analysis are to:

    a. Develop a working set of PFMs addressing the key vulnerabilities of the facility, as understood by the risk analysis team based on their review of design, construction, and analysis information as well as other relevant information.

    b. Assign an occurrence probability estimate, termed the AFP, to each of the credible PFMs, or develop a convincing set of arguments that explain why the PFM is not considered credible.

    c. Assign a consequence (life loss for high-hazard potential dams) estimate to each of the credible PFMs and estimate the ALL for each PFM.

    The information needed to calculate the ALL and AFP for each PFM is generally obtained using an expert elicitation process.

2) **Risk assessment**: The process of examining the safety of a specific dam facility, making specific recommendations, and guiding dam safety decisions using information determined during the risk analysis phase. Risk assessment forms the interpretive component of the RIDM process. The basic objectives of risk assessment are to:

    a. Assign a *total risk estimate* (AFP and ALL) to the facility.

    b. Understand the key sources of uncertainty and their potential impact on confidence in the portrayal of risk.

    c. Support a decision to reduce or better understand the risk, or to take no further action at a given decision point.

    The basic unit in risk assessment is the individual reservoir or facility. Risks are identified and managed at the level of the individual facility which may include multiple retention structures impounding the same reservoir (e.g., a reservoir that is impounded by a main dam and one or more dikes).

3) **Risk reduction**: A selective application of appropriate techniques and management principles to reduce either the likelihood of an occurrence or its adverse consequences, or both. The primary objective of risk reduction measures is to implement actions that result in the successful mitigation of unacceptably high dam safety risks, resulting in residual risks that are less than applicable guidelines and standards. Risk reduction measures can include dam modifications, emergency preparedness actions, changes or restrictions to limit downstream PAR exposure (such as relocating a residence, or adding a larger culvert under a road), monitoring and surveillance, and intervening countermeasures, such as reservoir restrictions.

4.1 Risk Management Cycle

The risk management cycle ensures that up-to-date risk assessments, which provide valuable information for managing and prioritizing SOD activities throughout the portfolio of high- and significant-hazard potential dams, are maintained. Throughout the risk management cycle, risk is estimated or evaluated. The activities in the risk management cycle include:

1) **CRs**: CR teams are tasked with performing risk analyses for a dam or facility. This process requires a quantitative risk analysis that includes the determination of AFPs and consequences for credible PFMs. In most cases, the results from previous risk analyses can be reviewed and used to inform the updated analysis. Calculated risks are communicated in the CR using detailed descriptions, PFM sketches, the risk portrayal chart, and an assigned DSPR. Risk management considerations are documented in the form of recommendations.

2) **PRs**: PR teams review the most recent risk analysis and evaluate the need to update the risk analysis. Additional risk management considerations are documented in the form of recommendations.

3) **Annual Inspections**: Any issues identified during the Annual Inspection will be used to identify the need for updating existing risk estimates. This inspection is informed by the most recent risk analysis.

4) **IEs**: An IE is a highly detailed investigation that is typically used to resolve uncertainties identified during a preceding risk assessment. The IE typically includes a detailed quantitative risk analysis that is generally specific to PFMs that require additional detail prior to the advancement of risk reduction measures or a decision to take no further action. IE studies are undertaken on an as needed basis.

5) **Risk Reduction Verifications**: A risk analysis is performed to confirm the adequacy of planned risk reduction measures. These estimates are developed based on future conditions as described in rehabilitation designs or planning documents and are used to help assure the post-modification residual risk is below BIA’s accepted risk guidelines.

4.2 Risk Analysis

Although many SOD risk analyses will likely be similar, a scoping process should be conducted *before* initiating a risk analysis to identify any unique considerations that need to be included. Typically, the risk analysis process will include a site examination and thorough review of existing technical analyses and performance records. In many cases, additional technical analyses and field investigations will be needed to resolve uncertainties prior to beginning the PFMs and risk analysis.

It should be recognized that each dam is unique in terms of purpose, geologic and demographic setting, design, structure, operations, and consequences. While certain dams may be similar to other dams in type, design, and size, there are unique factors that need to be considered when identifying PFMs and when estimating risk.

Numerical risk estimates by themselves provide an incomplete basis for dam safety decision making. There are several factors that should also be considered, including the uncertainty and confidence in the risk estimates. The dam safety case provides supporting justification for the numerical risk estimates. A well-constructed dam safety case should include a discussion that supports and supplements the numerical risk estimates.

A. PFMs and Risk Analysis

In the PFMRA process, a team of experienced dam safety engineers enumerate and describe all PFMs for a dam including the relationship between each PFM and the consequences of failure that are relevant to satisfying the statement of purpose. A structured and systematic process should be followed to complete thorough PFM identification. SOD follows the steps outlined in Best Practices for Dam and Levee Safety Risk Analysis[9] throughout the PFMRA process. The list of PFMs is narrowed to a list of those that are credible or physically plausible.

During a risk analysis meeting(s), the list of credible PFMs should be further reduced to those PFMs that are likely to drive the total risk portrayal of the dam. The PFMRA team should evaluate these risk-driving PFMs only.

For each risk-driving PFM estimated by the team, the following steps should be followed:

1) Prepare a detailed, sequential description of the PFM under consideration from loading through initiation and dam breach. This description can include a preliminary event tree diagram. An event tree is a progression of logical events in a failure mode analysis. Visual aids, such as dam cross-sections showing the failure mode pathway and progression of the PFM should be included to help the team visualize and communicate the PFM. It is critical that all team members have a thorough understanding of the mechanism and progression of the PFM being considered.

2) Develop a list of the key factors that make an event more likely (adverse factors) and less likely (positive factors) for each node of the event tree. Based on these factors, the team will

[9] Best Practices in Dam and Levee Safety Risk Analysis, USACE and BOR, 2019

develop a range of consensus estimates for each node of the event tree that includes a high, low, and best-estimate value. This range will be used to calculate uncertainty in the resulting risk portrayal.

3) Multiply the estimate (or range of estimates) for each node of the event tree together to develop an overall AFP estimate (or range of estimates) for the PFM being evaluated. Spreadsheet tools or other risk estimating software can be useful in performing this task.

B. Development of Risk Model

A risk model is used to calculate the risk of dam failure. Typically, an event-tree model is used. The form of this model builds on the risk scoping, including the risk-driving PFMs and other scoping considerations. The event-tree model typically includes the following:

1) Probability distribution(s) of loading (hazard): The probability of the occurrence of floods and earthquakes which is established by using their annual exceedance probability (AEP) distributions.

   - In the case of earthquake hazards, the probability of coincident reservoir pool levels is also considered. The frequency associated with the reservoir loading is typically determined with a stage-duration curve that identifies percent of time the pool is expected to be above a selected threshold elevation.

   - For static PFMs, the probability distribution of hazard(s) is represented by a reservoir loading node, which accounts for the annual exceedance probability that the reservoir level (or levels) is at or above a selected threshold elevation determined by the risk evaluation team to impact the PFM.

   - For all PFMs, whether static, seismic, or hydrologic, the loading probability distributions are the first nodes of the event tree and should be determined with evidentiary support, including annualized reservoir frequency data, reservoir operations records, and seasonal considerations.

   - The probabilistic characterization of the static, seismic, or hydrologic loads must match the key attributes of the static conditions, earthquakes, and floods that best inform the risk-driving PFMs without double-counting coincident loading probabilities.

2) Conditional (system response) probability distributions: The remaining nodes of the event tree are conditional (system response) probability distributions. These nodes represent the responses of all the key components of the dam-reservoir system for all risk-driving PFMs over the entire range of loads.[10] For example, in the case of internal erosion event trees, these nodes typically include flaw exists and erosion initiates (sometimes separated into two nodes), unfiltered exit exists, void forms, upstream zone fails to self-heal, upstream zone fails to limit flows, intervention fails, and dam breaches.

[10] The Best Practices in Dam and Levee Safety Risk Analysis identifies the nodes of the event tree for common PFMs.

All nodes of the event tree, including each conditional (system response) probability distributions node as well as the initial reservoir rises/loading probability node, must take place for a dam failure to occur. The only exception to this rule is the "intervention fails" node. Intervention fails is a node that quantifies the probability of response actions arresting the PFM at any point throughout its progression.

3) Load partitioning: For loading node(s) of an event tree, several loading ranges and probabilities may need to be considered. For example, if the system response is expected to be significantly impacted by various reservoir elevations, then a load partitioning (binning) strategy should be used to develop the event tree. Load partitioning is also often required to adequately calculate risks for seismic and hydrologic PFMs. For example, if a PFM resulting from seismically induced liquefaction is to be represented, then the system response under different intervals of earthquake magnitude should be evaluated since the liquefaction response is sensitive to earthquake magnitude.

4) Dams in series: For cases with dams in hydraulic series on the same waterway, the combined effect may be considered in risk assessments. This is done by assigning the consequences associated with failure of downstream dams that are initiated by a failure of an upstream dam, to the upstream dam. No change to the probability of failure of the downstream dam is made because of the potential for its failure to be initiated by the failure of an upstream dam.

4.3 Estimation of Consequences

Assessing the magnitude of potential consequences that can occur following postulated dam failures scenarios is an important component of each risk analysis performed for SOD dams. Dam failures can lead to human life loss, economic damage, environmental damage, and damage to cultural heritage sites. In extreme cases, the consequences of dam failure can be catastrophic, resulting in large-scale life loss and widespread devastation.

Dam failure modeling is a critical component used to estimate the consequences associated with the failure of a dam. Dam failure analyses typically involve breach modeling, hydraulic routing, and mapping of the resulting dam failure flood. These analyses help to determine the flood severity corresponding to each dam failure scenario, and care should be taken to ensure that failure scenarios adequately represent the identified PFMs in terms of mechanism, progression, and magnitude. At some dams, severe consequences can result from heavy releases through appurtenant structures (such as high spillway flows).

Additional guidance on modeling, mapping, and estimating dam failure and non-dam-failure (NDF) consequences at SOD dams can be found in SOD's Guidelines for Hazard Potential Classification and Dam Failure Consequence Estimation.

A. Life Loss Estimation Factors

Life loss estimation for risk analysis requires an assessment of site-specific and failure-mode-specific factors. These factors are used to refine modeling parameters and assumptions that affect the potential for life loss. Factors that may impact life loss estimates resulting from failure of SOD dams include:

- Flood severity
- Floodplain geomorphology
- Time of day and seasonality considerations
- EAP effectiveness and emergency response times
- Proximity of emergency responders
- Existence and effectiveness of a local evacuation plan
- Hazard awareness
- Motorist or recreationalist PAR
- Mobility limited or vulnerable PAR
- Transportation options for evacuation
- Reluctance to evacuate
- Timeliness of warning communications
- Population density differences such as occupancy rates in residences and at group gatherings, including after-school activities

B. Life Loss Consequence Estimation Methods

Various approaches may be used to estimate life loss associated with floods and dam failures, and the appropriate approach for estimating life loss may vary among SOD dams. The BIA SOD Officer will choose the best approach for each dam's safety risk analysis. In most cases, life loss estimates for high-hazard potential dams should be developed based on BOR's Reclamation Consequence Estimating Methodology (RCEM), as documented in their Guidelines for Estimating Life Loss for Dam Safety Analysis[11] and/or USACE's LifeSim method[12]. Refer to SOD's Formal Evaluation Guidelines and Guidelines for Hazard Potential Classification and Consequence Estimation for more detailed information on consequence estimation.

[11] RCEM – Reclamation Consequence Estimating Methodology: Dam Failure and Flood Event Case History Compilation, BOR, 2015
[12] LifeSim: Life Loss Estimation User's Manual, USACE, 2021

C. Non-Life Loss Consequences

While the developed consequence estimates are generally constrained to the magnitude of estimated human life loss for each high-hazard potential dam's failure scenario, other direct and indirect non-life loss consequences may occur. Because life loss is not expected following the failure of significant- and low-hazard potential dams, risk analysis of these facilities requires consideration of non-life loss consequences, such as:

1) Economic Loss: Potential economic losses could include agricultural, recreational, and industrial facilities; roads, vehicles, machinery, other infrastructure, and property; and sources of capital and labor. Recognizing the paramount importance of protecting human life from dam failure, economic consequences will generally not be estimated for dam safety risk assessments for high-hazard potential dams. If significant economic damages such as the destruction of key structures or infrastructure are likely following dam failure, consideration of economic loss may be useful in aiding decision making.

2) Cultural Resource Loss: Dam failure has the potential to result in loss of cultural resources, such as historic Tribal dwellings, artifacts, or burials. Cultural consequences are difficult to quantify. However, if the loss of cultural resources is likely following a dam failure, this loss should be considered as part of the RIDM process.

3) Indirect and Other Consequences: Indirect and other consequences are not typically estimated for risk analysis of high- and significant-hazard potential dams. However, when warranted, other consequences (e.g., environmental or lifeline losses) may be considered.

Refer to SOD's Guidelines for Hazard Potential Classification and Dam Failure Consequence Estimation for additional information pertaining to the quantification and application of potential economic, cultural, indirect, and other losses.

4.4 Risk Analysis Calculations

The AFPs and the ALLs for the PFMs of a dam can be calculated after event trees and estimations of consequences have been developed.

A. AFP

The AFP for an individual PFM is obtained by multiplying the individual probabilities for each node of the event tree together. The AFP may be a discrete value if best estimate values are used throughout the various nodes of the event tree; however, in most cases, it will be a range of values based on the range of values estimated for the various nodes. An example *best estimate* for an individual PFM is shown in Table 3 on the next page.

Table 3: Example Estimate of AFP

Event Tree Node	AFP Best Estimate
Reservoir Rises Above Threshold Elevation	1.0
Flaw Exists and Erosion Initiates	0.0005
Unfiltered Exit Exists	0.95
Void / Erosion Pathway is Sustained	0.90
Flows Not Limited	0.30
Intervention Fails	0.50
Dam Breaches	0.99
Failure Mode AFP	**6.3E-05**

B. ALL

The ALL for an individual PFM is calculated by multiplying the AFP by the estimated life loss (N), as shown below:

$$\text{ALL} = \text{AFP} \times N$$

The ALL may be a discrete value if *best estimate* values are used for both the AFP and the estimated life loss; however, in most cases the ALL will be a range of values based on the range of values determined for the AFP or the estimated life loss.

C. Uncertainty

Uncertainty is the result of imperfect knowledge concerning the present or future state of the dam-reservoir system, hazards, factors affecting dam performance, or the magnitude of consequences associated with dam failure. It is important to consider the effect of uncertainty on the risk estimates. Typical sources of uncertainty with respect to AFP may include lack of knowledge regarding the dam’s construction (e.g., compaction, presence or lack of toe drains, filters, or embankment zones), soil properties, geologic or foundation conditions, and seismic or hydrologic loading. Typical sources of uncertainty with respect to estimated life loss (N) include numeric modeling limitations, variability in flood hydrodynamics, and reliability of PAR estimates due to variability within residences, vehicles, or recreation areas. The risk assessment should convey the extent and significance of any uncertainty.

4.5 Risk Assessment

Risk assessment is the process of examining the safety of a dam (risk analysis, inspections, and technical studies) and making specific recommendations. Recommendations may include additional or enhanced monitoring; additional investigations, evaluations, or analyses; remedial actions; or no additional actions. The required level of detail for all risk assessments should be determined based on the level of confidence needed to support pending dam safety decisions.

A dam safety risk assessment typically includes:

1) Supporting Investigations:

   - Conduct a site inspection.

   - Perform any technical analyses needed to adequately characterize impactful risks or resolve any unacceptable existing uncertainties.

2) Risk Analysis:

   - Perform the PFMRA and include all details required to support potential follow-up decisions or actions.

   - Develop and document the risk model:

     - Estimate loading probabilities

     - Estimate system response probabilities for loading and internal hazards

     - Estimate consequences

     - Calculate the risk considering any uncertainties

3) Risk Evaluation:

   - Evaluate the risk and compare to applicable guidelines.

   - Make recommendations and provide evidentiary support (*make the case*) for all resulting decisions.

4.6 Prioritization

SOD uses prioritization systems for high- and significant-hazard potential SOD dams. The prioritization systems provide a measure of commonality that helps determine the order risk reduction activities are performed. Funding is typically prioritized for dams that present the greatest life-safety risk.

A. High-Hazard Potential Dams Prioritization

Prioritization for high-hazard potential dams is informed by the best available information including the DSPR, as defined in the current version of BOR's Public Protection Guidelines: A Risk Informed Framework to Support Dam Safety Decision-Making.

The DSPR system is generally comprised of the following five categories of ratings:

DSPR 1 - Immediate Priority: Immediate actions are necessary to reduce the risk of failure, including both interim actions and the implementation of long-term risk reduction alternatives.

DSPR 2 - Urgent Priority: Expedited actions are likely needed to reduce the risk of failure, including the implementation of long-term risk reduction alternatives and serious consideration of interim actions.

DSPR 3 - High Priority: The identified dam safety deficiencies are a concern, and interim actions may need to be considered while ways of addressing the long-term risks are being evaluated.

DSPR 4 - Moderate Priority: The risks as portrayed indicate a potential concern, but interim actions beyond routine monitoring may not be needed to effectively manage them.

DSPR 5 - Low Priority: The PFMs identified at the facility do not present a significant concern, and risks can be effectively managed via routine monitoring.

The DSPR system provides portfolio-normalized guidance for determining the priority of taking various non-routine actions to address dam safety issues or deficiencies at dams. DSPRs should be assigned based on current understandings of a dam's risk. Changes to a DSPR assignment will be made when: 1) better dam information becomes available; 2) dam features are modified; or 3) potential dam safety issues are identified.

B. Significant-Hazard Potential Dams Prioritization

The prioritization system for significant-hazard potential dams will be developed at such time as funding for rehabilitation for significant-hazard potential dams becomes available. When it is developed, the prioritization system for significant-hazard potential dams should include consideration of the following:

- Potential for direct or indirect loss of life
- Potential for critical life support system losses
- Likelihood of failure
- Potential magnitude of cultural or environmental or economic losses
- Potential magnitude of loss of benefit (loss of water storage)

More details on prioritizing significant-hazard potential dams can be found in SOD's Formal Evaluation Guidelines.

4.7 Risk Communication

Risk communication is a two-way exchange of information and opinions about hazards and risks. It is a critical component of the RIDM process that should result in a better grasp of dam safety risks and better risk management. Risk communication is not a standalone component and must be integrated into all aspects of the risk management process. Effective risk communication helps to ensure that stakeholders are aware of potential outcomes and impacts from implemented risk management decisions.

4.8 Risk Control

Risk control involves dam safety actions to reduce risk and activities to identify issues before PFMs can initiate. The risk management cycle, as described above, is used to inform and prioritize dam safety decisions to reduce the greatest amount of risk with the fiscal resources available. Once a dam safety decision is made, a series of activities are initiated, which may range from risk reduction measures, actions to reduce identified uncertainties, or no action. The next chapter describes risk reduction measures in more detail.

Chapter 5: Risk Reduction and Dam Modification

Risk reduction measures implemented by SOD may include:

- Expedited or interim actions, such as operational and storage restrictions.
- Improved warning time to downstream populations through risk communication, EAPs (see Chapter 7), and EWS installation (see Chapter 8).
- Increased monitoring and observation.
- Modifications or restrictions to limit downstream PAR exposure (such as relocating a residence or adding a larger culvert under a road).
- Structural modifications to reduce the risks of dam failure.

Structural modifications often require significant investments in data collection, pre-design, design, and construction activities. These activities should only be initiated following the determination that non-structural risk reduction measures will not adequately address known dam safety risks, and no other viable option reduces risk to an acceptable level.

Where feasible, risk reduction measures are formulated as distinct actions that can be phased and prioritized to reduce risks as quickly as practicable and in a robust, transparent, and cost-effective manner for all SOD dams.

5.1 Expedited and Interim Actions

When a potential dam safety deficiency is identified, expedited or interim risk reduction actions may be warranted. Such actions often require urgency. Examples of expedited and interim risk reduction actions include:

- EAP activation
- Increased monitoring
- Reservoir draining or drawdown
- Temporary closure of roads, campgrounds, and recreation areas
- Providing additional spillway capacity
- Installation of temporary filters and drains
- Reservoir restrictions
- EWS installation
- Dam breaching

When the condition of the dam warrants an interim action, alternatives are developed and evaluated by a SOD team. The evaluation team typically consists of the Regional SOD Officer, the BIA SOD Officer, and appropriate technical specialists.

If an operational restriction is the appropriate course of action, the Regional SOD Officer will notify the Regional Director, BIA Agency Superintendent, and/or Tribal government. The Regional SOD Officer will document the implementation of the operational requirement or restriction. All operational changes, restrictions, or modifications should be integrated into the EAP as described in Chapter 7 of this handbook.

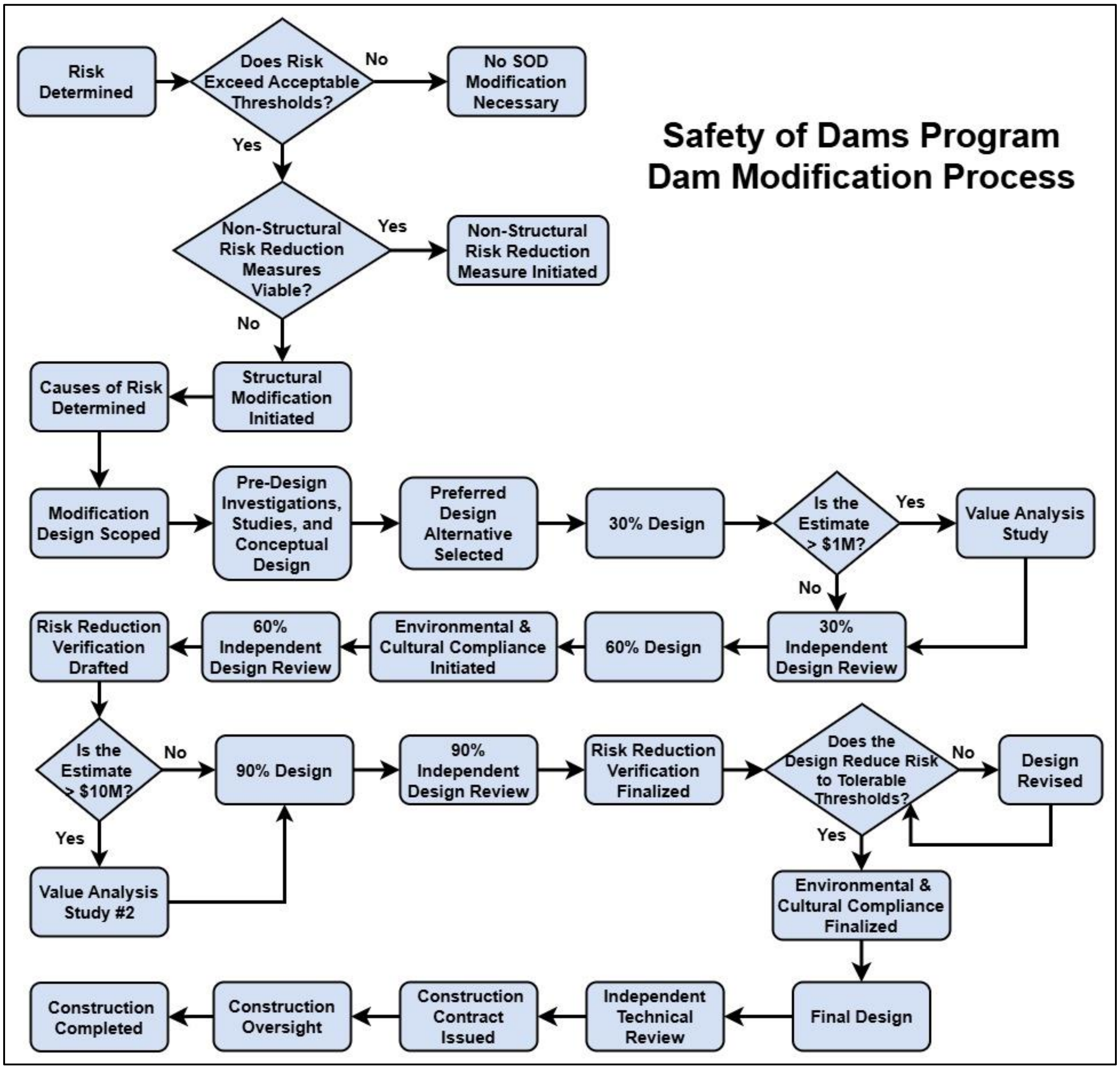
5.2 Dam Modification Process

When risk management priorities indicate dam modifications are needed, BIA initiates a sequence of design and construction steps. These steps include best management practices as the development of dam modification designs can be a complex process involving multiple features of a dam. Dam modification design often requires the involvement of dam safety professionals from a variety of disciplines that ensure all considerations are accounted for in the design. In all cases, only highly qualified and experienced dam safety professionals should be tasked with leading dam modification designs for SOD dams.

The dam modification design process begins by creating a scope for the dam modification that addresses the causes of the dam’s risk(s). Design steps include pre-design studies, several levels of design, value analysis studies, independent technical reviews, and risk reduction verification. Sections 5.3 and 5.4 of this handbook describe the pre-design studies and design steps in more detail. The environmental and cultural compliance and permitting, described in section 5.5, is initiated during the design process and is completed after the Final Design is approved. Once a Final Design is approved, the construction process can begin. Section 5.6 describes the construction process in more detail which includes procurement, construction-phase engineering, and final construction documents.

Figure 5 (next page) outlines the dam modification process as a flowchart.

Figure 5: Dam Modification Process Flowchart



5.3 Dam Modification Pre-Design Studies

Pre-design studies and investigations are required to adequately inform dam modification designs. These studies are used to provide additional data for identifying and evaluating conceptual design alternatives to reduce risk, and provide detailed data needed to support final design of preferred risk reduction alternatives. Prior to initiating any pre-design analysis, a thorough review of existing technical documentation, data needs, and sources of uncertainty should be performed.

The following are some of the investigations, guidelines, and analyses that are often needed to support elements of dam modification design:

- Field Investigations
- Design Guidelines
- Design Loading Conditions
- Engineering Analyses

A. Field Investigations

Field investigations are performed to develop and confirm data collected from the physical dam location that may influence dam modification designs or other dam safety analyses. More specifically, field investigations are often used to support dam analysis, risk analysis, and risk reduction design work at SOD dams. These investigations should address many different data needs and may involve the use of various specialty sub-contractors.

Prior to the initiation of any field investigations, the work is coordinated with the Tribe(s) to minimize cultural, environmental, and historical impacts, and access other potential impacts. In addition, all necessary permits and authorizations must be secured prior to initiating any field investigation. SOD complies with the National Environmental Policy Act (NEPA), the Historic Preservation Act, the Endangered Species Act, the Clean Water Act, Tribal Employment Rights Ordinances (TERO), and other applicable statutes and regulations. See section 5.5 of this handbook for more information on the permitting process. Project-specific evaluations and assessments are also performed to determine the appropriateness of a Categorical Exclusion (CE), Environmental Assessment (EA), or an Environmental Impact Statement (EIS).

Field investigations commonly performed at SOD dams include geologic reconnaissance, drilling exploration, test pit exploration, indirect investigation methods, site survey, and laboratory testing, and these are discussed in more detail below. The need and scope for each activity should be determined on a case-by-case basis for each project. Data collection field work requires Tribal permits, communication, and collaboration.

1) Geologic Reconnaissance: A field Geologist observes exposed geologic conditions in the areas of dam foundations and abutments, the reservoir rim, and potential borrow areas. Field measurements of exposed geologic features are made to prepare a geologic map. This work is considered non-intrusive and does not involve any excavations or boreholes. The deliverable is typically a geologic report that should include the following information:

    - Description of regional and site geology.
    - Identification of geologic hazards, including local and regional faulting, landslides, and ground subsidence.

- Site geologic map showing geologic units and any structural geology data (strikes and dips of bedrock discontinuities) of the dam, reservoir, and borrow areas measured during field reconnaissance.

- Assessment of suitability of potential borrow areas for project needs.

- Recommendations for subsurface exploration to supplement surface geology information, if appropriate.

2) Drilling Exploration: Drilling boreholes into the dam or natural ground is one method of exploring the subsurface conditions for engineering purposes. There are many reasons for drilling exploration, including:

   - Investigating the subsurface conditions in a dam, foundation, abutments, or potential borrow areas.

   - Obtaining soil and rock samples for classification and laboratory testing of engineering properties.

   - Performing field testing in the boreholes, such as Standard Penetration Testing (SPT), field permeability, down-hole geophysical testing, and field deformation.

   - Installing dam instrumentation such as piezometers, observation wells, and inclinometers.

   Drilling explorations should be performed in general conformance with BOR's Earth Manual.[13] The selection of the method of drilling should be determined based upon project requirements. However, special care should be used in drilling into an existing embankment dam to prevent hydro-fracturing and damage to the embankment. Drilling into an existing embankment dam should comply with the guidelines from BOR's Guidelines for Drilling and Sampling in Embankment Dams.

   All boreholes into an existing embankment dam and the underlying foundation should be supported using steel casing, augers, drilling mud, or other approved methods. Drilling of boreholes should be observed and logged continuously by a qualified Geologist or Geotechnical Engineer. All boreholes should be backfilled with a cement grout upon completion unless the boreholes will be used for dam instrumentation. At the completion of drilling, the locations of all boreholes should be surveyed.

   The deliverable for a drilling exploration plan is a Geotechnical Data Report that should include the following information:

   - Location plan of boreholes.

   - Description of method of drilling, sampling, and field testing.

[13] Earth Manual – Parts 1 and 2, BOR, 1998 and 1990

- Description of subsurface conditions, field observations, and any problems encountered during drilling.

- Evaluation of subsurface conditions relative to the objectives of the investigation.

- Detailed field logs and simplified drill logs with a legend.

- Results of all field test data, such as SPTs and field permeability.

- Results of all laboratory test data.

- Installation reports for any dam instrumentation such as piezometers and inclinometers.

- Conclusions and recommendations.

3) Test Pit Exploration: Excavating open test pits or test trenches is another method of subsurface exploration for engineering purposes. Reasons for test pit exploration include:

   - When exploratory boreholes are too small to observe subsurface features such as overall stratifications of soil and rock deposits, shear and fault zones, or sources of seepage.

   - Exposing a large cut face for evaluation to test potential fill.

   - When large bulk samples are required in a borrow investigation for laboratory testing such as compaction.

   - When test pits are adequately informative and more convenient than drilling boreholes.

   Test pit excavation should be continuously observed and logged by a qualified Geologist or Geotechnical Engineer. Test pits deeper than four feet should not be entered without adequate shoring.

   Upon completion, all test pits should be backfilled to their original ground surface. In a borrow investigation study, the materials excavated from the ground can be used as backfill, and compaction of the backfill is not required. The locations of all test pits should be surveyed at completion.

   The deliverable for a test pit exploration plan is a Geotechnical Data Report that includes the following information:

   - Location plan of all exploratory test pits.

   - Description of method excavation and backfill.

   - Description of subsurface conditions, including other field observations such as trench wall stability or groundwater inflow.

- Evaluation of subsurface conditions relative to the objectives of the investigation.
- Detailed field logs and simplified logs with a legend.
- Results of any field testing, such as field densities.
- Results of all laboratory test data.
- Conclusions and recommendations.

4) Indirect Investigation Methods: In contrast to subsurface investigation methods such as boreholes and test pits that involve determining subsurface conditions by collecting samples, indirect methods allow subsurface conditions to be investigated without obtaining samples. These methods may include the Cone Penetration Test (CPT), seismic refraction, seismic reflection, electrical resistivity, and geophysical survey methods. Such indirect methods have the advantage of being capable of providing subsurface information very rapidly, in a non-invasive way. These methods are potentially less costly than drilling or test pits, but there are also limitations. For dam safety investigations, indirect investigation methods may be used for:

   - Determining geologic structure, such as top of bedrock or stratigraphic boundaries of different layers.
   - Developing a continuous subsurface profile.
   - Determining excess pore water pressures, CPT tip resistances, and shear wave velocities for use in liquefaction analyses.
   - Locating subsurface features such as voids, buried pipes, and channels.
   - Determining depth to groundwater or sources of seepage.

   Indirect methods are most useful when they are combined with more direct methods of subsurface exploration such as boreholes and test pits.

5) Site Survey: Site surveys are typically performed to:

   - Obtain a topographic base map of the dam, reservoir, and vicinity for dam safety analysis, and to support design and construction of dam modifications.
   - Obtain reservoir bathymetry to establish current estimates of reservoir storage capacity.
   - Locate features of data collection such as boreholes, test pits, borrow areas, ordinary high water, and wetland limits.

- Install benchmarks and survey baselines for dam instrumentation monitoring and construction survey controls.

- Establish the location of legal property boundaries and easements.

- Measure configurations of existing structures such as outlet works, spillways, and diversion inlet and outlet canals.

- Measure ground cross-sections and key structure elevations downstream of the dam for hazard potential classification analysis, dam breach inundation analysis, and preparation of inundation maps.

The method and accuracy of the survey is based on the size of the site and project requirements. The deliverable for a site survey is typically a site map. A site map suitable for design and construction of dam modifications should contain the following information:

- New on-site survey control points with vertical datum referenced to the North American Vertical Datum, and the horizontal datum referenced to the applicable State Plane or Universal Transverse Mercator (UTM) zone.

- Topographic and bathymetric contours either in 1- or 2-foot contours, depending on the topographic relief.

- A topographic map or digital elevation model, prepared in both hard copy and electronic format.

- Property, easement, right of way, and other legal boundaries relevant to the project.

- Key existing features of the dam and appurtenances, such as limits of trees, riprap, pavements, dam instrumentation, spillways, outlet works, inlet and outlet conveyances, sinkholes, depressions, buried and exposed utilities, ordinary high water, wetland limits, etc.

6) Laboratory Testing: Laboratory testing is typically performed to:

- Obtain index properties of soil and rock samples to support field descriptions observed in a drilling or test pit exploration.

- Obtain index and engineering properties of the embankment, foundation, and borrow materials for geotechnical analysis and design.

- Evaluate the suitability of concrete aggregates, potential for alkali-silica reaction, and potential for freeze-thaw deterioration in concrete.

- Obtain concrete strength data.

- Gain quality assurance testing of earthwork, concrete, and other materials during construction.

The types and scope of laboratory tests are determined based on project requirements. Laboratory tests should be performed in accordance with methods and procedures in the American Society for Testing and Materials (ASTM) or other appropriate standards. Results for these tests should be included in the Field Investigation Report, Borrow Investigation Report, Design Report, or Construction Report, depending on the purpose of the testing.

B. Design Guidelines

Conceptual and Final Designs for risk reduction should be conducted in accordance with current federal guidelines and best practices. All BOR Design Standards and FEMA Technical Manuals can be found on the BOR website and the FEMA website, respectively. For reference, selected design guidelines are listed below:

- Design Standard No. 13: Embankment Dams, BOR, 2011 – present

- Design Standard No. 14: Appurtenant Structures for Dams (Spillways and Outlet Works), BOR, 2011 – present

- Filters for Embankment Dams, Best Practices for Design and Construction, FEMA, 2011

- Plastic Pipes Used in Embankment Dams, Best Practices for Design, Construction, Problem Identification, and Evaluation, Inspection, Maintenance, Renovation, and Repair, FEMA, 2007

- Conduits Through Embankment Dams, Best Practice for Design, Construction, Problem Identification and Evaluation, Inspection, Maintenance, Renovation, and Repair, FEMA, 2005

- Design Standard No. 2: Concrete Dams, BOR, in progress

- Design of Gravity Dams, BOR, 1976

- Design of Arch Dams, BOR, 1977

- Design Manual for Small Roller Compacted Concrete (RCC) Dams, Portland Cement Association, 2003

- Design Manual for RCC Spillways and Overtopping Protection, Portland Cement Association, 2021

- Roller-Compacted Concrete — Design and Construction Considerations for Hydraulic Structures, BOR, 2017

- Roller-Compacted Concrete, Engineering Manual 1110-2-2006, USACE, 2000

C. Design Loading Conditions

Dam modification designs need to ensure acceptable performance under normal operating, flood, and earthquake loading conditions. The static, seismic, and hydrologic loading conditions for SOD dams are described below.

1) Static Design Loading Conditions: These conditions are generally associated with typical reservoir surface elevations, such as the normal reservoir pool (the highest annual elevation associated with normal operations). The hydrostatic load under a normal pool is used to analyze: 1) slope stability of the embankment; 2) seepage conditions in the dam, abutments, and foundation; 3) sizing of the internal filters and drains; and 4) design of hydraulic structures.

2) Seismic Design Loading Conditions: The seismic performance and stability of existing dams, new dams, and for dam modifications is evaluated through risk analysis using a range of seismic loads from extreme large events to smaller earthquakes. For modification and design of SOD dams with life loss potential, the typical design seismic loading criteria is the earthquake with a 10,000-year return period.

   Under certain circumstances, the BIA SOD Officer may approve the modification of the design seismic load based on the estimated loss of life, the capacity for emergency response, dam operations, proximity to structures, and other considerations. For example, a dam that is upstream of critical infrastructure or vulnerable population centers may require an increase in seismic design loads, which would likely be established through a detailed site-specific seismic hazard analysis. Alternatively, the loading condition for design may be reduced from the standard criteria if an analysis can demonstrate that the seismic risks are below guidelines.

3) Hydrologic Design Loading Conditions: The hydrologic loading condition for the analysis of existing dams, design of dam modifications, and new dams is the Inflow Design Flood (IDF). The Federal Guidelines for Dam Safety define the IDF as the “flood hydrograph used in the design of a dam and its appurtenant works particularly for sizing the spillway and outlet works, and for determining maximum storage, height of dam, and freeboard requirements”.[14]

   The magnitude of the IDF is generally selected based on the hazard potential classification of a given dam. For example, the prescribed IDF for a high-hazard potential dam is the Probable Maximum Flood (see Table 4, next page). However, factors such as incremental flood hazard, population at risk, EM, proximity to structures, cultural resources, and operations could result in IDFs that differ from the prescriptive standards identified in Table 4.

[14] FEMA P-94, Selecting and Accommodating Inflow Design Floods for Dams, 2013

Table 4: IDF Requirements for SOD Dams

Hazard Potential Classification	Inflow Design Flood
High-Hazard	Probable Maximum Flood[(1)]
Significant-Hazard	0.1% Annual Chance Exceedance Flood (a 1,000-year return period)[(1)]
Low-Hazard	0.2% Annual Chance Exceedance Flood (a 500-year return period)[(2)]

(1) Incremental consequence analysis or risk-informed decision-making may be used to evaluate the potential for selecting an IDF lower than the prescribed standard with BIA SOD Officer approval. An IDF less than the 0.2% annual chance exceedance flood (a 500-year return period) should not be used.

(2) In accordance with the Federal Flood Risk Management Standard[15].

SOD may perform an Incremental Flood Hazard Assessment (IFHA) or risk-informed analysis to select an IDF below the specified magnitude in Table 4 with approval from the BIA SOD Officer. When warranted, engineers can perform additional investigations using advanced analytical tools and methods to evaluate incremental consequences and dam failure probabilities more precisely. This information can be used to select an IDF that reduces risk to the public without spending limited resources on conservative designs that do not significantly reduce flood risk. The IDF may also be reduced if the calculated risk under the proposed hydrologic loading conditions is below applicable guidelines. In all cases, the IDF should not be reduced to a flood magnitude lower than 0.2% AEP (a 500-year return period). These analyses should be performed in accordance with BIA's Flood Hydrology Guidelines.

D. Engineering Analyses

Several engineering analyses need to be performed on dam modification designs to ensure acceptable performance under the loading conditions described in the previous section. The most common analyses are described below.

1) Slope Stability Analysis: The static stability of an embankment dam is determined by slope stability analysis. Results of the slope stability analysis are used to evaluate the PFMs associated with the static stability of the dam embankment and foundations. The analysis is performed in conformance with BOR's Design Standard No. 13: Embankment Dams, Chapter 4: Static Stability Analysis, or similar accepted standards. Representative cross-sections of the embankment and foundations are typically analyzed under the following loading conditions:

    - Steady-state seepage condition: This loading condition corresponds to the long-term condition where the internal phreatic surface in the embankment is fully developed and stabilized under the normal reservoir pool.

[15] Federal Flood Risk Management Standard, FEMA, 2024

- Flood condition: This loading condition corresponds to a temporary elevated reservoir pool associated with the onset of a flood event where the internal phreatic surface within the embankment may exceed normal levels.

- Rapid drawdown condition: This loading condition is used to evaluate the resulting slope-stability of the upstream embankment slope following the rapid removal of the reservoir pool.

- Post-earthquake condition: This loading condition is used to evaluate the resulting slope stability of an embankment dam under normal loading following a significant seismic event.

- End of construction: This loading condition corresponds to the short-term condition in the embankment and foundation at the end of construction, either for risk reduction modifications or new dam construction. The reservoir pool and phreatic surface under end of construction are determined on a case-by-case basis.

Properly selected dimensions and material properties of the embankment and foundation should be used in the analysis for the different loading conditions. In general, the shear strengths (both drained and undrained) should be selected based upon: 1) rate of loadings; 2) laboratory strength tests; 3) field data; 4) empirical correlations; and 5) judgment and experience. The basis of the analyzed cross-sections and selection of material properties for the analysis should be documented in a technical memorandum or report.

2) Seepage Analysis: This analysis is performed to evaluate seepage-related performance issues and PFMs of the embankment, abutments, and foundation. The analysis will obtain data for design of seepage control and seepage reduction provisions such as cutoffs, filters, and drains. The analysis should conform to BOR's Design Standard No. 13, Embankment Dams, Chapter 5: Protective Filters and Chapter 8: Seepage, or similar accepted standards. This analysis typically includes the following information:

- Determining internal hydraulic gradients and exit hydraulic gradients from seepage flows in the embankment and foundation.

- Determining the phreatic surface and piezometric pressures in saturated flow zones.

- Determining potential uplift pressures.

- Determining quantities of flows.

- Evaluating and designing seepage cutoffs, seepage barriers, filters, and drains.

- Evaluating filter compatibility and piping potential in the embankment and foundation in saturated flow zones.

Seepage analysis can be performed using numerical methods. Regardless of the method of analysis, reasonable material parameters should be used. The analysis is typically supported by laboratory data such as gradation curves and Atterberg Limits to the extent possible.

3) Seismic Analysis: These analyses should be performed to evaluate the performance of the dam and foundation materials during the selected earthquake events. Seismic analyses should comply with the requirements of BOR’s Design Standard No. 13: Embankment Dams, Chapter 13: Seismic Design and Analysis, or similar accepted standards. Typical seismic analyses include:

- Susceptibility to liquefaction: The embankment and foundation soils should be evaluated for liquefaction susceptibility for a range of seismic events determined by a Probabilistic Seismic Hazard Assessment (PSHA), or similar means. Potentially liquefiable soils should be identified based on design and construction records, subsurface investigations, laboratory data, and other evidence. In addition, the continuity of potentially liquefiable materials should be determined.

- Post-earthquake stability analysis: A slope stability analysis should be performed on dams containing potentially liquefiable embankment or foundation materials, or other materials which may experience significant strength loss during an earthquake (for example, clay or clayey materials). The post-earthquake analysis is a static analysis using estimated residual undrained shear strengths. The post-earthquake residual strengths should be suitably selected to include loss in shear strength caused by the earthquake shaking.

- Seismic deformation analysis: A seismic deformation analysis should be performed to evaluate permanent deformations of the embankment. Such an analysis is appropriate even when the embankment and foundation would not liquefy sufficiently or otherwise experience sufficient strength loss to cause slope instability. Large seismic deformations may impair safe operation by causing a loss of freeboard, which could allow the reservoir to overtop the dam. Such deformation could also form cracks in the dam that would lead to internal erosion, or cause damage to appurtenant structures.

4) Hydrologic Analysis: Hydrologic analysis is typically required to determine the IDF and to evaluate the performance of SOD dams when subjected to various hydrologic loadings, including extreme flood events. Hydrologic analysis for SOD dams generally requires an evaluation of a full range of hydrologic loading conditions. AEPs are typically assigned to the developed peak discharge estimates to better relate the modeled hydrologic loadings to risk.

   Hydrologic analysis performed for SOD dams generally requires the use of one of the following modeling methods: rainfall runoff modeling, flood frequency analysis, or risk-informed flood determination. In all cases, these analyses should be performed in conformance with BIA’s Flood Hydrology Guidelines unless otherwise approved by the BIA SOD Officer.

- Rainfall-runoff Analysis: A method in which flood hydrographs are generated by simulating the drainage basin response to specified precipitation events. Rainfall-runoff analysis typically requires the development of several hydrologic parameters. These parameters include: 1) precipitation depths; 2) duration and distribution; 3) physical basin characteristics; 4) basin unit hydrographs; 5) antecedent moisture conditions and snow cover/frozen ground; 6) infiltration and other surface water losses; 7) stream baseflow; and 8) stream routing parameters. Where possible, rainfall-runoff parameters should be verified with historical flood data. Rainfall-runoff analysis will be performed in general conformance with BOR's Design Standard No. 14: Appurtenant Structures for Dams (Spillways and Outlet Works), Chapter 2: Hydrologic Considerations and USACE's Engineering Manual 1110-2-1417, Flood Runoff Analysis.

- Flood Frequency Analysis: A technique of reservoir inflow approximation from stream gauge data that may only be used in place of rainfall-runoff analysis in cases with pre-approval from the BIA SOD Officer. This is a procedure for computing the AEPs from observed discharge values recorded from streamflow gauging stations. Flood frequency analysis results are site-specific. The type of data and the record length used in the analysis determine the efficacy and credibility of extrapolated flood estimates. Flood frequency analysis should be performed in conformance with BOR's Design Standard No. 14: Appurtenant Structures for Dams (Spillways and Outlet Works), Chapter 2: Hydrologic Considerations and USACE's Engineer Manual 1110-2-1415, Hydrologic Frequency Analysis.

- Risk-informed Flood Determination: A method in which a site-specific evaluation of the probability of hydrologic events and performance of the dam during those events can be used to inform a quantitative risk assessment and select an appropriate IDF. These analyses can also include detailed evaluation of the social, economic, and environmental consequences of failure. Such an assessment requires an evaluation of a full range of hydrologic loading conditions and possible dam failure mechanisms tied to consequences of failure. Estimates of hydrologic loading occurrence frequencies, relative likelihoods of possible levels of response and damage, and various components of cost and consequences are assessed. Additional information regarding risk-informed flood determination can be found in BIA's Flood Hydrology Guidelines.

Hydrologic analyses should also consider the impacts of foreseeable future land use conditions, changes to hydrologic data, and snowmelt. While limited information is currently available to predict changes to extreme precipitation and flood estimates, hydrologic analyses should consider the best available guidance to assure that relevant considerations are accounted for. Similarly, altered future land use conditions resulting from wildfires, land development, and other causes has the potential to significantly impact the runoff generated by some watersheds. Hydrologic analyses should evaluate the need to consider changed land use conditions and account for potential impacts to the study results.

5) Hydraulic Analysis: Following the development of the desired dam failure and NDF flood hydrographs, downstream hydraulic modeling can be conducted to determine the expanse and flow properties of the resulting flood wave(s). These models are typically two-

dimensional (2D) or a 2D/one-dimensional (1D) composite model based on the requirements of a dam and downstream reach. In some cases, 1D hydraulic modeling may be acceptable; this exception will be determined in coordination with the BIA SOD Officer on a case-by-case basis. Computerized hydraulic modeling should be conducted using USACE's Hydrologic Engineering Center's River Analysis System (HEC-RAS)[16] unless otherwise approved by the BIA SOD Officer.

6) Incremental Flood Hazard Assessments and Risk-Informed Flood Hazard Analysis: The IDF may be determined using IFHA or risk-informed flood hazard analysis when approved by the BIA SOD Officer. The IDF selected using incremental consequence analysis is the flood above which there is a negligible increase in downstream water surface elevation, velocity, and/or consequences due to failure of the dam when compared to the same flood without dam failure. Alternatively, risk analysis can be performed to determine the IDF if it can be demonstrated that the calculated risk under the hydrologic loading conditions is below the guidelines for risk reduction. In all cases, IDFs determined using risk analysis should be developed in consultation with, and with approval from, the BIA SOD Officer. The IDF for any dam should not be reduced to a flood magnitude lower than 0.2% AEP (a 500-year return period).

7) Reservoir Flood Routing: Reservoir routing of floods identified through hydrologic analysis, including the IDF, is used to determine maximum reservoir water surface (MRWS) elevations and reservoir outflows corresponding to each flood event. Reservoir routing requires accounting for volumes of inflow, storage, and reservoir discharges. The level-pool reservoir routing method is typically used to determine the time-dependent pool elevations. However, in some cases, dynamic channel routing may be appropriate to account for variations in pool levels along the reservoir length.

   Reservoir routing requires the use of data derived from reservoir elevation-storage tables and elevation-discharge tables. Reservoir elevation-storage tables should be based on the best available topographic data and recent bathymetric surveys. Any projected loss of storage from sedimentation should be accounted for. At a minimum, the reservoir elevation-storage table should include elevations above the normal maximum pool to account for flood surcharge. Reservoir elevation-discharge tables should account for all applicable spillways and release facilities (such as outlets or powerhouse facilities). In most cases, releases from low-level outlet works and similar appurtenances are not used to route the IDF through the reservoir, unless otherwise approved by the BIA SOD Officer. Flows over the dam crest should be calculated to estimate overtopping depths and durations in cases where the reservoir outflow exceeds the discharge capacity of the spillway(s).

8) Spillway Hydraulics and Discharge Capacity: Discharge capacity of a spillway is determined by hydraulic analysis using manual or computer-based computation methods. Results of the hydraulic analysis are used to develop an elevation-discharge relationship for the spillway(s). The elevation-discharge relationship for the spillway(s) is used in routing the inflows through the reservoir and spillway(s) to determine the resulting maximum pool elevation. The hydraulic analysis should be performed in conformance with BOR's Design Standard No. 14:

[16] Information on HEC-RAS is located on the USACE's website here: www.hec.usace.army.mil/software/hec-ras/

Appurtenant Structures for Dams (Spillways and Outlet Works), Chapter 3: General Spillway Design Considerations, BOR's Design of Small Dams, Chapter 9: Spillways, USACE's Engineer Manual 1110-2-1603, Hydraulic Design of Spillways, or alternate standards approved by the BIA SOD Officer.

Hydraulic analysis of spillways typically includes the following:

- Approach conditions
- Crest discharge coefficients, accounting for crest submergence
- Abutment and pier effects
- Gate operations and obstructions (if applicable)
- Hydraulic and energy grade lines
- Flow regimes (critical, subcritical, supercritical, and transitions)
- Chute hydraulics
- Terminal structures
- Tailwater conditions

Spillway chute analysis should also consider:

- Velocity and depth of flow
- Air entrainment of the flow
- Pier and abutment waves
- Floor and wall pressures
- Super elevation of the flow surface at curves
- Standing waves due to the geometry of the chute

Terminal structure analysis should also consider:

- Site-specific requirements
- Magnitude of energy to be dissipated
- Duration and frequency of spillway use

The hydraulic analysis of terminal structures should be performed in conformance with BOR's Design Standard No. 14: Appurtenant Structures for Dams (Spillways and Outlet Works), Chapter 3: General Spillway Design Considerations, or alternate standards approved by the BIA SOD Officer.

Hydraulic analyses of spillways can be performed using computerized numerical methods. The basis and results of the hydraulic design and selection of design parameters for the analysis must be documented in a technical memorandum or report.

9) Outlet Works Hydraulics and Discharge Capacity: Discharge capacity of an outlet works is determined by hydraulic analysis using manual or computer-based computation methods. Results of the hydraulic analysis are used to develop an elevation-discharge relationship for the outlet works for reservoir control operations and for evacuation analysis.

Hydraulic analysis of flow through outlet works should consider two flow conditions: 1) open channel flow in a conduit; and 2) pressure flow when the conduit is flowing at full capacity. The hydraulic analysis of outlet works should be performed in general conformance with BOR's Design Standard No. 14: Appurtenant Structures for Dams (Spillways and Outlet Works), Chapter 4: General Outlet Works and Design Considerations, BOR's Design of Small Dams, Chapter 10: Outlet Works, USACE's Engineer Manual 1110-2-1602, Hydraulic Design of Reservoir Outlet Works, or alternate standards approved by the BIA SOD Officer.

Hydraulic analysis of the outlet works should include the following:

- Control crest and orifice discharge coefficient(s)
- Friction losses
- Minor losses
- Control device losses and discharge coefficients
- Hydraulic and energy grade lines
- Air vents and cavitation
- Terminal structures
- Tailwater conditions

Air vents should be included in all outlet works that utilize control devices and are subject to sub-atmospheric pressure. An air vent is required for each control device. The analysis of outlet works air vents and air-water flow should be performed in conformance with DOI's Engineering Monograph No. 41, Air-Water Flow in Hydraulic Structures, or alternate standards approved by the BIA SOD Officer.

Terminal structures should be included for all outlet works that have the potential for high velocity discharges. Hydraulic analysis of outlet works terminal structures or energy dissipators are generally dependent upon site-specific conditions and the magnitude of energy to be dissipated. The hydraulic analysis of outlet works terminal structures should be performed in conformance with BOR's Design Standard No. 14: Appurtenant Structures for Dams (Spillways and Outlet Works), Chapter 4: General Outlet Works and Design Considerations, BOR's Water Resources Technical Publication No. 24, Hydraulic Design of Stilling Basins for Pipe or Channel Outlets, FEMA's P-679 Technical Manual: Outlet Works Energy Dissipators,[17] or alternate standards approved by the BIA SOD Officer.

Hydraulic analysis of outlet works can be performed using computerized numerical methods. The basis and results of the hydraulic design, and selection of design parameters for the analysis, must be documented in a technical memorandum or report.

10) Reservoir Evacuation: This analysis is performed to evaluate the capability of an existing or planned outlet works to reduce failure risk by adequately allowing for reservoir drawdown within prescribed time periods during a dam incident or in advance of certain forecast flood events. The outlet works should be sized in general accordance with the evacuation requirements outlined in one of the following:

- Design Standard No. 14: Appurtenant Structures for Dams (Spillways and Outlet Works), Chapter 4: General Outlet Works Design Considerations, BOR, 2022 – present
- Technical Memorandum No. 3: Criteria and Guidelines for Evacuating Storage Reservoirs and Sizing Low-Level Outlet Works, BOR, 1990
- Other outlet evacuation criteria documents

In every case, determination of the appropriate reservoir evacuation criteria should be developed in collaboration with the BIA SOD Officer. The criteria used to determine the appropriate outlet works evacuation requirements may be waived or modified based on sufficient justification, as determined in collaboration with, and approved by, the BIA SOD Officer.

The maximum duration outlet evacuation criteria for a high-hazard potential dam, as measured from the normal water surface elevation, are:

- Five days to release the uppermost five feet of the reservoir pool
- Seven days to release 50% of the reservoir volume
- 14 days to release 85% of the reservoir volume

[17] FEMA P-679, Technical Manual: Outlet Works Energy Dissipators Best Practices for Design, Construction, Problem Identification and Evaluation, Inspection, Maintenance, Renovation, and Repair, 2010

The maximum duration outlet evacuation criteria for a significant-hazard potential dam, as measured from the normal water surface elevation, are:

- 7.5 days to release the uppermost five feet of the reservoir pool
- 10.5 days to release 50% of the reservoir volume
- 21 days to release 85% of the reservoir volume

For the evacuation analysis, an appropriate outlet works discharge rating curve should be used, depending on the anticipated conditions and reservoir operation. The basis and results of the reservoir evacuation analysis must be documented in a technical memorandum or report.

11) Freeboard and Wave Runup: Freeboard is the distance between a given reservoir water surface elevation and the dam crest. Freeboard is typically included in dam designs to better ensure a sufficient height of dam above the MRWS elevation to mitigate the potential for overtopping due to wind-generated wave runup or seismically induced slope failures. The minimum freeboard required at a dam is the distance from the MRWS elevation (typically corresponding to the reservoir surface during the IDF) and the top of the dam.

The anticipated wave runup should be determined for dams to evaluate the required freeboard. Wave runup is used to size riprap for wave erosion protection on the upstream slope of the embankment. Wave runup is influenced by several factors, including:

- Wind velocity and duration
- Wave height and velocity
- Wind direction with respect to the dam's orientation
- Reservoir depth
- Fetch length
- The characteristics of the upstream face (for example, the slope of and type of protection on the upstream face)

The basis and results of the wave runup and riprap sizing must be documented in a technical memorandum or report. The freeboard and wave runup should be determined in accordance with BOR's Design Standard No. 13: Embankment Dams, Chapter 6: Freeboard unless otherwise approved by the BIA SOD Officer. The sizing of riprap for upstream slope protection should be performed in accordance with BOR's Design Standard No. 13: Embankment Dams, Chapter 7: Riprap Slope Protection unless otherwise approved by the BIA SOD Officer.

12) Engineering Analysis of Structural Issues: Structural analyses of appurtenant structures and concrete gravity dams should be performed to evaluate the internal stresses, sliding stability, and overturning stability under usual, unusual, and extreme loading combinations. In general, structural analysis of appurtenant structures and concrete dams should comply with BOR's Design of Small Dams and other applicable standards as determined by the BIA SOD Officer. The determination of usual, unusual, and extreme loading combinations is based on the static, hydrologic, and seismic loading conditions, as follows:

- Usual loading combinations: Hydrostatic load at normal reservoir level, with appropriate dead loads, uplift pressures, sediment, ice, and tailwater.

- Unusual loading combinations: Hydrostatic load at maximum reservoir level during the IDF, with appropriate dead loads, uplift pressures, sediment, and tailwater.

- Extreme loading combinations: Usual loadings plus the effects of the design earthquake, including hydrodynamic load of the reservoir, and horizontal and/or vertical pseudo-static components of the dead loads.

5.4 Design Process

The design process used by SOD provides for risk reduction-based decision making in concert with economic efficiency.

A. Conceptual Design

Conceptual designs are intended to develop, evaluate, and present alternatives to resolve or mitigate deficiencies at SOD dams. During conceptual design, a preferred alternative is selected based on the available information. This may include a review and reassessment of risk, engineering analyses, and an evaluation of the alternatives. The design criteria for conceptual designs are based on current industry standards and SOD policies. All viable alternatives for resolving and mitigating potential dam safety deficiencies are investigated and documented in a Conceptual Design Report.

When developing designs and risk reduction estimates, future growth in the downstream inundation area, projected changes to the existing hydrologic or seismic loading estimates, and potential changes in state of the practice methods should be considered. Due to the potential for altered future land use conditions resulting from wildfires, land development, increased PAR and other causes, the design team should also evaluate the adaptability of conceptual design alternatives to future dam modifications.

In addition to addressing the PFMs, the design team should also consider addressing non-dam safety issues that affect the benefits provided by the dam. For example, if significant reservoir storage capacity has been lost due to sedimentation, or if a change in the configuration of the dam could restore or improve the benefit provided by the dam, then these issues should be evaluated as a conceptual design alternative.

Risk reduction alternatives are investigated and documented during the conceptual design phase. The Conceptual Design Report should present sufficient information on all viable alternatives, including: 1) drawing layouts of each concept; 2) proposed construction schedule; 3) key permitting issues; 4) constructability considerations; and 5) conceptual-level cost estimates to enable selection of a preferred alternative for development of Final Designs.

The conceptual designs are developed to define the initial alternatives that will be evaluated during the NEPA process. Environmental impacts are addressed in the NEPA compliance document. NEPA compliance may be initiated during this phase of the design process.

Key steps in the conceptual design study may include the following:

- Establishing design criteria and loading conditions.

- Formulating and evaluating various modification design alternatives, including design analysis.

- Acquiring field and laboratory test data, as required, to support design alternatives.

- Performing risk reduction analysis to document that the modifications adequately reduce the risk of dam failure for the identified PFMs.

- Preparing conceptual design drawings and cost estimates for the alternatives.

- Discussing and evaluating the advantages and disadvantages of alternatives.

- Recommending a preferred alternative for Final Design.

- Preparing a Conceptual Design Report, which documents the design criteria, basis of design, evaluation of alternative concepts, discussion of advantages and disadvantages, risk reduction analysis, construction cost estimate, and conclusions and recommendations.

- Completing an independent technical review of the conceptual design.

- Performing value analysis in accordance with the requirements of DOI’s 369 DM 1: Value Analysis – General Criteria and Policy.

B. Independent Technical Review (ITR)

In accordance with the Federal Guidelines for Dam Safety, an ITR is required for every dam modification or construction project where failure of the modified or completed dam would result in a significant threat to life or property. The review should be conducted by qualified engineers and other technical experts who are not involved in the design of the project. The ITR reviewer(s) should remain involved throughout construction of the project to the extent possible.

ITRs should achieve the following objectives:

- Ensure that all options have been adequately considered, and the appropriate solution is adopted.
- Evaluate the technical feasibility and identify any fatal flaws of alternative concepts.
- Assess whether the designer has adequately characterized the project site.
- Identify any problems with constructability of proposed construction methods.
- Identify any construction risks associated with construction safety, potential for claims, disputes, and delays.
- Review the estimated construction costs to determine whether they are appropriate.

ITR comments should be responded to by the designer in writing. All review comments should be satisfactorily addressed before finalizing the construction documents. During construction, the ITR members should be engaged and available for consultation to the extent possible.

C. Value Analysis (VA)

VA is the process of identifying potential value enhancements, cost savings, or improvements on a particular design feature while meeting the same technical criteria, intent, and project objectives used for design of the project. The DOI's 369 DM 1: Value Analysis – General Criteria and Policy outlines requirements for VA studies. At the time of this publication, 369 DM 1 requires all risk reduction modifications that will have an estimated construction cost of more than $1 million to undergo a design-stage VA study, and that two VA studies (conceptual and design stages) are required for projects with estimated construction costs over $10 million. The current VA criteria from 369 DM 1 should be confirmed prior to implementation of a BIA SOD construction project. The analysis may be performed in accordance with BOR's Value Program Handbook or similar accepted standards.

VA studies are performed near the end of the conceptual design phase, and prior to the start of the Final Design. It is important that VA ideas are compared with the original design features (the baseline) to evaluate cost avoidance of VA proposals. Each design concept or alternative is evaluated to identify potential cost savings to the project. The review team documents the results of the VA study in a report. The designer is required to respond to the recommendations given in the report. The designer must prepare an accountability report prior to initiating the Final Design. The accepted recommendation from the VA study should be integrated into the Final Design at the direction of the BIA SOD Officer or their appointed representative.

Specific steps in the VA study include:

- Presentation of the conceptual design concepts by the designer to the VA team.
- Identification and evaluation of VA ideas by the VA team.
- Preparation of the VA report and presentation of the VA ideas to the designer.
- Preparation of the accountability report by the designer on VA recommendations.

D. Risk Reduction Verification (RRV)

RRV is the process of verifying that the residual risk of a proposed dam rehabilitation design will meet program goals. Any modification intended to address a particular PFM should not increase the overall dam safety risk by creating new PFMs, increasing the probability that other existing PFMs occur, or increasing the estimated consequences. A diverse team performs an RRV study following the general risk analysis methodology adopted by BIA. Typically, at the 60- or 90-percent milestone, the team performs a PFMRA workshop based on the design. Following the workshop, the design team is then responsible for preparing an RRV Report that summarizes the findings of the PFMRA, including any necessary changes to the design.

E. Final Design

Final Design is the process of preparing construction documents for the preferred alternative. The Final Design alternative should address the results of the VA and RRV studies, if performed. It may be necessary at the start of the Final Design to collect additional field and laboratory data to supplement the existing data from previous studies. Required NEPA compliance permitting (and other permitting requirements, including Tribal permits) should be completed during this phase of the work effort, and prior to awarding a construction contract.

The construction documents must be prepared during the Final Design. These documents include:

- Construction drawings
- Technical specifications
- A bid schedule with bid quantities

A Design Summary Report should be completed prior to bidding in order to document the basis of the design. In addition to the Design Summary, separate Technical Memoranda (TM) should be completed prior to bidding in order to document the results of the various studies and analyses that were performed during the conceptual and the Final Designs. For example, such TMs may include:

- Reports on hydrology and geology/geotechnical data

- Filter analysis and design
- Slope stability
- Seismic analyses

The Design Summary Report along with all TMs should be stamped and signed by a PE licensed by any state within the U.S., preferably within the state where the dam is located.

BIA projects require that all bidding, award, and contract documents comply with current Federal Acquisition Regulations (FAR), and other applicable laws and regulations. Projects completed through Self-Determination contracts (P.L. 93-638, 25 CFR 900, Subpart J – Construction) must comply with BIA's regulations and applicable Tribal contracting requirements.

Typical construction documents prepared during the Final Design include the following:

- <u>Bid schedule</u>: The bid schedule is used to solicit prices from construction contractors and should be established early in the Final Design process. The bid must be refined and completed during the design. The bid schedule should include a list of all paid items, estimated quantities, and units. Measurement and payment provisions of the bid items should be included in the technical specifications and coordinated with the bid items. Bid options or bid alternatives may be incorporated into the bid schedule, when appropriate. Additional bid data may be considered prior to awarding the contract.

- <u>Construction drawings</u>: The construction drawings contain graphical requirements used by the construction contractor to build the dam modifications. These drawings are closely coordinated with the technical specifications. Generally, the construction drawings are developed in four submittals:

    - 30-percent design includes plans and typical sections of key design features.
    - 60-percent design includes all near final plans and typical sections of key design features.
    - 90-percent design includes all substantially completed key design features and is intended for SOD review.
    - 100-percent design is the final drawing package which addresses all SOD review comments.

  The actual design submittal sequence for each project should be determined based on project schedule. The 100-percent construction drawings should be stamped and signed by a PE licensed by any state within the U.S., preferably within the state where the dam is located.

- <u>Technical specifications</u>: The technical specifications contain material, procedural, installation, and other requirements for the construction contractor. These specifications are closely coordinated with the construction drawings and the bid schedule. At a minimum, this document should be prepared during the 60-percent submittal and then finalized by the 100-percent submittal. The 100-percent technical specifications should be stamped and signed by a PE licensed by any state within the U.S., preferably within the state where the dam is located.

The Final Design process may include:

- Establishing design criteria and loading conditions.
- Incorporating VA study recommendations.
- Acquiring additional field and laboratory test data, as required, to supplement existing data from previous studies.
- Performing risk reduction analyses to confirm that the modifications will adequately reduce the risk of dam failure by the identified PFM(s).
- Performing Final Design analyses.
- Preparing construction drawings.
- Preparing technical specifications.
- Preparing bid schedule and construction cost estimate.
- Preparing a Design Summary Report, along with appropriate TMs.
- Completing an independent technical review.

5.5 Regulatory Compliance and Permitting

Modifications of SOD dams are major federal actions that must comply with relevant environmental and cultural statutes and regulations.

A. NEPA Compliance and Permitting

NEPA compliance for the modification of dams are typically addressed by CEs, EAs, or EISs. Dam modifications can also be exempt from NEPA or covered by an existing NEPA environmental document. The Regional SOD Officer is responsible for ensuring that the appropriate NEPA compliance requirements are fulfilled. Environmental data collection field activities and permitting for NEPA compliance require Tribal coordination, communication, and collaboration.

B. Other Permitting and Compliance Issues

Besides NEPA, there are other key federal permitting and compliance issues that may include the following:

- Ensuring that there are no impacts to federally listed threatened or endangered species as required by Section 7 of the Endangered Species Act. Compliance with the Endangered Species Act is typically addressed by the local Ecological Services unit of the U.S. Fish and Wildlife Service (FWS).

- Ensuring that there are no impacts to cultural resources in accordance with Section 106 of the National Historic Preservation Act (16 U.S.C. § 470). Compliance with the National Historic Preservation Act is typically addressed by the Tribal Historic Preservation Officer (THPO).

- Ensuring that there are no impacts to waters of the United States, including wetlands in accordance with Section 404(b) of the Clean Water Act (33 U.S.C. §1251). Wetlands impacts are typically addressed by the local office of the USACE.

In addition to the compliance and permitting issues discussed above, there are often local, Tribal, state, and other permits that the Regional SOD Officer may need to identify and address. If such permits are required, appropriate permitting activities should be carried out as soon as possible so that the project schedule is not jeopardized.

5.6 Construction Process

Once a final dam modification design has been completed, the construction process can begin. The key activities of the construction process are construction procurement, construction-phase engineering, and preparing the final construction documents.

A. Construction Procurement

Construction procurement is the process of soliciting and evaluating bids from contractors for constructing dam modifications and awarding the construction contract. Construction procurement by BIA is accomplished in accordance with the FAR, procurement requirements, and P.L. 93-638 contracting requirements. The method of procurement can vary, depending on the Federal Government's requirements and complexity of the construction, including the following:

- <u>Competitive bidding</u>: Under this method, the Federal Government is required to award the contract to the bidder with the lowest offered price.

- <u>Pre-qualification</u>: This is a two-step process. The first step involves submittal of qualifications. Only pre-qualified contractors will be allowed to submit bids in the second step. Typically, the qualified contractor with the lowest bid will be awarded the contract.

- Best-value selection: In this method, the bidder submittal includes both technical qualifications and a bid at the same time. The Federal Government will evaluate the submittals based on a specific scoring system. This system includes both qualifications and price. The Federal Government is not required to award the contract to the bidder with the lowest bid.

- Sole-source negotiation: The Federal Government will negotiate a bid price with one specific contractor.

B. Construction-Phase Engineering

Construction-phase engineering includes typical engineering activities that are performed during construction projects to modify dams or construct new dams. These activities exclude construction management and administration that are performed to manage the construction contract. Examples of excluded activities include:

- Contract administration

- Meetings

- Change orders

- Payments

- Schedule issues

Only federal Contracting Officers (COs) can perform contract administration. Construction-phase engineering activities can be performed by BIA and Tribal personnel, or they can be performed by consultants.

The following is a list of typical construction-phase engineering activities and requirements for dam modifications:

- Pre-construction meeting: A pre-construction meeting should be conducted on site after notice to proceed has been issued by the CO. At a minimum, this meeting should be attended by BIA representatives, the contractor, and the Design Engineer. The meeting should address the following construction issues:

    - Overall construction schedule and timeline

    - Construction observation plan, including field personnel and testing

    - Contractor personnel and quality assurance/quality control

- Review of contract requirements and protocol

- Review of communication protocol, including points of contact for BIA, the Tribe(s), the contractor, and the Design Engineer

The proceedings of the pre-construction meeting should be documented in written minutes.

- Progress meetings: Regular progress meetings should be conducted on site to discuss ongoing construction work, construction problems and solutions, schedule projection and changes, and other contract issues. The frequency of progress meetings should be based on the size and duration of the project, urgency of the construction, and ongoing activities. This meeting should be attended by BIA representatives, the construction management team (whether BIA or a consultant), and the contractor. The Design Engineer and Tribal representatives may attend some of the progress meetings as needed. The proceedings of the progress meetings should be documented in written minutes.

- Review of contractor submittals: Contractors' administrative submittals are typically reviewed by the construction management team's Project Manager, but key technical submittals from the contractor should also be reviewed by the Design Engineer. Key technical submittals may include:

  - Construction schedule and sequencing
  - Construction permit compliance monitoring
  - Excavation
  - Dewatering
  - Demolition
  - Cofferdams
  - Diversions
  - Foundation treatments
  - Earthwork
  - Concrete
  - Rebar shop drawings
  - Fabricated metalwork
  - Hydraulic equipment

- Site restoration/revegetation
- Waste removal/handling
- Instrumentation products and installation

Review of the contractor submittals should be completed within the periods allowed in the contract. Results of the submittal review should be documented in a TM, including recommendations for acceptance or re-submittal.

- Response to contractor's Requests for Information (RFI): Whether the RFI is for contract and administrative matters or technical in nature, the response to a contractor's RFI should be completed in a timely manner. A quick response time will avoid undue delays to the contractor. The response to technical RFIs should be prepared by the Design Engineer. All information should be documented in a TM.

- Design changes: Changes to the original design may be needed during construction if requested by BIA. Changes may also be required due to unforeseen field conditions. Design changes should be documented in a TM prepared by the Design Engineer. These changes should be included in the Record Drawings that are prepared at the end of construction.

- Full-time field observations: Full-time field observations by qualified field personnel are required for the following field construction activities:
  - Development of the borrow areas and stockpiling of borrow materials
  - Placement of coffer dam protection and diversion facilities
  - Demolition of existing structures
  - Excavation, including earth excavation, rock excavation, or braced excavation
  - Control of groundwater inflows into the excavation
  - Foundation preparation or treatment, including dental concrete, slush grouting, shaping, pressure grouting, and cleaning
  - Placement of earthfill, including embankment fill materials, filters, drainage blankets, and riprap and bedding
  - Installation of toe drain pipes
  - Placement of cast-in-place concrete in spillways, outlet works, and other structures
  - Installation of outlet works conduits or spillway conduits, including filter collars (or diaphragms, as appropriate) around the conduits that penetrate through the dam

- Installation of hydraulic equipment such as gates and valves, fabricated metalwork, and electrical and supervisory control and data acquisition (SCADA) equipment
- Installation of dam instrumentation, including EWS equipment, staff gauges, weirs, piezometers, and inclinometers
- Execution of site restoration and clean-up
- Permit compliance monitoring

Field inspectors should prepare daily and weekly field observation reports (including photographs) documenting the observations.

- Foundation approvals: The foundation subgrades of key features, such as core trenches, spillway crest structures, stilling basins, gate towers, conduits, and intake structures should be inspected and approved by BIA or an approved technical representative. The field inspection and approval of foundation subgrades should be documented in a TM in addition to the daily and weekly field reports.
- Periodic site visits: BIA will perform periodic visits to the construction site to observe construction progress, resolve specific construction problems, inspect foundations, and verify design assumptions. Each periodic site visit is documented in a TM or Travel Report.
- Material testing: Earthwork, concrete, and other materials testing is performed for quality assurance by BIA's technical representative in addition to the quality control testing by the contractor. Specific testing requirements will be based on project requirements, but in general, will consist of the following types of tests:
  - Laboratory testing of on-site borrow materials
  - Gradation testing of the contractor's imported earthfill materials such as filter sand, drain gravel, and aggregate base course
  - Field testing of in-place compaction and moisture contents of earthfill
  - Field testing of delivered ready-mix concrete, including slump, air content, and temperature
  - Field fabrication of concrete cylinders from ready-mix concrete
  - Laboratory testing of concrete cylinders

  Test results are used to verify compliance with material and performance specifications. Test data should be included in the Final Construction Report at the end of construction.

- Final inspection: The final inspection to verify substantial completion or final completion of the construction should be performed by BIA representatives, the BIA technical representative, Tribal representatives, and the contractor. Punch-list items are developed from results of the inspection. The punch-list consists of outstanding items that are not yet completed. After these punch-list items are completed, another inspection should be performed to verify that all work has been completed.

C. Final Construction Documents

Upon completion of construction, the following documents should be prepared:

- Record Drawings: Record Drawings should be based on actual, as-built conditions encountered during construction from the contractor's records, designer's records, survey data, and field inspector's records. All design changes made during construction or new features added during construction should be clearly identified. The final Record Drawings should be stamped and signed by a PE licensed by any state within the U.S., preferably within the state where the dam is located.

- Final Construction Report: This report should include the following information at a minimum:

  - A summary and chronology of the construction
  - Record of contractor's approved submittals
  - A summary of design modifications and change orders
  - Documentation of foundation conditions and foundation approval
  - Construction photographs documenting typical activities, unusual features encountered, and major milestones
  - Compilation of daily and weekly inspection reports
  - A summary of laboratory and field test data of earthfill, concrete, and other materials used in construction of the project
  - An explanation of any areas of non-compliance with the plans and specifications, a discussion of the reason(s) for the non-compliance, and an indication of whether BIA should accept the project as constructed.

5.7 First Filling and Monitoring Plan

After the dam construction is sufficiently completed, reservoir filling can begin. This occurs when the partially or fully drawn down reservoir is filled for the first time. Before first filling of the reservoir, a First Filling and Monitoring Plan should be prepared in accordance with the directives of BOR’s Design Standard No. 14: Appurtenant Structures for Dams (Spillways and Outlet Works). This Plan should be followed during first filling, and should contain the following information and guidelines:

- Maximum allowable filling rate, in terms of feet per day.

- Identification of one or more intermediate reservoir elevations to be maintained for a period of time for observations and evaluations of performance.

- Schedule of inspection and instrumentation monitoring of the dam.

- Identification of key features of the modified dam and appurtenant structures that should be inspected.

- A long-term instrumentation and monitoring plan, containing the frequency of monitoring, data recording format, and graphical presentation of data. The O&M Manual for the dam should be updated to include this Plan.

- Identification of key personnel required for first-filling inspections.

Data and observations from the inspection and monitoring should be documented in writing and evaluated by the BIA technical representative. The initial filling is complete when the reservoir level has been stabilized under the normal operating pool and has been determined to be performing in a satisfactory manner. However, if performance is found to be unsatisfactory, then the reservoir needs to be drained to a safe level, and a subsequent risk reduction action, potentially including further dam modification, will need to be planned and executed to address the deficiency.

Chapter 6: O&M

Routine maintenance is a key element in reducing the risk of dam failure. Ultimately, this practice is critical in reducing long-term costs and government expense required to operate dams safely. Monitoring dam instrumentation is an important SOD activity. It provides field data on the performance of the dam and foundation. It also provides data for evaluation and analysis. The monitored performance parameters are useful for resolving existing PFM uncertainties and identifying new PFMs. These parameters serve as key inputs into IEs and risk analyses.

Each high- and significant-hazard potential SOD dam must have an O&M Manual that documents key operations, maintenance, and routine monitoring guidelines for the dam. The Dam Operator/Dam Tender is responsible for ensuring that the dam(s) under their jurisdiction are properly operated, maintained, and monitored in accordance with the O&M Manual. The level of detail and instruction contained in the O&M Manual will vary depending upon the complexity of the dam and its appurtenant structures.

6.1 O&M Manuals

O&M Manuals provide operational guidance for dams and reservoirs. One of the most important issues at any dam is to maintain a routine schedule for key operational activities. These activities include: 1) routine monitoring; 2) special inspections; 3) instrumentation readings; and 4) important maintenance activities.

One of the more important scheduled operations is exercising the outlet works control gates. This must be done at least annually. Exercising outlet works gates helps ensure that the outlet works controls are operable. These controls allow the reservoir to be efficiently lowered or drained if there is an unusual event or emergency incident at the dam. O&M Manuals for dams should include the following information at a minimum:

- A brief description of the purpose and history of the project.
- A description of items of special importance associated with the operation of the dam. Items of special importance could include:
  - A summary of prior incidents and significant loading events at the dam.
  - The maximum allowable outlet gate openings.
  - The structural design maximum reservoir load restrictions.
  - The procedure for exercising the outlet works gates.
  - Any key annual maintenance activities.
  - All safety procedures for key phases of dam operation.
  - The storage location of the logbook, access keys, and EAP.

- Documentation of who is responsible for key dam O&M activities at the dam.
- Directions and maps for access to the dam.
- A description of the schedule for routine monitoring.
- Communication protocol for unusual observations or operations.
- A description of coordination requirements with other dams or facilities that may be located upstream or downstream of the dam.

6.2 Instrumentation and Monitoring

O&M Manuals should document the following instrumentation and monitoring information:

- A description and map of the instrumentation system installed in the dam and documentation of the purpose of the instruments.
- Instrumentation plan, section, and installation detail drawings where available.
- Instrumentation data collection forms where appropriate.
- Instructions for reporting instrumentation data and a description of who is responsible for evaluating the data.
- An instrumentation data collection schedule and routine operator inspection schedule.
- A description of abnormal instrumentation reading thresholds and actions to take when the abnormal instrumentation thresholds are exceeded.
- A description of routine maintenance recommended for various instrumentation types.

6.3 Maintenance

O&M Manuals document routine maintenance activities and recommended maintenance procedures that are required at the dam to increase the operational life of the facility. Typical dam maintenance activities include:

- Control of rodents and repair of rodent damage in embankment dams.
- Control of vegetation and repair of vegetation damage in embankment dams, at a minimum in accordance with USACE's Guidelines for Landscape Planting and Vegetation.

- Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures.[18] In the vegetation free zone, grasses should be mowed to three to six inches in height when growth has reached 12 inches. Woody vegetation should be removed as described below:
  - By excavation, remove the trunk (or stem), stump, root ball, and all roots with diameters greater than half an inch. All such roots in or within 15 feet of the dam should be completely removed
  - Assure that the resulting void is free of organic debris
  - Fill and compact the void according to the original soil and compaction specifications. If no specifications exist, match adjacent soil and compaction. Deviations from these requirements must be approved by the BIA SOD Officer.
- Re-establishment of freeboard or camber in embankment dams.
- Repair of erosion damage in embankment dams.
- Repair of cracking in concrete dams or structures.
- Sealing of concrete joints.
- Repair of deteriorated or spalled concrete.
- Lubrication and maintenance of gates and valves.
- Application or reapplication of coatings on gates, valves, and metal work.
- Verification of voltage and amperage or replacement of electrical controls.
- Repair of electrical or instrumentation conduits.
- Repair or replacement of fences, locks, gates, or other security features.
- Improvements or repairs to the dam access road.
- Other maintenance issues.

Manufacturers' O&M Manuals for gates, controls, and other specialized equipment should be kept and included as appendices in each BIA O&M Manual.

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[18] EP 1110-2-18, Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures, USACE, 2019. See also FEMA-534, Technical Manual for Dam Owners: Impacts of Plants on Earthen Dams, 2005.

6.4 Unusual and Emergency Operations

When unusual conditions are observed or abnormal instrumentation readings are made at the dam, consideration should be given to moving from the normal operations documented in the O&M Manual to emergency operations documented in the dam's EAP (described in Chapter 7 of this handbook).

The O&M Manual provides directions and decision guidance about when and how to evaluate unusual and emergency conditions at dams. The latest version of the decision-making guidance tables in the EAP should be referenced in the O&M Manual. These guidance measures will aid in facilitating a seamless transition to the EAP and into the Incident Command System (ICS) for emergency operations.

Chapter 7: Emergency Management (EM)

The main focus of SOD's EM is on preparedness and response to incidents at dams through the preparation and exercising of EAPs, which are formal written documents to follow during emergency situations or unusual occurrences at dams. EAPs are required for all SOD high- and significant-hazard potential dams.

EAP exercises ensure that key personnel and emergency responders involved are prepared for dam safety emergencies. The result is that lives can be saved and damage to property minimized in the event of a dam failure. SOD's EM complies with FEMA's Emergency Action Planning for Dams[19] and all applicable federal and DOI guidelines and policies.

As stated in section 2.3 of this handbook, dam-related incidents are much more common than dam failures. Dam safety incidents can include, but are not limited to:

- Sinkholes
- Cracks
- Slides
- Floods
- Sand boils
- Increasing or muddy seepage
- Earthquakes
- Spillway erosion

Many identified dam incidents can develop into dam failures within hours or days, unless appropriate and timely actions are taken to immediately reduce the risk of dam failure. Dam incidents may be discovered by dam O&M monitoring personnel during routine dam safety inspections. The general public may also discover dam incidents when visiting a dam.

Consistent with the RIDM approach, the estimation of potential life loss or property damage is better understood as a result of properly developed and exercised EAPs. When appropriate, the lessons learned during the emergency planning process may be used to review and update the consequences estimate for the dam.

[19] FEMA P-64, Emergency Action Planning for Dams, 2013

7.1 EAPs

EAPs are used to help responsible officials protect lives and reduce property damage in the event of flooding caused by a dam failure. EAPs are planning documents that are intended to guide BIA and Tribal officials through the steps of: 1) detection; 2) decision making; 3) issuing required notifications and taking expected actions; and 4) terminating the event.
In addition, EAPs provide vital information to emergency response personnel regarding inundation areas downstream from the dam and follow-up reporting guidance. EAPs are coordinated with Local Emergency Operations Plans (LEOPs) to the extent possible. Local Tribal, municipal, and county EM officials are responsible for preparing and implementing their own LEOPs, and warning and evacuation plans for their jurisdictions.

Major storm events may result in flooding downstream of dams even if the dam does not fail. These storm events may have the potential for life loss or property damage. In accordance with 55 IAM 1, it is SOD policy to encourage floodplain management downstream of dams and along reservoir shorelines. Therefore, NDF Advisory Flood Maps are typically included in the appendix of each EAP to assist downstream communities in preparing for the potential consequences associated with natural flooding unrelated to dam failure scenarios. The magnitude of the flooding event depicted on the NDF Advisory Flood Map will be determined on a case-by-case basis in collaboration with the BIA SOD Officer. Refer to SOD's Dam Failure Inundation Mapping Standards document for more information.

A. Responsibility

SOD has the overall responsibility to make sure that an EAP is prepared for each high- and significant-hazard potential dam under its administration and that those EAPs are regularly exercised. The BIA SOD Officer is responsible for EAP management, including annually reviewing and updating the EAP for each dam and tracking and maintaining electronic records of all EAP updates, revisions, exercises, and after-action reports.

In accordance with the Federal Guidelines for Dam Safety and 753 DM 2, SOD is required to exercise and update each EAP on a five-year cycle. These updates are due with the signed Certification Page by the end of the applicable calendar year. Regional SOD Officers are required to provide annual updates to the Communications Directory for each EAP covering their dams. These annual updates are due by the end of each calendar year. The annual EAP updates will be documented electronically, typically as a spreadsheet, by the Regional SOD Officer. The updates will be provided to SOD Central Office. Hard copy versions will be sent to all official holders of the EAPs.

B. Response Levels

EAPs address the following three emergency Response Levels:

<u>Response Level 1</u>: A Response Level 1 is a non-failure situation at the dam. It is an unusual situation that, although no adverse impacts are anticipated, does require inspection and investigation. The potential for adverse impacts is not yet serious but could progress into a potentially threatening event if the situation continues or intensifies.

Response Level 2: A Response Level 2 is a developing situation in which there are immediate or inevitable adverse impacts to the dam, or the integrity of the dam cannot be verified. Conditions are more serious than a Response Level 1. The dam MAY BECOME unstable. PAR(s) must be notified to "standby" and prepare to evacuate areas identified on the inundation maps within this EAP.

Response Level 3: A Response Level 3 is one of the following: 1) dam failure is imminent (it has been determined that the dam will fail); 2) dam failure is occurring; or 3) dam failure has occurred. Life-threatening flooding will definitely affect the PAR(s). Immediate evacuation of the PAR(s) is recommended.

These response level definitions may be modified in the future based on program and industry updates.

C. Decision Criteria Matrix

EAPs contain a Decision Criteria Matrix that assists the decision maker in determining the Response Level for various triggering events, including, but not limited to, overtopping, movement and cracking, earthquakes, and landslides. The Decision Criteria Matrix is modified for each dam as needed.

D. General Incident Response Procedure

These five key steps are followed in response to a dam incident:

1. Detection of the unusual or emergency situation

2. Determination of the response level using the Decision Criteria Matrix in the EAP

3. Notification/expected actions

4. Termination of the event

5. Post-incident reporting

E. Spillway Discharge Curves

Spillway discharge curves are included in the EAP when the dam has a defined spillway. The curves provide relevant information associated with major storm events that may result in significant releases from the dam. The primary purpose of the spillway discharge curve is to provide an estimate of the flowrate being released from the dam spillway(s). The flowrate is associated with reservoir water surface elevations ranging from the lowest spillway crest elevation to the top of the dam. Additionally, specific reservoir elevations may be indicated on the spillway discharge curve to identify elevations that correspond to known downstream threshold flowrates. Such thresholds may include but are not limited to: 1) downstream culvert and road crossing capacities; 2) safe channel capacities; and 3) dam infrastructure indicators such as bridge decks and dike elevations.

The primary purpose of including threshold elevations is to provide advance flood warning. Threshold elevations allow notification of potentially impacted infrastructure associated with the natural release of flood waters through the spillway channel during storm events. Dam personnel should be contacted to facilitate the determination of such threshold elevations.

F. Certification Page

The Certification Page is a signatory approval sheet in the preface of the EAP. This page contains the signature blocks for the Regional SOD Officer, the BIA Agency Superintendent or other decision-making entity, the Tribal SOD Lead (if applicable), and Tribal decision-making entities, as well as any other key jurisdictional players in a dam safety emergency. The required signatories on the Certification Page depends on the Tribe's P.L. 93-638 contract or compact status.

If a Tribe has a P.L. 93-638 contract or a compact for SOD activities, the Tribe is a certifying signatory to the EAP. In these instances, the Tribe has also assumed the EM responsibilities, unless waived. If these responsibilities are waived, or the Tribe has not contracted the SOD responsibilities, then the Tribal representative's signature is only requested on a Statement of Acknowledgement on the Certification Page. Unlike the Certification Page, a signed Statement of Acknowledgement is not necessary to finalize an EAP. The signature on the Certification Page acknowledges the role of the EAP. The signature also indicates the Tribe's agreement to activate the downstream LEOP in the event of a dam incident.

After an EAP has been revised and validated through a Tabletop or Functional Exercise, the Certification Page is routed for signature among the signatories. This Certification Page must be signed by all signatories within 120 days of the Exercise. Since the EAP is a BIA document, only BIA signatures are required to make it a valid document. However, every effort is made to acquire the approval and signature of Tribal leadership. Once the Certification Page has all required signatures, it is inserted into the Final EAP prior to final distribution.

G. Inundation Maps

Dam failure inundation maps are used to demonstrate the downstream flooding extents associated with hypothetical failure scenarios at dams. EAPs for SOD dams include dam failure inundation maps that depict both sunny day and hydrologic dam failure scenarios.

Dam failure inundation maps prepared for SOD dams should be developed in general conformance with the standards and methodologies provided in FEMA's Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures[20] and SOD's Inundation Mapping Standards Technical Memo. These documents outline the types of inundation maps and provide the requirements for formatting, layouts, and disclaimers. These documents should be followed unless otherwise directed within this handbook or approved by the BIA SOD Officer.

[20] FEMA P-946, Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures, 2014

H. Distribution of EAPs

EAPs are produced in two formats: 1) an EAP, which includes the decision-making information and tools described above and the inundation maps; and 2) a stand-alone Inundation EAP. Both documents include two Distribution Lists, one for each of these formats. The EAP is only distributed to the dam safety staff and the emergency decision makers to address incidents at the dam. The Inundation EAP is distributed to the downstream response personnel and includes only the inundation maps for the dam and the associated figures and tables as well as a few key pages within the EAP document.

7.2 SOD Dam EAP Exercises

SOD is responsible for holding routine dam exercises at all high- and significant-hazard potential dams. The objective of the EAP exercise schedule is to ensure that EAPs are maintained as effective preparedness and response tools to help save lives and minimize downstream property damage. Electronic and hard copies of all EAPs are maintained by the BIA SOD Officer. The EAP exercises focus upon plan familiarization exercises to ensure effective responses during a dam incident, emergency event, or dam failure. The exercises provide valuable training for Dam Operators/Dam Tenders, emergency responders, and others who would be involved in a dam incident. The exercises provide a process to continuously improve and update EAPs. EAP exercises should be coordinated with applicable Tribal EM personnel. The EAP exercises include the following types:

- Initial Planning Meetings
- Communication Drills
- Tabletop Exercises
- Functional Exercises

A definition of each exercise type is provided in the Definitions section of this handbook. Other exercise types may be used for significant-hazard potential dams, including seminars and workshops.

A. Initial Planning Meetings and Communication Drills

The EAP Initial Planning Meetings are part of the Tabletop and Functional Exercise planning process. They include a thorough review and introduction to the EAP and dam incident response. EAP communication drills are conducted as part of the annual EAP update. The Regional SOD Officer is responsible for performing this task. A communication drill involves calling the contacts on the EAP's Communications Directory to verify their current position and contact information. It also serves to update information for the Resources, Contractors, Equipment, and Suppliers List. During the communication drill, it is important to verify that the plan holder has an updated copy of the EAP and knows where it is located. Other aspects of the EAP may also be exercised as part of the communication drill such as: 1) testing detections; 2) the Decision Criteria Matrix; or 3) preventative actions.

B. Tabletop Exercises and Functional Exercises

Tabletop Exercises and Functional Exercises alternate every five years. More frequent exercises can be scheduled based upon: 1) requests from the Tribe; 2) the condition of the dam; or 3) key personnel changes. More frequent exercises should be considered when new personnel become involved in key operational or emergency response roles at SOD dams.

A Tabletop Exercise is an informal activity involving discussions of actions to be taken based on described emergency situations. A Tabletop Exercise is done without time constraints, which allows the participants to practice emergency situation problem solving. A Functional Exercise is an activity in which participants respond in a coordinated manner to a timed, simulated incident that parallels a real operational event as closely as possible. An actual incident or emergency event at the dam is judged to be an acceptable substitute for a Functional Exercise provided that the EAP is activated at a Response Level 2 or 3 and an Incident Report is generated. The Incident Report must document the incident details, including: 1) communications made; 2) lessons learned; and 3) recommended corrective actions.

The planning, conducting, and reporting of dam EAP Tabletop Exercises and Functional Exercises are conducted in general conformance with Homeland Security Exercise and Evaluation Program (HSEEP) guidelines.[21] Tabletop Exercises are discussion-based and Functional Exercises are operations-based. To maximize exposure and familiarity with EAP procedures, Functional Exercises should be designed in a modified exercise format where all parties involved in the exercise are in the same location. These measures ensure that all the participants can be involved in all of the associated communications and actions that are tested. All EAP Tabletop and Functional Exercises include the BIA Regional SOD Officer as part of the exercise planning team. Exercise objectives should focus on the following elements of the EAP:

- Detection
- Decision Making
- Notification
- Dam Failure Inundation Maps
- Communication

The most recent documented PFM reports, instrumentation and monitoring data, and recent incidents reports should be reviewed in the development of exercise scenarios. Referencing this data will assist in the development of realistic events that could affect populations downstream of the dam.

[21] Homeland Security Exercise and Evaluation Program (HSEEP), DHS, 2020

C. After-Action Report and Improvement Plan (AAR/IP)

As recommended in FEMA's Emergency Action Planning for Dam Owners, a draft AAR/IP is prepared following any Tabletop Exercise, Functional Exercise, or after any incident which results in an EAP activation of Response Level 2 or greater. The draft AAR/IP is reviewed and approved by the BIA SOD Officer and finalized within 120 days of the exercise or conclusion of the incident. SOD keeps a record of all dam EAPs and exercise AAR/IPs. AAR/IPs typically contain the following minimum elements:

- An Exercise Summary that describes key strengths and areas of improvement for the EAP.
- An Exercise Overview section that describes the exercise details and participants.
- An Exercise Design Summary section that describes the exercise objectives and scenarios that were exercised.
- An Exercise Evaluation section that documents identified issues and the participant's AAR/IP forms.
- A Conclusions section that documents the overall effectiveness of the exercise.
- An Improvement Plan section that includes a listing of specific recommendations for corrective actions to improve the exercise and emergency response actions.

The Regional SOD Officers will keep electronic records for incident-related AAR/IPs and will provide copies to the SOD Central Office

Chapter 8: Early Warning System (EWS)

The SOD EWS provides automated remote environmental monitoring capabilities and alert messages to supplement onsite observations. Most high-hazard potential SOD dams are equipped with an EWS site(s) that provides remote monitoring of reservoir elevation, stream level, and rainfall.

Some conditions, such as high reservoir levels or heavy rainfall, trigger EWS alert text and email messages. For some alerts, phone calls are also made by the National Monitoring Center (NMC), which is a call center for SOD EWS. NMC staff make phone calls to identified responsible individuals, typically Tribal or BIA agency SOD staff and Regional SOD Officers, to verify that alert messages have been received.

8.1 EWS Sites

A typical EWS site includes sensors to monitor the reservoir elevation or stream water depth, and rainfall. Some sites have cameras installed, which provide remote visual monitoring of the dam. Specialized instrumentation is considered on a case-by-case basis.

8.2 EWS Website

Authorized SOD staff can access current and historical site data for all components monitored using the EWS website. SOD staff are encouraged to use the website to check their site data between in-person site inspections. The elevations shown on the website are those used to trigger alerts, including alerts related to the EAP Response Levels. If the reservoir elevations on the website are incorrect, the appropriate Regional SOD Officer and the SOD Central Office EWS staff should be contacted with the correct elevation information. SOD Central Office maintains and administers the website.

Tribal, BIA agency, or Regional SOD staff request access to the EWS website through the Regional SOD Officer, who then coordinates access with SOD Central Office EWS staff.

8.3 EWS Operation and Maintenance Considerations

Regular EWS site maintenance is essential to ensure the equipment is clean and functioning properly. Relative elevations of the reservoir water surface and key appurtenances and infrastructure (such as spillway crest, outlet works intake, and float switches) must be confirmed regularly to ensure the system remains accurate. Monthly maintenance activities and operational checks are performed by local BIA agency staff or Tribal staff conducting EWS site work under a self-determination contract or compact. Monthly maintenance guidelines and a maintenance checklist are available on the EWS website or by request. Annual inspections and maintenance are typically arranged by the SOD Central Office and Regional SOD Officer.

Requests for training, manuals, maintenance checklists, technical support, or additional information can be made through the Regional SOD Officer, who then coordinates requests with the SOD Central Office staff.

8.4 EWS Alert Messages

Alert messages are sent out via text and email to specified SOD staff to alert them of conditions at a site that might require attention. Examples include high reservoir elevations corresponding to an EAP Response Level, heavy precipitation, or low batteries. For high priority alarms, the NMC calls a list of designated individuals to confirm receipt of the text and email messages. Data that triggers alarm messages can be verified by looking at the EWS website, and website data can be used to help determine what action to take in response to an alarm message.

Tribal, BIA agency, or Regional SOD staff request access to the EWS alarm messages through the Regional SOD Officer, who then coordinates access with the SOD Central Office staff.

8.5 EWS Integration in EAPs

The EWS is designed to have a reliable monitoring and messaging system that is integrated with the EAP. An EWS supplements in-person site visits and enhances the detection and decision-making functions associated with the EAP. If the EWS detects a condition consistent with an EAP Response Level (typically reservoir elevation), an alarm is triggered, and automated texts and emails are sent to local Tribal/BIA agency, regional, NMC, and SOD Central Office staff.

Once an EAP-related alert is sent, an NMC staff member calls (by telephone) identified contacts in a specified order, typically Tribal or BIA agency SOD staff and Regional SOD Officers, to verify that alert messages have been received. The decision maker should refer to the EAP and, if warranted, may choose to activate the EAP at one of the Response Levels, following the corresponding expected actions.

Data from the EWS site can be referenced by the Dam Operator/Dam Tender or Facility Manager during an event by using the EWS website. The EWS is a supplement to onsite monitoring and is not a part of the formal EM system. Alarm levels should be reviewed and confirmed as part of routine dam inspections or risk assessment updates.

Chapter 9: Dam Security

Effective dam security serves to reduce the potential for dam failure and malevolent, damaging attacks on dams and dam appurtenances, such as spillways and outlet works. Without effective dam security, communities could lose valuable resources provided by dams such as water supply, irrigation water, flood control, hydropower, and recreation. This can have devastating impacts on local communities and could take years to replace. Dam security also aims to reduce nuisance, vandalism, and sabotage damage to dams. Such damage would not result in dam failure but may affect dam operations and could result in costly repairs to the facility.

The BIA SOD Officer is responsible for implementing, maintaining, and monitoring the security program for effective security risk management in accordance with the security requirements contained in 444 DM 1[22], dam sector DHS documents[23], and in other federal documents, such as the Risk Management Process: An Interagency Security Committee Standard, DHS, 2021, and Presidential Policy Directive (NSM-22): National Security Memorandum on Critical Infrastructure Security and Resilience, White House Security Council, 2024.

Key elements of dam security include:

<u>Security awareness</u>: Involves understanding the security risks associated with threats, vulnerabilities, and consequences at dams. Security awareness also involves effectively and appropriately communicating these security issues to Central Office, regional, agency, and Tribal dam safety staff.

<u>Mitigation</u>: Involves activities and/or systems designed to reduce or eliminate risks to persons or property or to lessen the actual or potential effects or consequences of an incident.

<u>Protective measures</u>: Involves installing physical features or modifying operational procedures to minimize the risk and consequences of potential security threats.

9.1 Security Awareness

Security awareness involves understanding the threats, vulnerabilities, and impacts of attacks on dams. All DOI employees and contractors are required to take annual Security Awareness training, which is available in DOI Talent, DOI's online learning library.[24]

Individuals or organized groups who possess the capability and intent to do harm at dams are threats. Potential threats can originate from one or more of the following:

- Adversary nations
- Domestic and international adversary groups

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[22] 444 DM 1: Physical Protection and Building Security - Physical Security Program Requirements, DOI, 2013
[23] DHS Cybersecurity & Infrastructure Security Agency dam sector publications can be accessed at www.cisa.gov/dams-sector-publications.
[24] DOI Talent is available for federal employees and contractors at https://doitalent.ibc.doi.gov/.

- Disaffected individuals or groups
- Disgruntled or former employees

Malevolent attacks on dams can include:

- Physical attacks or cyberattacks that are intended to damage facilities
- Stealing equipment or information
- Disrupting the mission or resources provided by the dam

Security Risk Assessment Reports (also known as SRs) are prepared to identify the security risks associated with threats, vulnerabilities, and impacts of attacks on a specific dam. SRs are conducted at least every five years for Facility Security Level I and II facilities (for more information, see 444 DM 1).

Another important aspect of security awareness is effectively and appropriately communicating security issues to key BIA stakeholders who need to know this information. Security communication also involves effectively encouraging the general public to report suspicious activity at SOD dams (such as the “If You See Something, Say Something™” public awareness campaign sponsored by DHS).

9.2 Mitigation

Mitigation involves the implementation of plans and protective measures that aid in minimizing the security threat or impacts associated with attacks on dams. The likely threats to dams are typically identified in a SR. After vulnerabilities have been identified, they can be mitigated by implementing specific protective countermeasures. Other mitigation measures may involve preparing a Facility Security Plan at high security risk dams. Per 444 DM 1, a security plan should describe the practices, procedures, responsibilities, and equipment that provide for the security of assets/facilities.

9.3 Protective Measures

There are numerous protective measures that may be implemented to improve the security at dams. Required protective measures and security standards are identified using the latest DHS ICS Risk Management Process. Many effective measures are relatively simple and cost effective to implement such as installing locks, fences, and vehicle barriers on key features of the dam. Other protective measures involve security forces, training, personnel screening, and cyber security.

The following list provides examples of the types of protective measures that may be implemented at dams, if determined to be necessary based on the results of a dam-specific SR:

- Wherever possible, prevent the public from driving vehicles on the crest of the dam by installing locked gates or barriers at each end of the dam crest or at other convenient locations on the access road(s) leading to the dam crest.

- Restrict access to any discharge structure (with the capacity to make releases exceeding safe downstream channel capacity) by using barriers and/or structural hardening, as appropriate.

- The operating controls for any gates or valves should be located within a locked and secured structure.

- The instructions for operating any gates, valves, or other critical equipment should be locked within secured structures or containers. By no means should this equipment be accessible or in view of the public.

- The exterior doors on structures containing operating equipment should:

    - Be constructed of steel

    - Have interior hinges or protected exterior hinges

    - Have protected deadbolt locks

- Exterior windows on structures should be protected with bars placed over the interior of the windows.

- Signs such as “No Trespassing” and “Government Property–Authorized Personnel Only” should be posted in areas where the public is not allowed, as appropriate.

- Use chain link fencing with locked gates to delineate the areas where the public is to be excluded. Track and document the keys to all locks at the dam to ensure only authorized personnel have keys. A key control plan should be in place to change the locks if keys to critical facilities are lost.

- Provide locks on dam instrumentation manhole covers, piezometer casings, and toe drain cleanout access points.

Chapter 10: Dam Safety Training

It is important for all SOD personnel to understand dam safety fundamentals and maintain knowledge of advances made in the practice of dam safety. SOD personnel involved with the operation, maintenance, and evaluation of dams should be particularly focused on developments in risk analysis and risk management for dams. Dam safety training topics recommended for Regional SOD Officers, SOD professional staff, Dam Operators/Dam Tenders, and EAP decision makers are listed below. Local BIA personnel, BIA Agency Superintendents, and local Tribal dam safety staff are also encouraged to participate in dam safety training. Dam safety training is a recurring or routine activity.

10.1 Regional SOD Officer and SOD Training

It is recommended that Regional SOD Officers and SOD professional staff complete dam safety training courses covering the following topics:

- General knowledge of dams and their benefits, risks, responsibilities/liabilities.
- General understanding of hydraulics/hydrology, geotechnical/geology, dam operations, dam maintenance, design, construction methods, construction management.
- Knowledge of Federal Government and Tribal environmental policies and compliance.
- Basic knowledge of dam safety analytical procedures such as current methodology for producing inundation maps, static stability, liquefaction, seepage, PFMs, dam risk assessment, risk-informed decision making, and estimating consequences.
- Dam inspection and monitoring procedures, and dam instrumentation.
- EM procedures and the ICS.
- Dam security and public safety.

It is also recommended that Regional SOD Officers and SOD professional staff attend at least one conference or technical seminar per year that is sponsored through DOI, FEMA, or a professional dam safety organization. The BIA SOD Officer, Regional SOD Officers, and other BIA SOD staff involved in dam safety decisions and analyses are also encouraged to attend a Dam Safety Risk Analysis Best Practices Class sponsored by a professional dam safety organization and maintain familiarity with industry developments related to the course material.

10.2 Dam Operator/Dam Tender Training

Dam Operators/Dam Tenders play a crucial role in maintaining the safety of the dams where they work. They identify potential dam safety issues at these dams, and they respond to dam safety incidents. As such, it is required that they receive dam tender training a minimum of once every two years. SOD and other agencies coordinate dam safety training sessions throughout the

BIA regions. The appropriate Regional SOD Officer should be contacted to identify an appropriate course as necessary.

It is recommended that Dam Operators/Dam Tenders complete dam safety training courses that cover the following topics:

- General knowledge of dams and dam components.
- General knowledge of the benefits, risks, responsibilities, and liabilities associated with dams.
- General understanding of hydraulics/hydrology, geotechnical/geology, dam operations, dam maintenance, design, construction methods, construction management.
- Knowledge of Federal Government and Tribal environmental policies and compliance.
- Requirements of dam inspection and monitoring programs, and dam-specific performance monitoring, including instrumentation.
- How to identify and classify a developing dam incident and dam intervention techniques.
- EM procedures and the ICS.
- Dam security and public safety.

10.3 EAP Decision Makers Training

Anyone involved in the monitoring, operation, or maintenance of dams could become involved in a dam safety incident associated with the dam. This involvement could result from an unusual condition observed at the dam to a rapidly developing emergency situation or dam failure. For EAP decision makers (typically the BIA Agency Superintendents or a Tribal EM official) and other potential ICS staff, SOD recommends attending dam safety training courses that address the following topics:

- EM procedures
- ICS
- Dam security and public safety

The appropriate Regional SOD Officer should be contacted to identify appropriate courses as necessary.

Definitions

For additional dam safety definitions not included below, see FEMA's Glossary of Terms for Dam Safety (FEMA P-148).

Abutment: That part of the valley wall against which the dam is constructed. Left and right abutments are defined on the basis of looking in the downstream direction.

Aggregate: Crushed rock or gravel screened to sizes for use in road surfaces, concrete, or bituminous mixes. A mass or cluster of soil particles, often having a characteristic shape.

Annual Exceedance Probability (AEP): The probability of an event occurring in any year.

Annualized Failure Probability (AFP): The probability of a dam failure occurring in any given year. It is the product of the: 1) probability of the load; and 2) probability of dam failure given the load. AFP is sometimes equated with Individual Risk.

Annualized Life Loss (ALL): The product of the annualized failure probability and the life loss that is expected to result from a dam failure. ALL is sometimes equated with Societal Risk.

Appurtenant structures: The structures or machinery auxiliary to dams which are built to operate and maintain dams, including outlet works, spillways, gates, valves, channels, diversion facilities, etc.

Bedrock: The solid rock at the surface or underlying other surface materials. Rock of relatively great thickness and extent in its native location. A general term for any solid rock, not exhibiting soil-like properties, that underlies soil or other unconsolidated surficial materials.

Borrow: A source of soil or rock materials used in heavy civil construction such as dam construction.

Camber: The extra height added to the crest of embankment dams to ensure that the freeboard will not be diminished by foundation settlement or embankment consolidation. The amount of camber is different for each dam and is dependent on the amount of foundation settlement and embankment expected to occur.

Cavitation: The formation of partial vacuums in fast-flowing water that subsequently implode, releasing substantial energy that can cause damage to flow surfaces and adjacent items; typically initiated by obstructions or offsets in flows, and usually accompanied by noise and vibration.

Chute: Portion of spillway between the gate or crest structure and the terminal structure, where open-channel flow conditions will exist. A conduit for conveying free-flowing materials at high velocity to lower elevations.

Closed Circuit Television (CCTV): A television system that transmits images on a closed loop, where images are only available to those directly connected to the transmission system.

Communications drill: A type of operations-based exercise, which is employed to test a single specific operation or function in a single agency. Drills are commonly used to provide training on new equipment, develop or test new policies or procedures, or practice. Drills also assist in maintaining current skills such as making contacts to check the information included in the EAP's communications directory.

Conduit: Typically, a pipe, box, or horseshoe structure that is constructed by means of cut and cover. A conduit can convey water or house other conduits, pipes, cables, wires, etc.

Consequence: Loss based on population at risk, economic impact, mission impact, symbolic value, national security impact, interdependencies, and public behavioral impact.

Core: In a zoned embankment, the core is the portion of the embankment having the lowest permeability and is intended to limit the quantity of seepage through the embankment to an acceptable amount.

Crest: The highest controllable surface of a structure, such as a dam crest or a spillway crest.

Critical infrastructure: Systems and assets, whether physical or virtual, so vital to the bureau/office mission that the incapacity or destruction of such systems or assets would have a debilitating impact on daily operations, economic security, public health or safety, or any combination thereof.

Cultural resources: Any building, site, district, structure, or object significant in history, architecture, archeology, culture, or science, including a community's heritage and way of life.

Cutoff trench: An excavation in the foundation of an embankment dam below the original streambed elevation that is intended to reduce under-seepage.

Cutoff wall: A wall of impervious material (e.g., concrete, cement-bentonite, or steel sheet piling) located in the foundation beneath the dam, which forms a water barrier to reduce under-seepage.

Dam: An artificial barrier that has the ability to impound water, wastewater, or any liquid-borne material; built for the purpose of storage or control of water.

Dam crest: The top surface of a dam.

Dam embankment: An earth structure, the top of which is higher than the adjoining surface. Fill material, usually earth or rock, placed with sloping sides and with a length greater than its height.

Dam failure: Catastrophic event characterized by the initiation and complete progression of a dam failure mode that results in the sudden, rapid, uncontrolled, and unconstrained release of impounded water.

Dam height: The vertical difference between the lowest point in the original streambed at the dam axis (or the crest centerline) and the crest of the dam.

Dam operational incident: The controlled operation or misoperation of the features of a dam results in adverse consequences in the areas downstream or immediately upstream from the dam.

Dam Operator/Dam Tender: The person responsible for the daily or routine operation and maintenance activities of a dam and its appurtenant structures. The Dam Operator/Dam Tender commonly resides at or near the dam.

Dam safety deficiency: An existing condition of a dam that would result in a dam failure under one or more related credible failure modes and presents enough of a threat to the safety of the downstream public and property to warrant action(s) to address the condition/situation. Dam safety deficiencies evolve from an assessment of a dam's condition, performance, loadings, expected response, and other factors.

Dam safety incident: Adverse conditions or damage at a dam characterized by the initiation or partial progression of a PFM where control of the impounded water is maintained throughout the event or where control of the impounded water is lost but release of the reservoir is constrained, slow, or prolonged.

Dead load: All structural loads that are relatively static over time, including the structure itself, gates, bridges, spillways, and outlet structures.

Downstream slope: The inclined surface of a dam away from the reservoir.

Drain: A feature designed to collect water and convey it to a discharge location. Typically, a drain is intended to relieve excess water pressures.

Drawdown: Lowering of a reservoir's water level; process of depleting a reservoir or ground water storage.

Dynamic stability: The stability of a structure under earthquake loading. For embankments and foundations, dynamic stability is typically evaluated in terms of whether predicted deformations or movements (that might result from earthquake shaking) are significant enough to result in excessive crest settlement, or a liquefaction-type failure.

Earthquake loading: The forces an earthquake places on a dam structure.

Emergency Action Plan (EAP): A formal written document for EM personnel and Dam Operators/Dam Tenders to follow during emergency situations or unusual occurrences at a dam. EAPs reduce the potential for downstream life loss and property loss and provide proper notification to downstream authorities.

Emergency: A condition that develops unexpectedly which endangers the structural integrity of a dam, or downstream human life or property, and requires immediate action.

Event tree: Progression of logical events in a failure mode analysis, leading ultimately to dam failure.

Facility Security Level (FSL): A security risk-based criticality level for federal facilities determined by using the latest Interagency Security Committee's Risk Management Process.

Facility: Structures, buildings, dams, grounds, real property and/or office space occupied by a DOI component whether owned, leased, or controlled by DOI or BIA.

Failure mode: A specific way a dam could reasonably be expected to fail. The loadings and the unique characteristics of the dam (as it currently exists) and its foundation in response to the loadings are central to the development of PFMs.

Filter: A material or constructed zone of earth fill that is designed to permit the passage of flowing water through it. It prevents the passage of significant amounts of suspended solids through it by the flowing water.

Flood surcharge: The storage volume between the top of the active storage and the design water level.

Floodplain: An area adjacent to a natural waterway (river, stream, etc.) that is inundated by floodwater when flows within the waterway exceed the capacity of the channel.

Foundation: Soil or rock materials upon which a dam is built. Foundation materials that are consolidated into rock or rock-like material may be referred to as bedrock. Unconsolidated materials may be referred to as surficial materials.

Freeboard: The difference in elevation between the reservoir water surface and the dam crest.

Functional Exercise: An activity in which participants respond in a coordinated manner to a timed, simulated incident that parallels a real operational event as closely as possible. This exercise is generally conducted in an emergency operations center or incident command post. Messages are passed to the participants in written form, by telephone (landline or cellular), radio, fax, email, text, or other method of communication. The Functional Exercise uses information such as emergency plans, maps, charts, and other information available in a real event, and creates stress by increasing the frequency of messages, intensity of activity, and complexity of decisions and/or requirements for coordination. It does not involve actual mobilization of emergency response forces in the field. Participants will include management, key agency staff, and personnel from outside organizations, as appropriate.

Gate tower: A tower that contains the mechanisms to open the gates, which control the flow in a conduit.

Hazard potential classification: The rating for a dam based on the potential consequences of dam failure. The rating is based on potential threat to life and damage to property or cultural resources that failure of the dam could cause.

High-flow incident: The passage of natural flood events through the appurtenant structures of a dam that results in adverse downstream consequences.

Hydrodynamic load: The loads that result from water flowing against and around a structure.

Hydrograph: A graphical relationship depicting the flowrate bypassing a specified location with respect to time during a given hydrologic event.

Hydrologic hazard: The relationship between elevated water surface elevations and the flood loading recurrence intervals that cause them.

Hydrostatic load: The loads that result from water at equilibrium behind a structure.

Inactive status: A dam that is unable to impound or divert water for the purpose of storage or control of water. For example, the dam is breached, or the reservoir is filled in with sediment.

Inclinometer: An instrument used for measuring the slope or angle of an object based on gravity.

Indian lands: For SOD purposes, any land to which the title is held: 1) in trust by the United States for the benefit of an Indian Tribe or an individual Indian; or 2) by an Indian Tribe or an individual Indian, subject to restriction against alienation under laws of the United States.

Individual risk: Individual risk is the sum of the risks from all failure modes associated with the hazards that affect a particular person.

Inflow Design Flood (IDF): The flood hydrograph used to design a specific dam and its appurtenant structures, particularly for sizing the spillway and for determining surcharge storage requirements.

Interagency Security Committee: A DHS organization that develops security standards for all non-military federal facilities.

Internal erosion: The process of erosion of dam or foundation soils by flowing water, resulting in the loss of embankment fill or foundation soils.

Inundation map: A map of the flooding limits downstream of a dam showing the probable encroachment by water released because of dam failure or from abnormal flood flows released through a dam's spillway. Various inundation maps are created to illustrate one or more different dam failure or flood scenarios.

Inventory: Listing of all dams on Indian lands that SOD is aware of, in accordance with 753 DM 2.

Issue Evaluation (IE): An engineering evaluation and risk analysis process used to determine if a PFM actually represents a dam safety deficiency that needs to be addressed.

Landslide: The movement of a mass, debris, or earth down a slope.

Large dam: A dam with a height of 50 feet or greater from the lowest foundation to crest, or a dam between 15 feet and 50 feet impounding more than 2,400 acre-feet.

Levee: A levee system is a manmade barrier along a watercourse with the principal function to exclude flood waters from a portion of the floodplain (referred to as the "leveed area") for a limited range of flood events.

Lifeline: Infrastructure that is regarded as indispensable for the maintenance or protection of life.

Liquefaction: A sudden loss of strength in saturated soils caused by an increase in pore pressure during earthquake shaking.

Logbook: A dated, written record of performed operation and maintenance items, and observations pertinent to a dam or structure.

Maximum reservoir surface elevation: The highest acceptable water surface elevation with all factors affecting the safety of the structure considered.

Maximum storage capacity: The total volume of water, usually reported in acre-feet, impounded by a dam at the maximum reservoir surface elevation (often equivalent to the dam crest). Also called maximum impounding capacity.

Mitigation: Activities or systems designed to reduce or eliminate actual or potential effects or consequences. Mitigation measures may be implemented prior to, during, or after an incident, and are often developed in accordance with lessons learned from prior incidents.

Non-dam impoundment: Structures that are less than six feet in height and store less than 15 acre-feet of water.

Normal reservoir pool: The highest elevation at which water is normally stored.

Original streambed: The lowest-point elevation in the streambed at the axis or centerline crest of the dam prior to construction.

Outlet works: An outlet (conduit or tunnel) in a dam through which normal or emergency releases from the reservoir can be made.

Overtopping: Inundation of a structure by rising flood water. For an embankment dam, overtopping occurs when the reservoir level is higher than the dam crest.

Performance parameters: Measurable and observable indicators of dam performance specifically related to dam safety and PFMs, such as seepage flows, piezometric levels, and ground movements.

Permeability: The resistance of a material to the passage of water through it. Continuous, uncracked concrete typically has very low permeability. Clay typically has low permeability. Sand and gravel typically have high permeability as water can move fairly easily and rapidly through them.

Phreatic surface: The top of the zone of saturation in an embankment.

Physical security: Measures that prevent or deter the overall risk to DOI assets, systems, networks, or their interconnecting links resulting from exposure, injury, destruction, incapacitation, or exploitation. Physical security includes actions to deter the threat, mitigate vulnerabilities, or minimize consequences associated with a terrorist attack or other incident. These measures can include (among various others) a wide range of activities, such as hardening facilities/structures, building resiliency and redundancy, incorporating hazard resistance into initial facility design, initiating active or passive countermeasures, installing security systems, promoting workforce security, and implementing cyber security measures.

Piezometer: A device for measuring the pore water pressure at a specific location in earthfill or foundation materials.

Piping: The removal of dam embankment or foundation material by flowing water through a continuous opening along the flow path. Piping progresses upstream from a downstream exit location and can lead to dam failure.

Population-At-Risk (PAR): Those people located within the inundation limits resulting from flooding caused by a dam failure.

Pore water pressure: Internal hydrostatic pressure in an embankment caused by the level of water in the reservoir acting through pressure-transmitting paths between soil particles in the fill. Also known as uplift pressure.

Potential Failure Mode (PFM): Postulated mechanism of physical events that would lead to failure of a dam.

Probability of failure: Product of the likelihood of a structural load and the probability of an adverse structural response.

Probable Maximum Flood (PMF): A hypothetical flood for a given drainage basin such that there is virtually no chance of its being exceeded. It is the maximum runoff estimated by combining the most severe meteorological and hydrologic conditions.

Pseudo-static: The representation of a non-static force as a static force for analysis purposes.

Public safety incident: When one or more people are harmed through their physical interaction with a dam, appurtenant structure, or reservoir. These incidents are often characterized by physical harm to a person or persons from the general public, or to an employee or employees from an agency or organization performing professional duties related to the dam.

Punch list: List of work that remains to be completed. The list is identified during final inspection at the end of a construction project.

Rating curve: A graph of discharge versus stage for a given point on a stream or through a water conveyance structure.

Record drawings: Construction drawings prepared after construction showing as-constructed configurations and features.

Recovery: Involves fulfilling the humanitarian needs of people affected by the emergency and can include temporary relocation of the affected downstream population and reconstruction of damaged property affected by the emergency. The recovery phase begins immediately after the threat to downstream life has ended.

Reservoir evacuation: The release or draining of a reservoir through an outlet works, spillway, or other evacuation features at the dam.

Reservoir restriction: An operational limitation for a storage reservoir to below the normal operation level to reduce dam failure risk.

Residual risk: The portion of risk that is leftover after taking corrective action(s).

Restricted fee land: Land for which the Tribe or individual Indian holds legal title. The land contains legal restrictions against alienation or encumbrance.

Return period: The average time until the next occurrence of an event. The inverse of the probability of an event occurring.

Riprap: Rock fragments, rock, or boulders placed on the upstream slope of a dam to provide erosion from wave action, or in spillways or outlet works to provide scouring protection from flowing water.

Risk: The probability of adverse consequences. When viewed in the context of the potential for dam failure due to the occurrence of one or more PFMs, it is defined based on the estimated AFP and ALL for the PFM(s) in question. When viewed in a dam safety and security context, it refers to the relationship or coexistence between consequences, vulnerabilities, and threats.

Risk analysis: Use of available information to estimate the risk to individuals or populations, property, or to the environment from hazards.

Risk assessment: Process of making a decision or recommendation on whether existing risks meet guidelines. Included in the assessment are consideration for all important and related cultural, economic, social, environmental, cost, and other factors, and present risk control measures that are adequate. If these control measures are not adequate, consideration must be given to whether alternative risk control measures are justified or should be implemented.

Risk estimation: The process of quantifying probabilities and consequences for all credible and significant failure modes.

Risk identification: The process of determining what can go wrong, why, and how.

Risk management: Systematic application of management policies, procedures, and practices to the tasks of identifying, analyzing, assessing, mitigating, and monitoring risk.

Risk reduction: Selective application of appropriate techniques and management principles to reduce either the likelihood of an occurrence, or its adverse consequences, or both. Also, often referred to as risk control.

Risk-Informed Decision-Making (RIDM): A management framework in which relative risks at a given dam and within an inventory of dams can be compared to inform decisions regarding dam safety investments.

Security plan: A written document describing the practices, procedures, responsibilities, and equipment that provide for the security of assets/facilities. A security plan may be a stand-alone document or may be part of Standard Operating Procedures (SOPs), O&M Manual, EAPs, or other similar documents, as appropriate for the facility/structure.

Security Review (SR): An evaluation of assets or facilities that includes an analysis of the security and physical protection conditions at an asset/facility/structure in order to identify gaps and overall resiliency to specific hazards.

Seepage: Flow through a dam, its foundation, abutments, or appurtenant structures.

Seismic hazard: The relationship between earthquake loading parameters and their probability.

Societal risk: Probability of adverse consequences from hazards that impact on society as a whole and create a socio-political response because multiple fatalities occur in one event.

SOD dam: Any dam that meets the definition of a dam and is located on Indian lands that has been officially designated as under the administration of the SOD Program.

Spillway: An appurtenant structure in a dam that regulates the normal pool and/or passes flood flows. A dam may have more than one spillway.

Staff gauge: A graduated scale on a plank or metal plate used to indicate the height of the water in a location.

Static stability: The stability of a structure under non-seismic operating conditions. Static stability is typically evaluated as a factor of safety against sliding or overturning.

Stilling basin: A component in a hydraulic structure used to dissipate the hydraulic energy.

Structure: For the purposes of this handbook, a structure is a monument, building, dam, grounds, and/or other real property whether owned, leased, or controlled by DOI or BIA that does not fit the definition of a federal facility or a National Critical Infrastructure (NCI) as defined in 444 DM 1.

Sunny day dam failure: Mode of dam failure scenarios under normal reservoir operating conditions on a rainless day or night.

Tabletop Exercise: An informal activity involving discussions of actions to be taken based on described emergency situations. A Tabletop Exercise is done without time constraints, which allows the participants to practice emergency situation problem solving. The participants evaluate plans, policies, and procedures to resolve questions of coordination and assignment of responsibilities. A series of messages are issued to participants in the exercise, and they respond to the simulated incident in a low stress atmosphere. Participants are encouraged to discuss issues in depth and develop decisions through slow-paced, problem solving rather than the rapid, spontaneous decision making that occurs under actual or simulated emergency conditions. This exercise will involve management, key agency staff, and personnel from outside organizations, as appropriate.

Tailwater: The water in the natural stream immediately downstream from a dam. The elevation of water varies with discharge from the reservoir. Applied irrigation water that runs off the lower end of a field. Tailwater is measured as the average depth of runoff water, expressed in inches or feet.

Threat: An indication of possible violence, harm, or danger.

Toe (toe of dam): The point of intersection between the bottom of a slope or the upstream or downstream face of a dam and the natural ground (e.g., the upstream or downstream toe of a dam). The junction of the face of a dam with the ground surface.

Toe drain: Drain pipe located at or near the toe of the dam to collect and convey seepage to a downstream outfall.

Total risk: Sum of the AFP and ALL for all PFMs associated with a structure.

Trust land: Land for which the Federal Government holds legal title, but the beneficial interest remains with the Tribe or individual Indian.

Uplift pressure: The upward pressure in the pores of a material (interstitial pressure) on the base of a structure. An upward force on a structure caused by frost heave or wind force. The upward water pressure on a structure.

Upstream Slope: The inclined surface of the dam that is in contact with the reservoir.

Value analysis: An evaluation process to identify potential value enhancements, cost savings, or improvements on a particular design feature while meeting the same technical criteria, intent, and project objectives used for design of the project.

Wave runup: Vertical height above the sill water level to which water from a specific wave will run up the face of a structure or embankment.

Weir: A device designed to allow the accurate measurement of the flow rates at a pipe discharge point or for the seepage collected at ground surface.

Acronyms

AAR/IP	After-Action Report and Implementation Plan
AEP	Annual Exceedance Probability
AFP	Annualized Failure Probability
ALL	Annualized Life Loss
ASTM	American Society for Testing and Materials
BIA	Bureau of Indian Affairs
BOR	U.S. Bureau of Reclamation
CCTV	Closed Circuit Television
CE	Categorical Exclusion
CFR	Code of Federal Regulations
CO	Contracting Officer
CPT	Cone Penetration Test
CR	Comprehensive Review
DHS	U.S. Department of Homeland Security
DM	Departmental Manual
DOI	U.S. Department of the Interior
DSPR	Dam Safety Priority Rating
DWP	Division of Water and Power
EA	Environmental Assessment
EAP	Emergency Action Plan
EIS	Environmental Impact Statement
EM	Emergency Management
EWS	Early Warning System(s)
FAR	Federal Acquisition Regulations
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FSL	Facility Security Level
FWS	U.S. Fish and Wildlife Service
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HSEEP	Homeland Security Exercise and Evaluation Program
IAM	Indian Affairs Manual
ICS	Incident Command System
IDF	Inflow Design Flood
IDSA	Indian Dam Safety Act
IE	Issue Evaluation
IFHA	Incremental Flood Hazard Assessment
ITR	Independent Technical Review
LEOP	Local Emergency Operations Plan
LTRO	Land Titles and Records Office

MRWS	Maximum Reservoir Water Surface
NCI	National Critical Infrastructure
NDF	Non-Dam-Failure
NEPA	National Environmental Policy Act
NID	National Inventory of Dams
NMC	National Monitoring Center
O&M	Operations and Maintenance
OIG	Office of the Inspector General
PAR	Population-At-Risk
PE	Professional Engineer
PFM	Potential Failure Mode
PFMRA	Potential Failure Mode and Risk Analysis
P.L.	Public Law
PMF	Probable Maximum Flood
PR	Periodic Review
PSHA	Probabilistic Seismic Hazard Analysis
RCC	Roller Compacted Concrete
RCEM	Reclamation Consequence Estimating Methodology
RFI	Request for Information
RIDM	Risk-Informed Decision-Making
RRV	Risk Reduction Verification
SCADA	Supervisory Control and Data Acquisition
SOD	Safety of Dams
SPT	Standard Penetration Test
SR	Security Review
TERO	Tribal Employment Rights Ordinances
THPO	Tribal Historical Preservation Office
TM	Technical Memorandum
TVA	Tennessee Valley Authority
USACE	U.S. Army Corps of Engineers
UTM	Universal Transverse Mercator
VA	Value Analysis