ERDC/CERL TR-21-7

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Sustainment Management Systems Program

Sustainment Management System, Water Control Structures

Inventory and Inspection Template

James P. Allen, Matthew H. Werth, Marissa A. Campobasso,
and Yazen F. Kashlan

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Final report

Prepared for Assistant Secretary of Defense for Energy, Installations, and Environment
(ASD) (EI&E) and Facilities Investment and Management (FIM)
Washington, DC 20301

Under Project L9GDHG, “SMS Dam Inspection Module - WHS” OASD EI&E FIM

Abstract

Department of Defense (DoD) military services own and maintain a portfolio of dams, dikes, and levees including over 800 assets with a total replacement value of over $2 Billion. The Inspector General has previously found that the DoD requires an inspection policy for dams, to prevent failures. The Office of the Secretary of Defense (OSD) directed the U.S. Army Engineer Research and Development Center, Construction Engineering Laboratory (ERDC-CERL), to create an inspection method and integrate that method with the Enterprise Sustainment Management System, with aims to provide OSD a consistent description of all DoD real property and facilitate calculation of the Facility Condition Index (FCI) for each asset.

This report builds upon ERDC-CERL TR-18-9 to propose a method for both inventory and inspection rating for DoD dams, levees, and dikes. A new real property classification system for DoD water control structures is proposed. To better fulfil the OSD requirement for consistent condition and FCI reporting, it is proposed that DoD reevaluate the replacement values and sustainment cost factors for its water retaining structures. A draft guide for linear segmentation for levees is proposed. Future work will allow CERL to develop an Initial Operating Capability for a module within the Enterprise Sustainment Management System to support the OSD requirement.

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Preface

This study was conducted for the Assistant Secretary of Defense for Energy, Installations, and Environment (ASD) (EI&E) and Facilities Investment and Management (FIM) under Project L9GDHG, "SMS Dam Inspection Module - WHS" OASD EI&E FIM. The technical monitor was Mr. Robert Lang.

The work was performed by the Engineering Processes Branch of the Facilities Division, U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory, (ERDC-CERL). At the time of publication of this report, Mr. Charles Schroeder was Chief of the Engineering Processes Branch; Ms. Giselle Rodriquez was Chief of the Facilities Division; and Mr. Andrew Nelson was the Technical Director for Installation Readiness. The Acting Deputy Director of ERDC-CERL was Ms. Michelle Hanson, and the Interim Director was Dr. Kirankumar Topudurti.

COL Theresa A. Schlosser was the Commander of ERDC, and the Director was Dr. David W. Pittman.

1 Introduction

1.1 Background

The U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), is the Sustainment Management System (SMS) Technical Center of Expertise. Therefore, ERDC-CERL assists other offices and agencies within the Department of Defense (DoD) with SMS-related work in terms of development, implementation planning, and data management. Some of the existing SMS tools created by the U.S. Army Corps of Engineers (USACE) are BUILDER™ SMS and PAVER™ SMS for the sustainable management of the Army's buildings and pavements. These tools consist of an inventory, inspection ratings, a condition rating assigned to each structure and its components, condition prediction modeling, parametric repair cost software, and prioritization capabilities to assist in work planning. Currently, the DoD water retention facilities lack an SMS tool with these capabilities. To comply with the 2013 Under Secretary of Defense for Acquisition, Technology and Logistics (USD AT&L) policy "Standardizing Facility Condition Assessments," which makes it mandatory for DoD components to use the SMS for conducting and documenting facility inspections; an SMS tool based off existing tools will be created to better maintain the DoD dams, levees, and dikes. USACE envisions all its SMS tools to be merged in an Enterprise SMS where the DoD can effectively manage all its infrastructure assets. This report outlines the proposed methodologies of the inventory, inspection, and condition ratings sections of the dams, levees, and dikes SMS tool (Allen et al. 2018).

1.2 Objective

The goal is to outline the inventory, inspection rating criteria, and condition rating criteria for implementation in an SMS tool for the DoD inventory of dams, levees, and dikes to assist in work planning strategies and comply with the USD AT&L "Standardizing Facility Condition Assessments." This SMS tool will help the DoD safely and economically maintain and manage its dams.

1.3 Approach

This report begins with defining dams, levees, and dikes according to various governmental agencies, describing the types of failure modes of the structures along with their respective causes, and listing dam, levee, and dike safety-related laws and federal documentation.

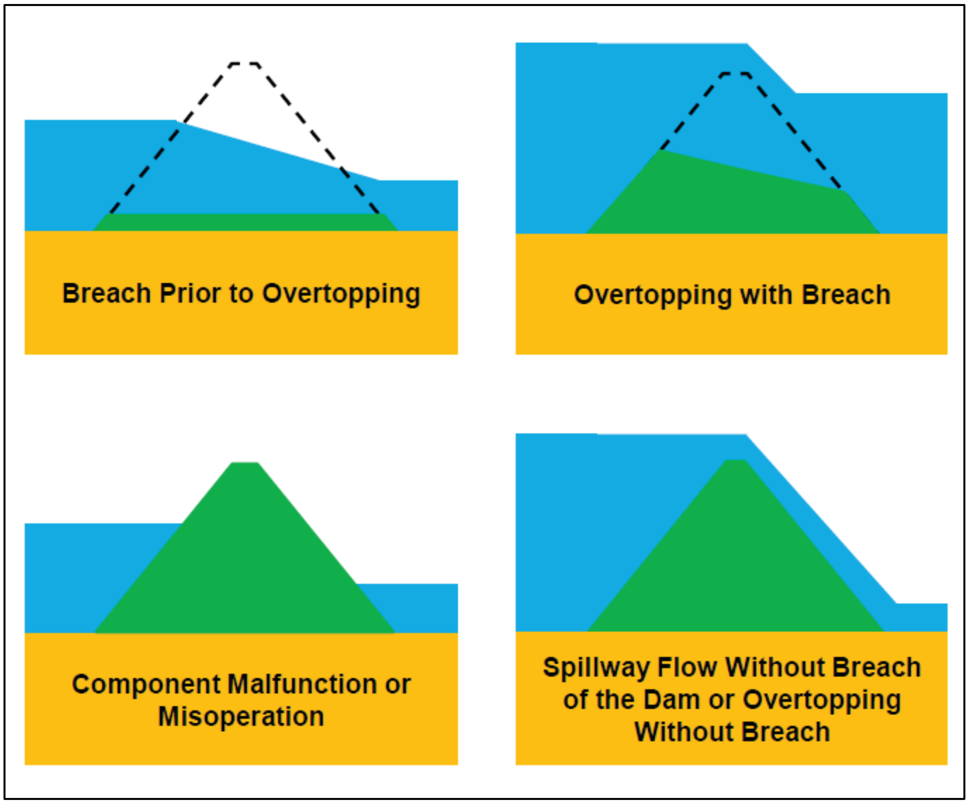
The succeeding sections of the report describe the current and proposed methodologies for a DoD dams, levees, and dikes inventory, inspection criteria and standardized rating scales of the distresses on the structures' components, and standardized condition ratings to the structures. The inventory, inspection ratings, and condition ratings are to be implemented into an SMS tool to consistently and sustainably maintain the DoD dams, levees, and dikes.

2 Dam, Levee, and Dike Safety

2.1 Failure of water control structures

Failure is described as the sudden, rapid, and uncontrolled release of impounded water (FEMA 2004a). This failure of uncontrolled release of impounded water results in four inundation scenarios for dams and levees (Figure 1). These scenarios are breach prior to overtopping, overtopping with breach, dam or levee component malfunction or misoperation, or interior drainage capacity exceeded behind the levee, and spillway flow without breach/overtopping without breach (U.S. Department of the Interior, Bureau of Reclamation and USACE 2015). *Breaching* is when a section of a levee (or dam) is damaged to the point where an opening is formed and allows floodwaters to pass in the leveed or dammed area (Levee Safety Program 2018).

Figure 1. Four inundation scenarios of dams and levee (U.S. Department of the Interior, Bureau of Reclamation, and USACE 2015).



Dam failure modes that can result in these inundation scenarios include foundation, piping, hydrologic, seismic, and structural failures (Stedinger et al. 1996). Table 1 below lists distresses that lead to those dam failure modes. However, the most common dam failures are when the spillway has an inadequate capacity (fourth inundation scenario) and when piping occurs in the dam or its foundation. (Michael Baker International 2019). Figure 2 and Figure 3 display some of these distresses on embankment and concrete dams.

Table 1. Dam failure causes (IMCOM Academy School of Public Works 2017).

Embankment Dam Failure Causes	Concrete/Masonry Dam Failure Causes
Seepage/piping/boils	Major cracks/spalling
Animal burrows	Misalignment
Vegetation	Seepage
Erosion	Stability of rock on abutments
Slide, slough, scarp	Damaged mechanical equipment
Surface cracking	Vegetation
Unusual movement	Debris stuck under gates
Inadequate spillway capacity/Debris blocking spillway or causing backwater that saturates downstream of the dam	Inadequate spillway capacity/Debris blocking spillway or causing backwater that saturates downstream of the dam

Figure 2. Embankment dam distresses (USFS and FEMA 2016).

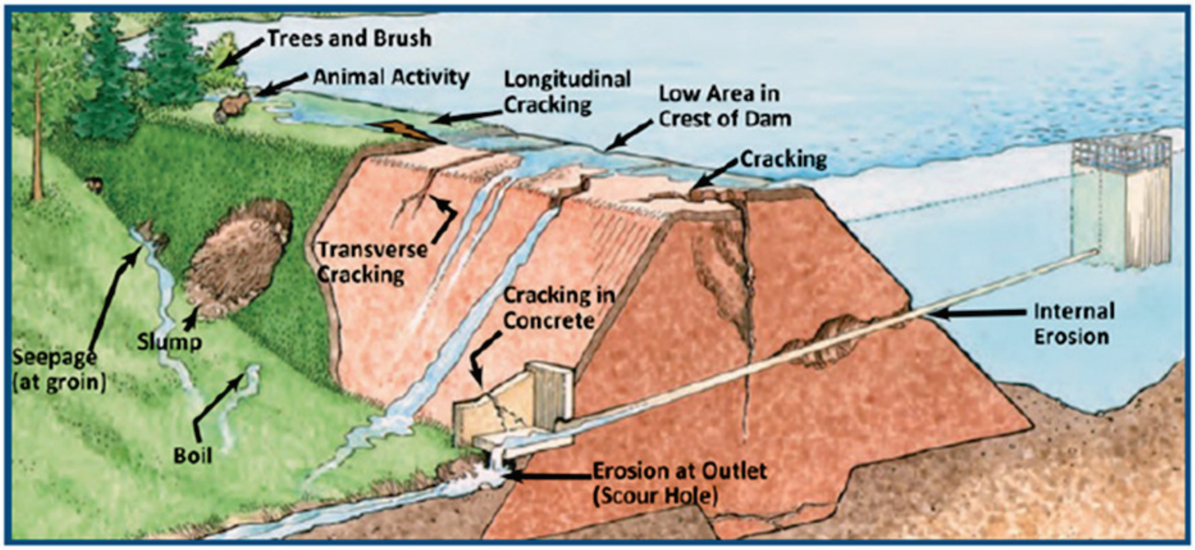
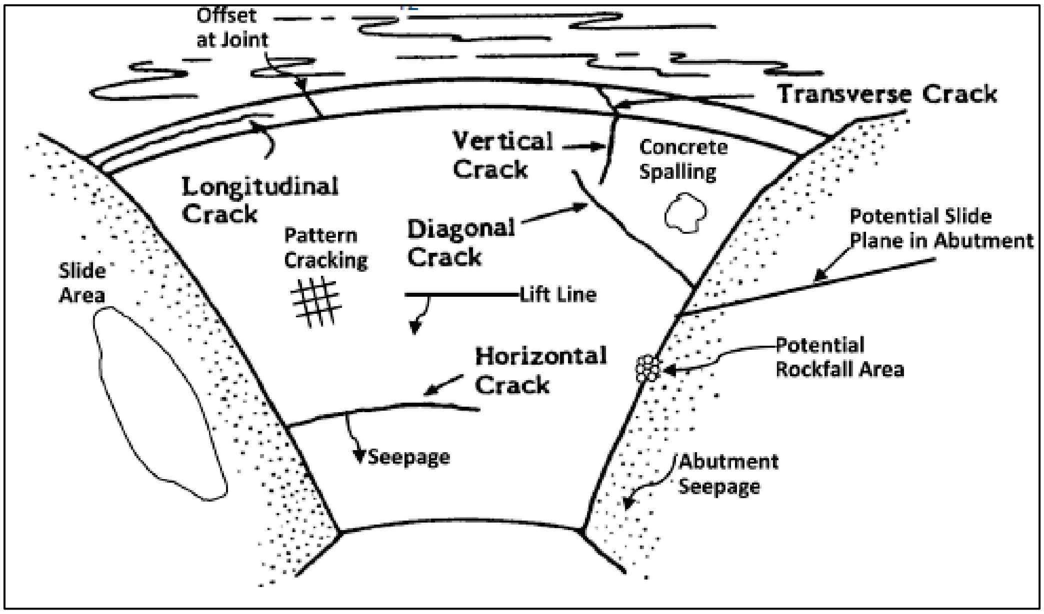


Figure 3. Concrete dam distresses (USFS and FEMA 2016).



The most common failure scenario for levees is overtopping with breaching (second inundation scenario). Table 2 lists the different hazardous developments that may occur along levees.

Table 2. Failure modes and associated hazards.

Failure Mode	Hazards
Primary	Embankment and foundation seepage and piping Embankment stability Embankment erosion Closure structures malfunction Floodwall stability Floodwall seepage and piping Levee overtopping resulting in breach
Secondary	Encroachments Woody vegetation Animal burrowing Sod cover quality Culvert and relief well condition

For dikes, breaches are most commonly caused by external erosion (i.e., overtopping), internal erosion (i.e., seepage), slope failures, and embedded structural failures such as I-walls and sheet pile wall supports (Danka and Zhang 2015).

Photos of actual distresses/hazards that lead to water control structure failure are included in Appendix H.

2.2 Legislation

2.2.1 Dams

After devastating dam failures, the National Dam Inspection Act (Public Law 92-367) (U.S. Congress 1972) of 1972 authorized the Secretary of the Army to inspect non-federal dams, give the states and Congress recommendations to improve dam safety, and create a national inventory of dams. USACE is responsible for carrying out the duties outlined in the Act (FEMA 2004b). The National Inventory of Dams (NID) was then created in 1975 by USACE. However, it does not contain levees or dikes. Currently, USACE works alongside the Federal Emergency Management Agency (FEMA) as well as state regulatory offices to maintain a more detailed inventory,[*] which is updated yearly as of 2019. There are nearly 87,000 dams in the NID, and USACE operates and maintains 700 dams in the United States and Puerto Rico (U.S. Army Corps of Engineers n.d. Dam Safety Program).

A minimum of one of the following criteria is met for dams in the NID (U.S. Army Corps of Engineers n.d. National Inventory of Dams):

- High hazard potential classification (Table 6)
- Significant hazard potential classification (Table 6)
- Greater than or equal to 25 ft[†][‡] in height and exceed 15 acre-ft storage
- Greater than or equal to 50 acre-ft storage and exceed 6 ft in height.

Table 3 defines each hazard potential class, where the classes are defined as low, significant, or high. These categories are dependent upon the possibility of lives or property being lost in the event of a dam breach.

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[*] https://nid.sec.usace.army.mil/ords/f?p=105:1::::::

[†] For a full list of the spelled-out forms of the units of measure used in this document, please refer to US Government Publishing Office Style Manual, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

[‡] For a full list of the unit conversions used in this document, please refer to US Government Publishing Office Style Manual, 31st ed. (Washington, DC: US Government Publishing Office 2016), 345-7, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

Table 3. Hazard potential classification of dams (FEMA 2004).

Hazard Potential Classification	Loss of Human Life	Economic, Environmental, Lifeline Losses
Low	None expected	Low and generally limited to owner
Significant	None expected	Yes
High	Probable. One or more expected	Yes (but not necessarily for this classification)

Several other public laws related to dam inspection and safety have been enacted since Public Law 92-367. Table 4 lists these laws.

Table 4. Laws relative to dam inspection.

Year	Public Law (P.L.)	Dam Relevance
1972	P.L. 92-367, National Dam Inspection Act (U.S. Congress 1972) (Association of State Dam Safety Officials n.d.)	This law authorized the Secretary of the Army to inspect non-federal dams, give the states and Congress recommendations to improve dam safety, and create a national inventory of dams.
1986	P.L. 99-662, Water Resources Development Act (U.S. Congress 1986) (Association of State Dam Safety Officials n.d.)	This act established a National Dam Safety Review Board of seven members, granted state dam safety program assistance of $13 million, allocated $500,000 to help maintain and update the NID, and allocated $2 million towards research.
1996	P.L. 104-303, Water Resources Development Act (U.S. Congress 1996) (Association of State Dam Safety Officials n.d.)	This act established a National Dam Safety Review Board of 11 members, granted state dam safety program assistance of $4 million, allocated $500,000 to help maintain and update the NID, and allocated $1 million towards research and $500,000 towards training.
2002	P.L. 107-310, Dam Safety and Security Act (Association of State Dam Safety Officials n.d.)	This act established a National Dam Safety Review Board of 11 members, granted state dam safety program assistance of $6 million, allocated $500,000 to help maintain and update the NID, allocated $1.5 million towards research and $500,000 towards training, and added security to critical dam safety issues.
2006	P.L. 109-460, Dam Safety Act (U.S. Congress 2006)	This act amended the National Dam Safety Program Act to reauthorize the National Safety Program and for other purposes such as redefining duties and allocating more funds towards dam safety for the fiscal years of 2003–2011.

2014	P.L. 113-121 Water Resources Reform and Development Act (U.S. Congress 2014)	This act amended the National Dam Safety Program Act to reauthorize the National Safety Program and for other purposes such as replacing the term "director" with "administrator," redefining objectives of the National Dam Safety Program, adding section 11, which outlines public awareness and outreach for dam safety, and allocating more funds towards dam safety (annual amounts) for the fiscal years of 2015–2019.

There are several governmental documents that provide information regarding dam safety, hazards/risks, management, inspection and maintenance guidelines, and emergency action plans including the following:

- USACE ER-1110-2-1156, Safety of Dams-Policy and Procedures
- FEMA 93, Federal Guidelines for Dam Safety
- FEMA 64, Federal Guidelines for Dam Safety, Emergency Action Planning for Dam Owners
- FEMA 65, Federal Guidelines for Dam Safety, Earthquake Analyses and Design of Dams
- FEMA 333, Federal Guidelines for Dam Safety, Hazard Potential Classification System for Dams
- FEMA 145, Dam Safety: An Owner's Guidance Manual
- Safety Evaluation of Existing Dams, A Water Resources Technical Publication, U.S. Department of the Interior Bureau of Reclamation.

2.2.2 Levees

In the National Levee Safety Act of 2007 (U.S. Congress 2007), Congress created the principal authority dedicated to levee safety, the National Committee on Levee Safety (NCLS). This committee was tasked with developing recommendations for, and strategies to implement, a national levee safety program. Chaired by the USACE, the NCLS presented 20 recommendations in its 2009 report to Congress (NCLS 2009). These recommendations collectively established the basis for a National Levee Safety Program (Levee Safety Program 2018).

Also known as the Water Resources Development Act of 2007, the National Levee Safety Act "directed USACE to inventory, inspect, and assess risks associated with the USACE levee portfolio. In addition, Congress recognized that many levees exist outside of the USACE levee portfolio and directed USACE to establish a database with an inventory of all the nation's levees" (Levee Safety Program 2018). Thus, the National Levee Data0base (NLD)* was initiated and made publicly available. In addition to the NLD, DoD branches have their own levee inventories.

The principal documents regarding levee safety guidelines are the Report to Congress from the National Committee on Levee Safety (NCLS 2009), the Government Accountability Report (United States Government Accountability Office 2016), and the USACE Levee Safety Portfolio Report (Levee Safety Program 2018). These documents and others that outline maintenance and inspection progress and procedures for levee systems are listed below:

- Title 33. Code of Federal Regulations (CFR). Navigation and Navigable Waters (33 CFR § 208.10: Local Flood Protection Works n.d.)
- CECW-CE: Policy Guidance Letter - Periodic Inspection Procedures for the Levee Safety Program (U.S. Army Corps of Engineers 2008a)
- Rehabilitation Assistance for Non-Federal Flood Control Projects (USACE 2009)
- Recommendations for a National Levee Safety Program: A Report to Congress from the National Committee on Levee Safety (NCLS 2009)
- US GAO, Army Corps and FEMA Have Made Little Progress in Carrying Out Required Activities Report to Congressional Committees (United States Government Accountability Office 2016)
- USACE, Levee Safety Portfolio Report (Levee Safety Program 2018)

In addition to the National Levee Safety Act of 2007 (P.L. 110-114, U.S. Congress [2007]), numerous legislative acts authorize and regulate levee inspection and maintenance. Table 5 lists these laws.

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* See database: http://nld.usace.army.mil

Table 5. Public laws: relevance to levees.

Year	Public Law (P.L.)	Levee Relevance
1955	P.L. 84-99, Disaster Control Operations (U.S. Congress 1955)	Congress authorized the USACE to perform inspections of non-federal projects, if requested by the local sponsor. The Inspection of Completed Works and the Rehabilitation and Inspection Program are the two special programs dedicated to facilitating these inspections. This document was amended by USACE in 2009 (USACE 2009) to provide a detailed list of levee components used in current USACE inspections (see section 7 below).
1976-1992	P.L. 95-587, Water Resources Development Act of 1976 (U.S. Congress 1976) P.L. 99-662, WRDA, 1986 (U.S. Congress 1986) P.L. 100-676, WRDA, 1988 (U.S. Congress 1988) P.L. 101-640, WRDA, 1990 (U.S. Congress 1990) P.L. 102-580, WRDA, 1992 (U.S. Congress 1992)	Spread across two decades, these acts authorize the Secretary of the Army to carry out specified water resources development and conservation projects across the United States including many specific levee projects. No general levee safety guidelines are authorized in these acts.
1996	P.L. 104-303, Water Resources Development Act of 1996 (U.S. Congress 1996)	This act directs the Secretary of the Army "to: (1) prepare a levee owner's manual to be followed by non-Federal interests in order to receive Federal assistance under a project; (2) review and revise if necessary the current policy guidelines on vegetation management for levees; and (3) enter into an agreement with the National Academy of Sciences to study and report to the Congress on the use by the Army Corps of Engineers (Corps) of risk-based analysis for the evaluation of hydrology, hydraulics, and economics in flood reduction studies."*
1999	P.L. 106-53, Water Resources Development Act of 1999 (U.S. Congress 1999)	This act authorizes improvements and safety reviews of specific levee systems across the United States. No general levee safety guidelines are authorized in this act.
2000	P.L. 106-541, Water Resources Development Act of 2000 (U.S. Congress 2000)	Amends the WRDA of 1990 to extend through Fiscal Year 2005. Reauthorizes appropriations for the rehabilitation of Federal flood control levees.
2005	P.L. 109-148, Department of Defense, Emergency Supplemental	Under Public Law 109-148, "$30 million of emergency supplemental funds were appropriated for the Corps of Engineers to initiate a National Inventory of Flood and

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* https://www.govtrack.us/congress/bills/104/s640/summary

	Appropriations to Address Hurricanes in the Gulf of Mexico, and Pandemic Influenza Act of 2006 (U.S. Congress 2005)	Storm Damage Reduction projects." This act authorized the creation of the National Levee Inventory and Database since it formalized levee condition assessments (Levee Safety Program 2018).
2007	P.L. 110-114, National Levee Safety Act (U.S. Congress 2007)	Also known as the Water Resources Development Act (WRDA) of 2007, this legislative document directed USACE to "inventory, inspect, and assess risks associated with the USACE levee portfolio" and "to establish a database with an inventory of all the nation's levees," recognizing that the USACE portfolio does not capture all the nation's levees. The National Levee Database (NLD) was developed following this act.
2014	P.L. 113-121, Water Resources Reform and Development Act (WRRDA, 2014) (U.S. Congress 2014)	This legislative act amends the National Levee Safety Act of 2007 and authorizes a National Levee Safety Program (to create guidelines and support local initiatives promoting levee safety). The Secretary of Army is directed through this act to complete a one-time inventory of all levees added to the NLD since its authorization in 2007 and an evaluation of all federally authorized levees. All that to facilitate decisions by FEMA regarding levee accreditation, the mapping of areas protected by levees, and the scheduling of activities under the National Flood Insurance Program (NFIP).
2016	P.L. 114-322, Water Resources Development Act of 2016 (U.S. Congress 2016)	Included as part of the Water Infrastructure Improvements for the Nation Act, this act amends the National Levee Safety Act of 2007 to include regional districts' flood damage reduction projects, making them eligible for assistance from (1) FEMA to establish a levee safety program and (2) the USACE for flood mitigation activities. Also states that regional district participation must be captured in the NLD inventories, review procedures, and safety guidelines.
2018	P.L. 115-270, Water Resources Development Act of 2018 (U.S. Congress 2018)	Also known at the Water Infrastructure Now Act, this legislative document reauthorizes the 2007 Levee Safety Initiative for the years 2019–2023. It also outlines certain improvements in levee maintenance procedures, eliminating barriers in the relationship between local governments and the Secretary of the Army.

2.2.3 Dikes

Few federal regulations or laws make explicit mention to dikes. Where they do, the intent of the term *dike* is often ambiguous. This is because dikes are more difficult to define in practice than levees and dams. As described in Chapter 3, structures classified as dikes can sometimes fit the legal definition of either a dam or levee. A broad generalization of the body of federal law pertaining to water control structures indicates that the intent in many of the statutes listed above is to improve public safety by adding additional requirements for structures, which could cause loss of life or property in the event of failure. A result of this assumption is that wherever the law specifies regulations for a "dike or dam," or a "dike or levee," the intent is to group those structures listed as dikes wherever they perform a similar function to that of a dam or levee. Specifically, it is assumed that retaining water in either the normal or flood stage is a critical feature in determining if a dike is regulated by any of the public laws mentioned above.

For the purposes of the Enterprise Sustainment Management System (ESMS) module for water retaining structures, Chapter 3 lays out guidelines of what should and should not be considered a dike. These guidelines are intended to clearly delineate dams and levees that fall under federal regulations from dikes. By the definition proposed in this report, DoD dikes would not fall under the legal definitions or regulations regarding either dams or levees because the proposed definition excludes structures that retain water or pose significant safety risks.

2.3 Future dam, levee, and dike safety

Currently, USACE has a standard methodology of dam and levee inspection (see chapters 4 and 5) but does not have a user-friendly tool for the utilization of asset management for the Army's dams, levees, and dikes. By borrowing ideas from BUILDER SMS and PAVER SMS, USACE is creating an SMS tool for dams, levees, and dikes. The methodology used in BUILDER SMS and PAVER SMS has to be adjusted, as dams, levees, and dikes are more complex in nature and do not break down into components as distinctively as buildings and pavements.

3 Inventory

3.1 Purpose

Inventory and inspection data are commonly collected in a variety of formats. The NID imposes a defined template for inventory data for applicable dams, as does the DoD for the purposes of real property inventory. A functioning SMS system has higher requirements for inventory data than these systems, due to the need for more granular data of both component types and quantities and associated distresses. The proliferation of data fields and points results in a comparatively large cumulative data requirement for effective inventory and inspection tracking.

Unstructured data, like are commonly collected via formal inspections, is well suited to creating a narrative description of the condition of a dam and is therefore useful for communicating inspection knowledge to future inspectors and work planners. However, the type of data usually found in those inspections reports are very difficult to parse automatically and analyze efficiently. A specific data structure is proposed that will allow inspectors to input inventory data into the SMS, to allow consistent analysis and make inventory more objective.

3.2 Definitions

The primary function of dams, levees, and dikes is water retention. Figure 4 below shows how levees and dams are oriented with respect to a river. Whereas dams control rivers by imposing a perpendicular barrier to water flow, levees are generally aligned parallel to the flow of a waterway. Dikes, like dams, are constructed perpendicular to the flow of water. However, they are usually smaller than dams and may not always span the whole width of the river (Figure 5) (U.S. Army Corps of Engineers Applied River Engineering Center n.d.).

Figure 4. Dam and levee orientation with respect to river (Phoon 2008).

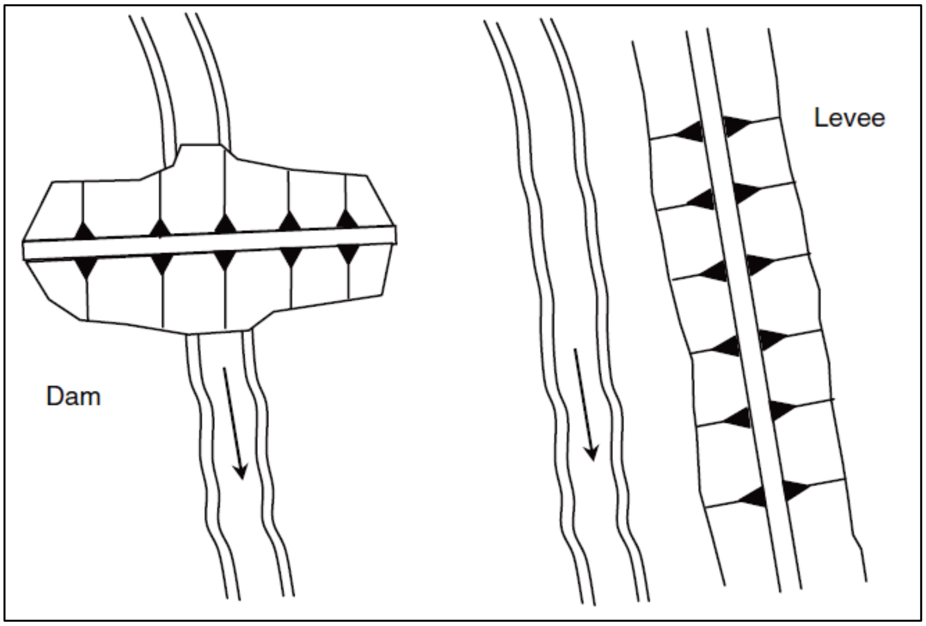
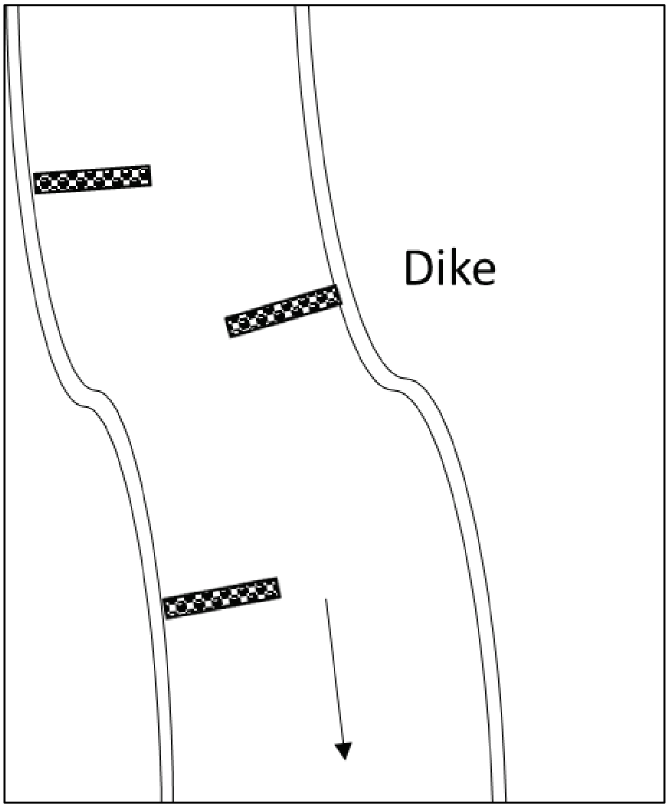


Figure 5. Dike orientation with respect to river.



3.2.1 Dams

In Table 6, a list of dam definitions according to different governmental agencies is provided. Appendix A contains the full federal definition of a dam per U.S. Code (U.S.C.) Title 33, "Navigation and Navigable Waters."

Table 6. Dam definitions.

Agency	Definition
33 U.S.C. (33 U.S. Code § 467: Definitions n.d.)	"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…" It is at least 25 ft in height and has an impounding capacity for maximum storage elevation of at least 50 acre-ft. The barriers also need to be at least 6 ft high and the storage capacity at the maximum water storage elevation has to be greater than 15 acre-ft.
Federal Guidelines for Dam Safety, FEMA 93 (FEMA (Federal Emergency Management Agency) 2004)	"Any artificial barrier, including appurtenant works, which impounds or diverts water…" It has the same height and storage criteria as listed in 33 U.S.C.
USACE ER 1110-2-1156 (USACE 2014)	"An artificial barrier, including appurtenant works, constructed for the purpose of storage, control, or diversion of water…" It has the same height and storage criteria as listed in 33 U.S.C.

Dams provide many benefits to people such as supplying water and hydropower, flood control, providing a means of navigation, recreation, and more. Some of the most common dam material types include earth, concrete, and masonry while common dam design types include the earth embankment, concrete gravity, concrete arch, and the concrete buttress (USFS and FEMA 2016). Examples of these dam designs are provided in Figure 6 through Figure 9.

Figure 6. Earth embankment cross-section (Shiksha 2014).

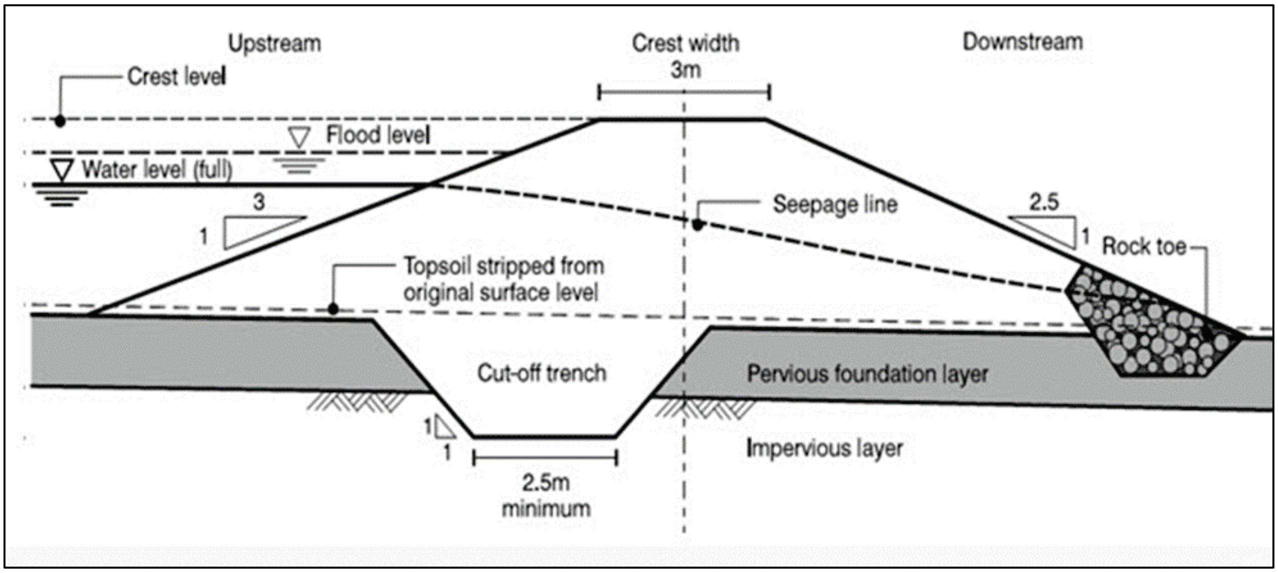


Figure 7. Concrete gravity dam plan and profile views (USFS and FEMA 2016).

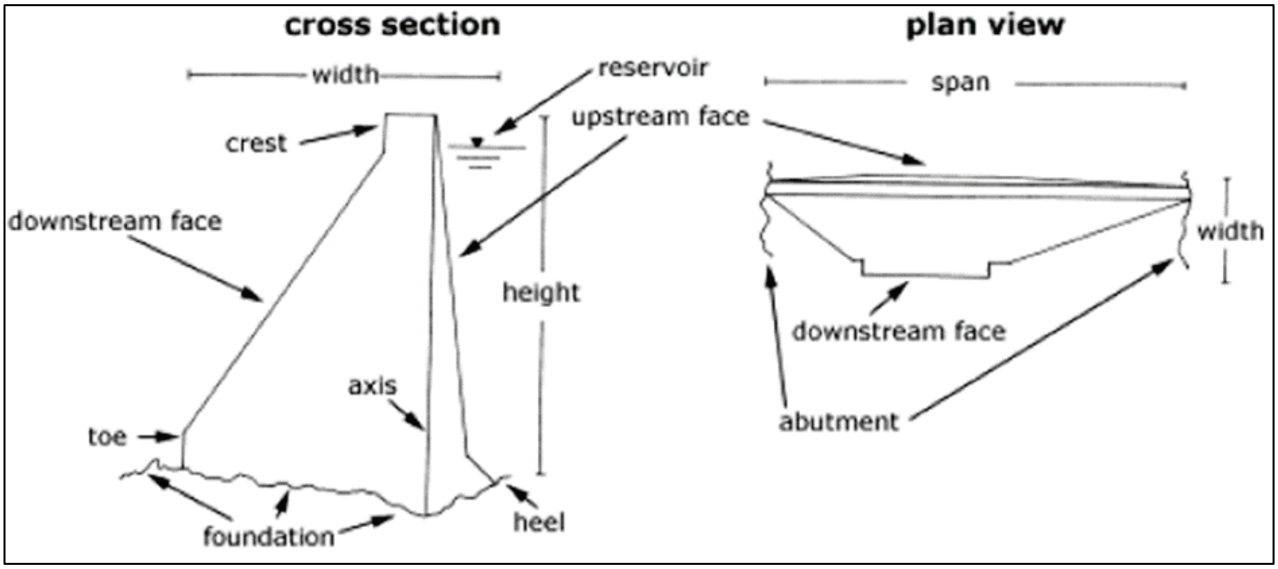


Figure 8. Concrete arch dam plan and profile views (USFS and FEMA 2016).

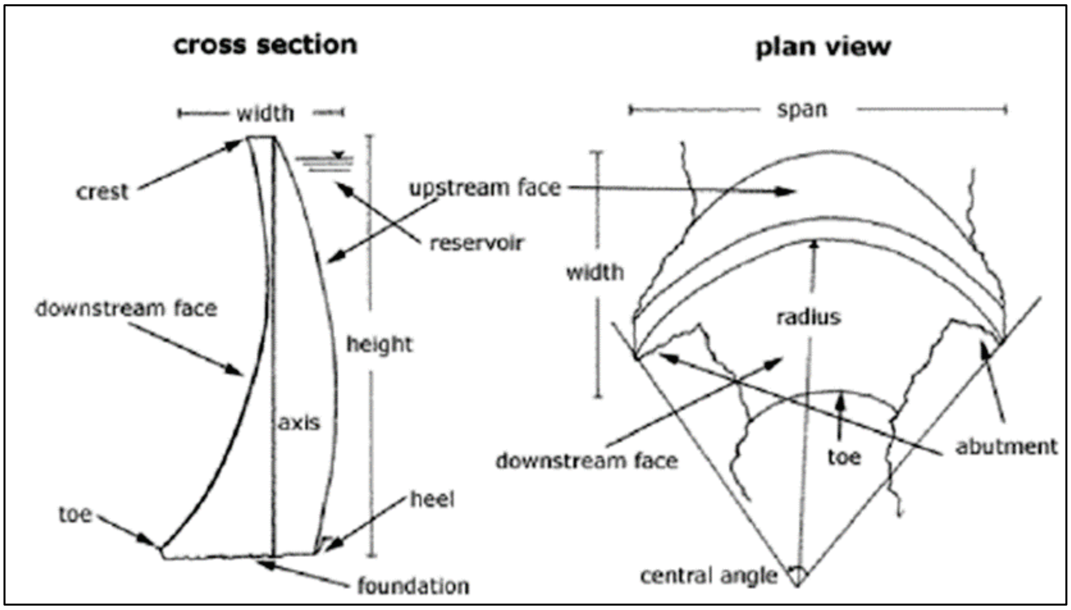
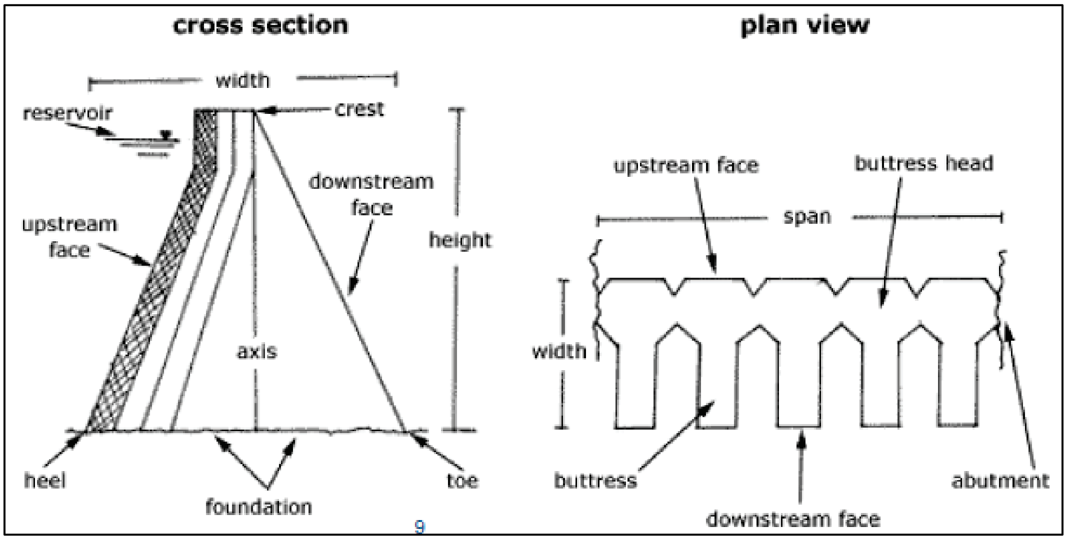


Figure 9. Concrete buttress dam plan and profile views (USFS and FEMA 2016).



3.2.2 Levees

Table 7 lists levee definitions according to different government agencies. Appendix B provides an official levee definition per Public Law 113-121, Title III. A summary is provided in Table 7.

Table 7. Levee definitions.

Agency	Definition
FEMA and 44 CFR	A man-made structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water in order to reduce risk from temporary flooding (FEMA 2016). Defined in Title 44 CFR, Chapter 1, section 59.1 (44 CFR § 59.1: Definitions n.d.).
Public Law 113-121, Title III	A manmade barrier (such as an embankment, floodwall, or other structure) (i) the primary purpose of which is to provide hurricane, storm, or flood protection relating to seasonal high water, storm surges, precipitation, or other weather events; and (ii) that is normally subject to water loading for only a few days or weeks during a calendar year (U.S. Congress 2014).
National Committee on Levee Safety	A manmade barrier (embankment, floodwall, or structure) along a watercourse constructed for the primary purpose to provide hurricane, storm, and flood protection relating to seasonal high water, storm surges, precipitation, and other weather events; and that normally is subject to water loading for only a few days or weeks during a year (NCLS 2009). Levees also may be embankments, floodwalls, and structures that provide flood protection to lands below sea level and other lowlands and that may be subject to water loading for much, if not all, portions of the year, but that do not constitute barriers across watercourses or constrain water along canals. This levee definition does not apply to shoreline protection or riverbank protection systems such as revetments, barrier islands, etc.

Levees can be classified based on the areas they protect, their purpose, or construction type. Levees can be classified as urban or agricultural. Urban levees protect industrial, commercial, or residential areas while agricultural levees protect farmland. Levees can also be referred to as mainline and tributary levees, ring levees, setback levees, sublevees, and spur levees. Examples are provided in Figures 10–12. Mainline and tributary levees lie along a mainline of a river and its tributaries, ring levees encircle an area, setback levees are constructed landward of existing damaged levees, sublevees aid in underseepage control, and spur levees project from a main levee to protect it from hydraulic erosion. Most levees are earth embankments, and the construction types include compacted, semi-compacted, and uncompacted (Pohland 2019).

Figure 10. Mainline Mississippi River levee (USACE 2011).

Figure 11. Ring levee (Olson 2011).

Figure 12. Setback levee (Seattle Daily Journal of Commerce 2018).

3.2.3 Dikes

According to 33 CFR § 321.2, a dike or dam is "any impoundment structure that completely spans a navigable water of the United States and that may obstruct interstate waterborne commerce" (33 CFR § 321.2: Definitions n.d.).

In many cases, dikes are similar to dams in terms of how they are constructed and what the intended purpose is. However, they may be differentiated based on size and capacity characteristics. The U.S. Army defines dikes as follows:

"An artificial barrier that impounds or diverts water away from areas or facilities to avoid damage but does not meet either of the criteria for a dam (89270). Dikes are artificial barriers that are both

1. less than 25 feet in height from the natural bed of the stream or watercourse to the maximum water storage elevation and

2. have an impounding capacity at maximum water storage elevation of less than 50 acre-feet. Dikes may be constructed of earth, concrete, or other materials." (U.S. Army 2012)

Dikes are constructed in a river perpendicular to its flow to redirect the river's energy and vary in height and length. In large rivers, they are typically constructed at a height midway up the channel instead of spanning the whole river. Dikes can manage sediment response distribution in a large river, deepen the channel, and enhance navigation. They can divert the flow in smaller rivers and preserve eroding banks. This results in decreased dredging requirements, increased channel stabilization, and increased bank protection. Dikes can be made from stone and other materials such as timber piles, sand-filled geotextile bags and tubes, and concrete. The main dike types include notched dikes, stepped-up dikes, and pile dikes. Table 8 describes the different types of dikes while Figures 13–17 illustrate these different designs. ((U.S. Army Corps of Engineers Applied River Engineering Center n.d.; U.S. Army Corps of Engineers Portland District n.d.).

Table 8. Dike types (USACE Portland District n.d.; USACE Applied River Engineering Center n.d.).

Notched Dikes	Stepped-Up Dikes	Pile Dikes
Also known as rock dikes. As the name implies, notches are added to dikes to enhance navigation and support diverse habitats. The river can move in between the notches, which creates the four primary river habitats. Between the dikes, sandbars form.	The dikes are arranged in a sequence where the elevation increases by 2 ft per dike. This reduces sediment deposition, which prevents the river from transitioning to a terrestrial environment.	Contains alternating timber piles supported by a horizontal spreader and a king pile (tall bundle of piles) identifies the end of the dike for mariner visibility. Stone covers the base of the dike along the dam's length.

Figure 13. Notched dike profile view (USACE Applied River Engineering Center n.d.).

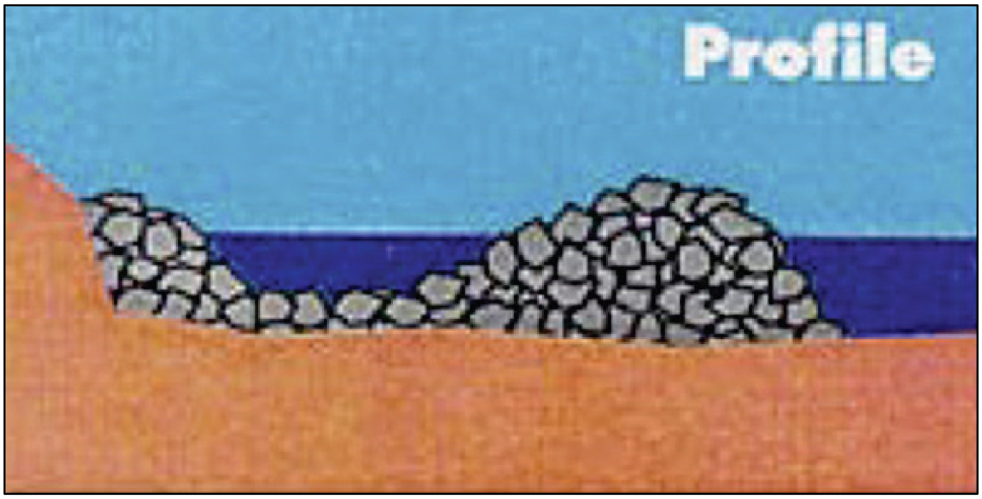


Figure 14. Notched dike in real-world application (USACE Applied River Engineering Center n.d.).

Figure 15. Pile dike (USACE Portland District n.d.).

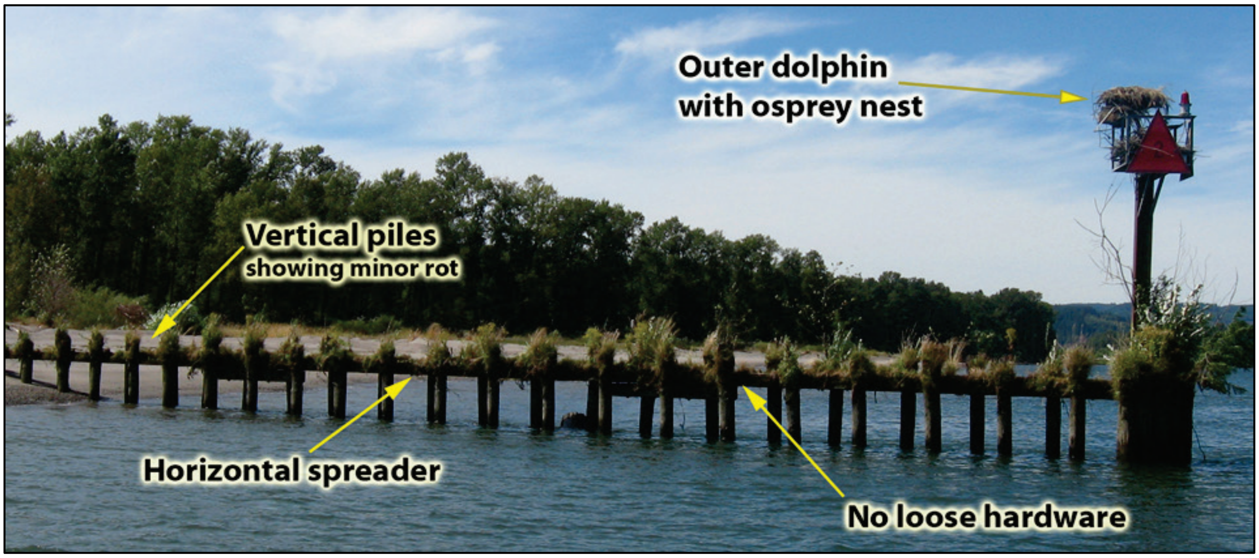


Figure 16. Stepped-up dike profile view (USACE Applied River Engineering Center n.d.).

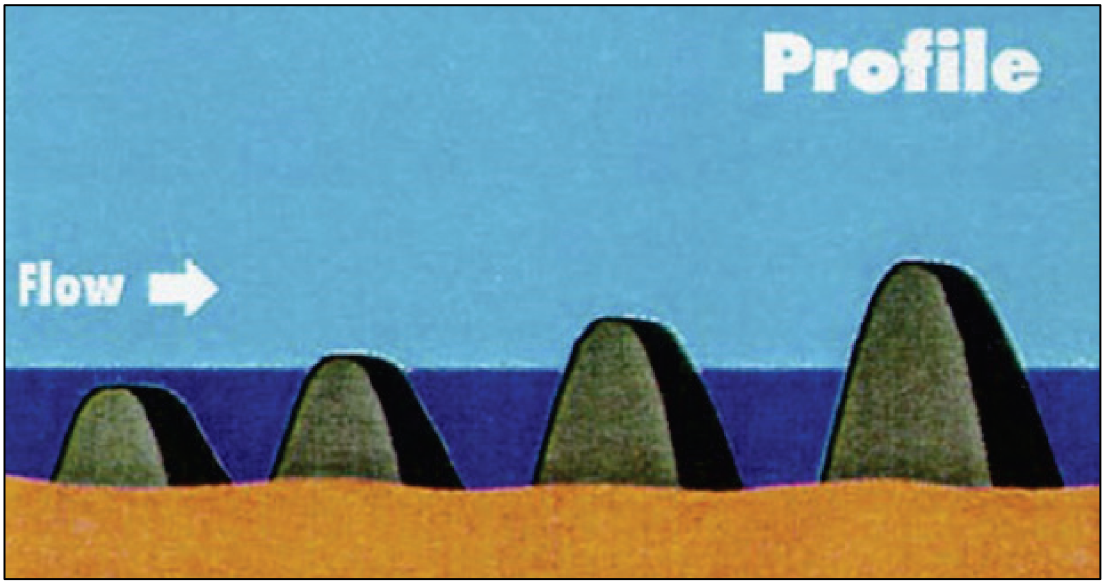
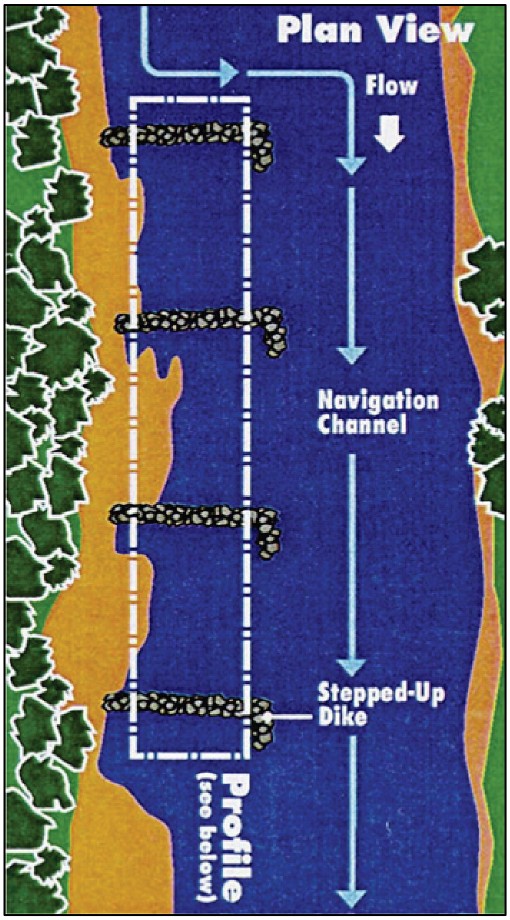


Figure 17. Stepped-up dike plan view (USACE Applied River Engineering Center n.d.).



3.3 Data schema

3.4 Proposed definitions for dams, dikes, and levees

The determination of a dam vs. a dike can be subjective. The following proposed rules provide a subjective way to differentiate between these terms for the purposes of the ESMS.

- A *dam* is a structure that meets the NID criteria for a dam, or any structure that impounds water at normal stages and has an axis perpendicular to normal flow of water.
- A *levee* is a structure that constrains the flow of water, whether at normal flow or flood stage, but its axis lies parallel to the normal flow of water.
- A *dike* is a structure with an axis that is not parallel to the normal flow of water, impounds no water under typical stages, and does not contribute to the safety of the body of water which it controls.

Note that there is a broad interpretation of what constitutes a Dam. This definition can be construed to include everything from large high-hazard dams for which there are explicit federal inspection requirements, to small low hazard dams exempt from federal inspection requirements. As will be seen in Chapter 6, those dams which have federal inspection requirements can have significantly different basic requirements when it comes to the SMS including higher inspection requirements, repair standard, and special considerations for the consequences of failure.

Table 9 shows a proposal for a re-alignment of DoD water control structures real property classification codes to coincide with the definitions given above. While it is not strictly necessary, Facility Activity Code (FAC) and Category (CAT) code realignment would produce some meaningful benefits for DoD that would be difficult to gain otherwise.

Table 9. Proposed water control structure FAC.

New FAC	New FAC Title	New Description	Current FACs
FAC #1	Levees	A structure that meets the definition of a levee.	8714, 8822, 8821
FAC #2	Dikes	A structure that meets the definition of a dike.	8714, 8822, 8821
FAC #3	Non-NID Reportable Dam	Any structure that meets the definition of a dam but is not currently included in the National Inventory of Dams.	8811, 8821, 8713, 8714
FAC #4	Low Hazard, NID Dam	A dam that is listed in the National Inventory of Dams and is classified as Low Hazard.	8811, 8821, 8713, 8714
FAC #5	Significant Hazard, NID Dam	A dam that is listed in the National Inventory of Dams and is classified as Significant Hazard.	8811, 8821, 8713, 8714
FAC #6	High Hazard, NID Dam	A dam that is listed in the National Inventory of Dams and is classified as High Hazard.	8811, 8821, 8713, 8714

First, the real property classification code given to an asset determines the sustainment cost factor for that asset. Currently, NID reportable dams are being funded at the same level regardless of hazard classification and in some cases the same as non-NID dams due to a common FAC/CAT code being assigned to all dams. It may be that a different repair standard, or at least a different priority for repairs, is warranted for dams based on either their hazard classification or NID report ability.

Second, the real property classification also determines the plant replacement value used to calculate the Facility Condition Index (FCI) of an asset. Dams that pose a more significant risk may warrant a higher amount of resources in engineering, planning, and execution of repairs when major failure occurs compared to lower hazard dams. Insomuch as this can be quantified, it would increase the accuracy of the resulting FCI calculation to break out those costs for each hazard classification.

Third, a more detailed breakout of dam assets by hazard classification may be a simple but effective asset visibility improvement. Currently, dams which pose a life safety risk are grouped with a large variety of structures including those which pose essentially no risk to downstream areas. Previous research has shown that readily available databases of DoD dams do not provide adequate links to the rich NID database and the real property system that would allow senior leaders visibility of their portfolio. Making a small investment of time and effort to break out DoD dams into classification codes that match their design and risk characteristics would likely aid in visibility of those features.

3.4.1 National Inventory of Dams (NID)

It is intended that the ESMS will receive regular updates of the NID, either by direct manipulation of the database or via application programming interface (API). The structure of the NID will be determined by the USACE and is currently described by a data dictionary (U.S. Army Corps of Engineers 2016).

The primary key in this table is the NID identifier (ID) number, NID_ID. There should be a 1:1 relationship between NID_ID and Real Property Unique Identifier (RPUID) and therefore a 1:1 relationship between NID_ID and a single Managed Asset.

It is understood that USACE will continue to determine the schema for the NID and maintain the database separately. From the perspective of the ESMS, it is highly desirable that there be an API established for data within the NID to facilitate low-cost, reliable, and near real-time data link between the NID and the ESMS. At the time of this writing, USACE has already expressed interest in creating such an API, or at least merging the NID and NLD, which would have the same effect since the NLD currently has a functional API.

3.4.2 National Levee Database (NLD)

It is intended that the ESMS will receive regular updates, either by direct manipulation or update of the database or via API interface with the NLD. The structure of the NLD is determined and maintained by the USACE, which currently maintains an API for data contained in the NLD. It is understood that the ESMS database will be regularly updated with NLD data via this API, using a common access portal in the ESMS architecture.

The primary key in this table is the NLD Segment ID number, Segment_ID. The link between the ESMS and NLD will be slightly different compared to the NID in that NID records correspond in a 1:1 fashion to real property RPUID. NLD Segments are not necessarily complete real property records in themselves. In fact, it will often be the case that multiple NLD segments will be associated with a single real property record. The ability to accept NLD records as *first class citizens* in the ESMS database schema is the primary reason why the Water Control module contains three inventory levels as opposed to only two. Two inventory levels would be simpler to organize the various components of most dams and dikes. The third, *extra*, inventory level (Level II, Segments) adds the capability to include a single NLD segment and then subdivide that segment into components for inspection purposes.

Levees are unique among the asset classes considered in this report in that the service they provide requires that the structure traverse land. OSD has required special consideration for the inventory of such structures to better inform senior leadership about the disposal of such real property. OSD previously published business rules on how to comply with this mandate. However, the guide as published in 2013 included specific instructions for several different types of linear structure but did not include guidelines for levees.

A general provision in the OSD guide is made such that published guidance from ERDC-CERL could suffice in lieu of specific guidance from OSD. It is recommended that OSD update its guidance and implement rules for segmentation of levees. However, for the purposes of the inventory and inspection system presented here, a preliminary system is needed to begin the system design for the ESMS. Appendix D proposes a method for subdividing levees according to the intent of the OSD mandate on linear segmentation.

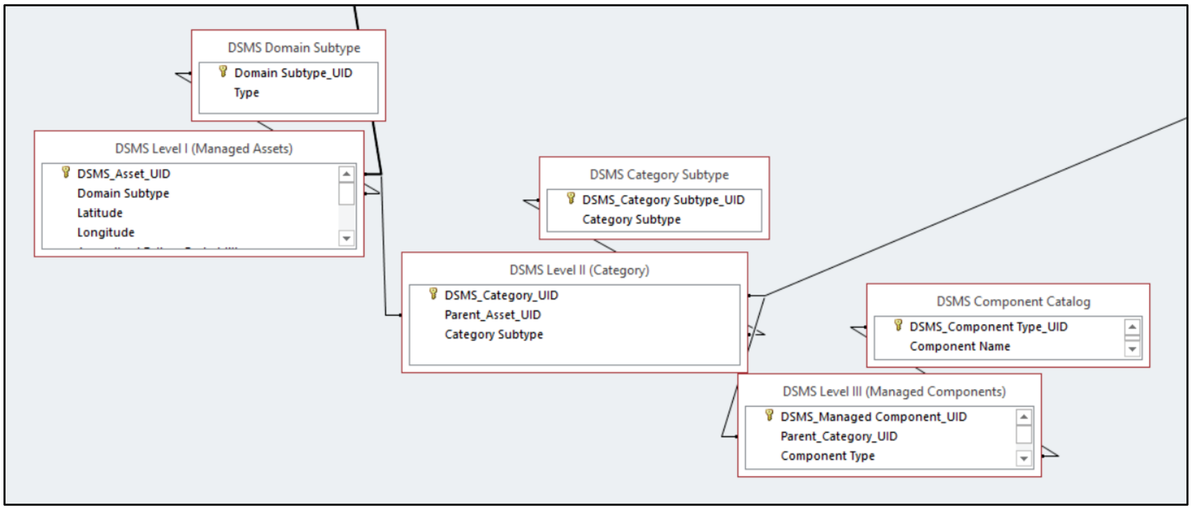
3.4.3 Schema overview

The basic schema of the Water Control Structures is a three-tiered inventory system, generally equivalent to UNIFORMAT levels 1–3 (Figure 18). Several variables are required features for assets included in the ESMS central database. A real property record is considered a core classification variable, specifically an RPUID number (coded variously as RPUID or RPA_UID). A unique ID number will be assigned to each asset, likely through an auto-numbering system per the ESMS system designers.

Each asset in the ESMS database is assigned an Enterprise_Type, which in this case will always be “Water Control Structures.” The remaining required variables can be extracted via the ESMS link to General Fund Enterprise Business System GFEBS) and the provided RPUID.

One notable gap in data at the time of this writing is that all DoD services do not appear to have a readily available list of NID reportable dams and their respective RPUIDs. Previous research by ERDC-CERL was not able to create this link from generally accessible data sources. This gap will need to be closed to properly populate the ESMS inventory.

Figure 18. Data schema graphical representation.



This schema will likely be continually developed by ERDC-CERL during the software development phase of the Water Control Structures module. Current schema designs are available upon request to ERDC-CERL but are not currently hosted on the ESMS production server.

3.4.4 Level I (managed assets)

Managed assets are distinct structures that appear in DoD real property as distinct assets. There should be a 1:1 match between a real property RPUID and a Managed Asset. Each managed asset should therefore have exactly one FAC code and one or more CAT codes assigned via link with the real property system of record.

Each managed asset is assigned a sub-type within the dams and levees ESMS domain. It is assumed that the same condition prediction models and inspection types will be applied uniformly throughout any given sub-type. There are seven total sub-types that differentiate Dikes, Levees, and Dams. Dams are further subdivided between NID inclusion criterion (FEMA 2004) and hazard classification (FEMA 2004). These domain sub-types match the proposed RPCS realignment shown in section 3.3.

Most physical attributes will exist at lower levels of inventory (such as individual components). However, some relevant data belong at this level such as the design inflow flood event, actual downstream hazards, design elevation, etc.

3.4.5 Level II (material types and segments)

This is predominantly a database design choice to further subdivide types of dams and levees into categories that share sufficiently similar characteristics that the same inspection methodology and condition rating can be used. For instance, the differentiation of earth embankment dams from concrete gravity dams will allow inspection forms to be generated with context correct component lists and deficiencies.

This inventory level also identifies segments of a real property asset for linear structures. Therefore, an NLD levee segment should have only one level II inventory unit assigned to it.

There is a one-to-many relationship between each possible sub-type in level I inventory and the several possible material types. However, it is intended that for each managed asset, there be only one corresponding material type for that asset record.

3.4.6 Level III (components)

Components are the basic unit of inventory in the dams and levees domain of the ESMS. Components serve as the Managed Object in the ESMS data schema. There is a one-to-many relationship between each level II inventory record and several components. Higher level inventory units are implemented as *groups* in the ESMS scheme.

Further development of the engineering module for dams and levees may attach additional data fields necessary to the condition rollup, prediction, and work planning aspects of the ESMS.

Components are assumed to be inclusive of all constituent parts and sub-components implied by the description of the component as listed below. For example, a Control Mechanism will likely have several moving parts including possibly electrically powered circuits and motors but should be inventoried as a single component for the purposes of the SMS.

Appendix C is a proposed catalog of components for water control structures. A general template for the data structure for these components is given below.

- Component Name/Unique Identifier (UID)
- Toggle variable indicating applicability to the particular asset
- Extensive quantity and unit of measure
- Basic SMS variables such as Install_Date, Expected_Service_Life (may not be used by this module), Refurbish_Date
- Geographic Information System (GIS) Layer information, to include: Use ESMS Managed Component UID as foreign key for GIS-specific data, GIS-specific UID if applicable, service-specific GIS feature type.

4 Dam Inspection

DoD dams are required to be inspected in accordance with the National Dam Inspection Act of 1972 and FEMA 93, “Federal Guidelines for Dam Safety,” to ensure safety and functionality. They are inspected periodically by qualified individuals trained in inspection procedures. The training required for a dam is dependent upon how complex the structure is and the type of inspection that is required for it. Each dam should have an inspection schedule where the components inspected, the frequency and dates of inspections and reports, and maintenance and repairs are recorded. The frequency and type of inspection is dependent upon the hazard classification of the dam as well as the dam’s history and importance.

4.1 Types and frequency of inspections

4.1.1 FEMA 93 inspection definitions

FEMA 93 categorizes dam inspections as informal, intermediate, formal, and special as described here:

Informal inspections are made by trained employees at the site to ensure continual surveillance of the dam, including its appurtenances, operation, and maintenance. This inspection may include instructions and a checklist of components to be inspected, and abnormal conditions are to be reported. The frequency of inspections is scheduled as needed and is determined by more experienced and trained engineers.

Intermediate inspections are more thorough than informal inspections. If the inspector detects something unusual and outside his/her expertise, the expert opinion of specialists shall be sought. It is preferred to have intermediate inspections yearly; however, they should at least be performed every other year. This is especially important for high-hazard potential dams. Inspectors for this level of inspections should be technically qualified and experienced engineers who are familiar with the operation and maintenance of the dam. The team of inspectors should include the dam tender or operator.

Formal inspections are to be performed routinely, but no longer than 5 years apart, to ensure the structure meets current design standards to ensure adequate safety. Depending on the dam's history, it may need to be inspected more frequently. The documentation of instrumentation, operation, and maintenance is to be examined. Documentation regarding investigation, design, and construction of the dam should be analyzed to the necessary extent. There should be inspection checklists for assessing the conditions of the structural, mechanical, and electrical components. Inspection should also ensure there is an adequate plan arranged for emergencies. This is a more detailed inspection that should include diving inspections to examine the underwater appurtenances crucial to the structural soundness of the dam. Only experts who are highly trained in dam inspection and have specialized knowledge regarding the different aspects of the dam are to perform formal inspection. They must be accompanied by a licensed professional engineer with knowledge and experience in the investigation, design, construction, and operation of dams.

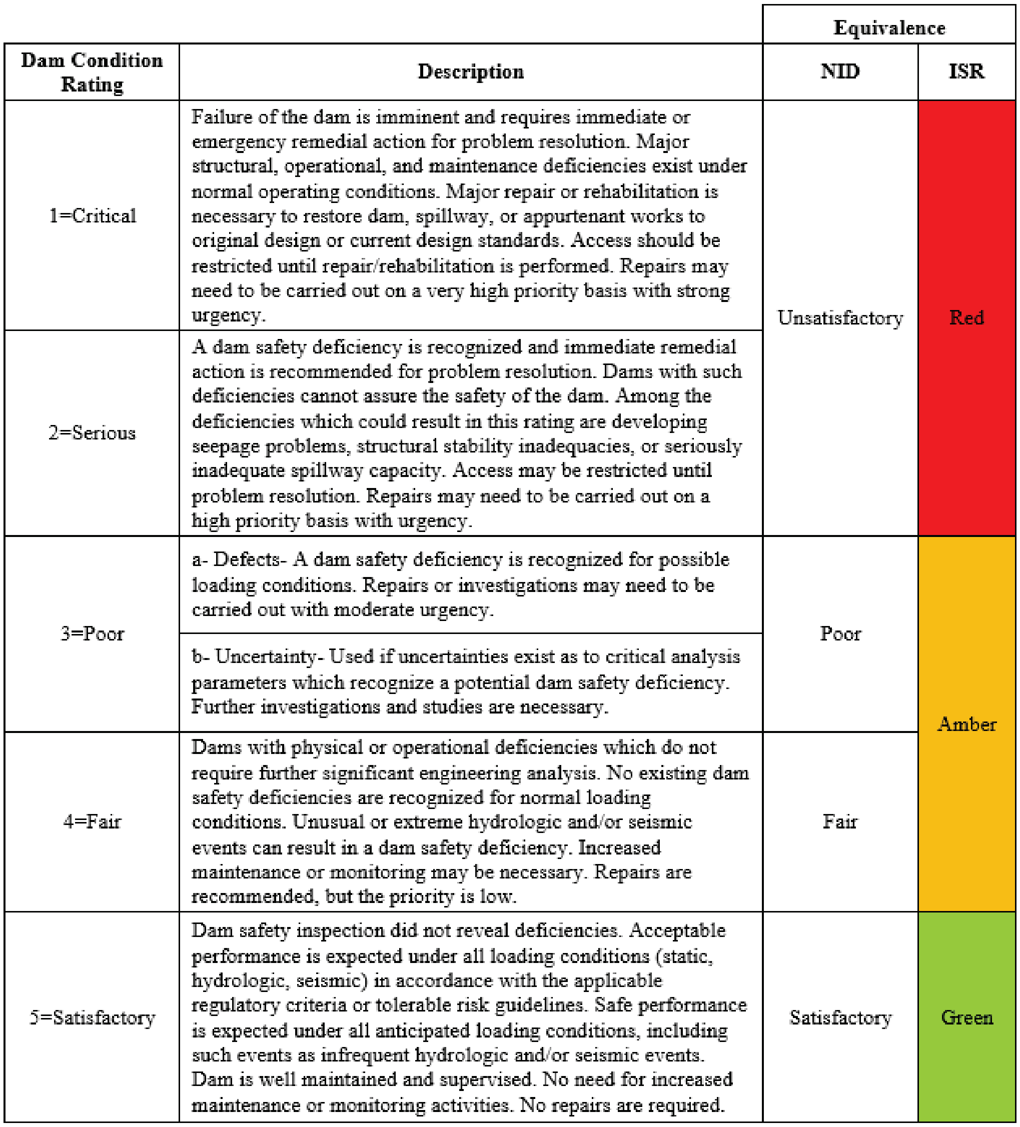
A special inspection is to occur urgently after an unusual event such as a large flood, earthquake, sabotage, vandalism, or another unusual event. Only experts who are highly trained in dam inspection and have specialized knowledge regarding the different aspects of the dam are to perform formal inspections. The inspectors must be accompanied by a licensed professional engineer with knowledge and experience in the investigation, design, construction, and operation of dams.

4.1.2 USACE inspection definitions

USACE has two different types of dam inspections: Annual Inspection and Periodic Inspection. The Annual Inspection, as the name implies, is performed annually to verify that the dam is appropriately operated and maintained. The Periodic Inspection is performed every 5 years. This is similar to the FEMA formal inspection definition where a meticulous inspection is led by a professional, experienced engineer. In the Periodic Inspection, the inspection team reviews annual inspection items, the operation and maintenance of the dam, the structural stability, design, and safety of the dam, and construction records (USACE n.d. Program Information: Dam Inspections).

The USACE current inspection rating scales for the dam components are included in Appendix E, while Table 10 below is the overall condition rating scale used for dams. Images of different distresses on dam components identified during inspection are included in Appendix H.

Table 10. Overall condition rating for dams (Landers et al. 2015).

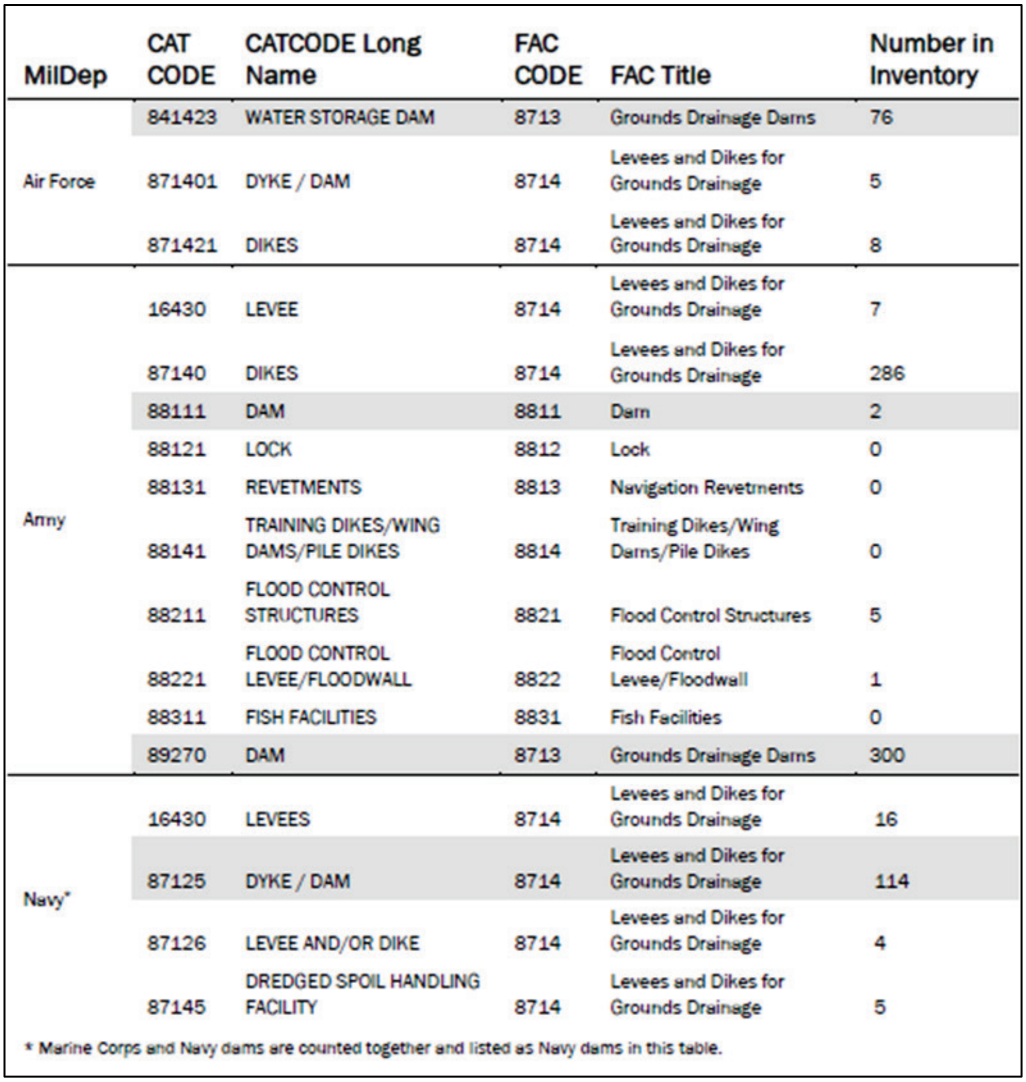


		Equivalence	
Dam Condition Rating	**Description**	**NID**	**ISR**
1=Critical	Failure of the dam is imminent and requires immediate or emergency remedial action for problem resolution. Major structural, operational, and maintenance deficiencies exist under normal operating conditions. Major repair or rehabilitation is necessary to restore dam, spillway, or appurtenant works to original design or current design standards. Access should be restricted until repair/rehabilitation is performed. Repairs may need to be carried out on a very high priority basis with strong urgency.	Unsatisfactory	Red
2=Serious	A dam safety deficiency is recognized and immediate remedial action is recommended for problem resolution. Dams with such deficiencies cannot assure the safety of the dam. Among the deficiencies which could result in this rating are developing seepage problems, structural stability inadequacies, or seriously inadequate spillway capacity. Access may be restricted until problem resolution. Repairs may need to be carried out on a high priority basis with urgency.		
3=Poor	a- Defects- A dam safety deficiency is recognized for possible loading conditions. Repairs or investigations may need to be carried out with moderate urgency.	Poor	Amber
	b- Uncertainty- Used if uncertainties exist as to critical analysis parameters which recognize a potential dam safety deficiency. Further investigations and studies are necessary.		
4=Fair	Dams with physical or operational deficiencies which do not require further significant engineering analysis. No existing dam safety deficiencies are recognized for normal loading conditions. Unusual or extreme hydrologic and/or seismic events can result in a dam safety deficiency. Increased maintenance or monitoring may be necessary. Repairs are recommended, but the priority is low.	Fair	
5=Satisfactory	Dam safety inspection did not reveal deficiencies. Acceptable performance is expected under all loading conditions (static, hydrologic, seismic) in accordance with the applicable regulatory criteria or tolerable risk guidelines. Safe performance is expected under all anticipated loading conditions, including such events as infrequent hydrologic and/or seismic events. Dam is well maintained and supervised. No need for increased maintenance or monitoring activities. No repairs are required.	Satisfactory	Green

4.2 Current DoD methodologies

Currently, each branch of the military has its own CAT CODEs and FAC CODEs for its dams, levees, and dikes. Table 11 below displays these data as well as the quantities of each structure in the branches’ inventories. It can be observed that the Army maintains the majority of the nation’s dams, levees, and dikes.

Table 11. FAC CODEs and CAT CODEs of the military's water control structures (Allen, Foltz, and Werth 2018).



MilDep	CAT CODE	CATCODE Long Name	FAC CODE	FAC Title	Number in Inventory
Air Force	841423	WATER STORAGE DAM	8713	Grounds Drainage Dams	76
	871401	DYKE / DAM	8714	Levees and Dikes for Grounds Drainage	5
	871421	DIKES	8714	Levees and Dikes for Grounds Drainage	8
Army	16430	LEVEE	8714	Levees and Dikes for Grounds Drainage	7
	87140	DIKES	8714	Levees and Dikes for Grounds Drainage	286
	88111	DAM	8811	Dam	2
	88121	LOCK	8812	Lock	0
	88131	REVETMENTS	8813	Navigation Revetments	0
	88141	TRAINING DIKES/WING DAMS/PILE DIKES	8814	Training Dikes/Wing Dams/Pile Dikes	0
	88211	FLOOD CONTROL STRUCTURES	8821	Flood Control Structures	5
	88221	FLOOD CONTROL LEVEE/FLOODWALL	8822	Flood Control Levee/Floodwall	1
	88311	FISH FACILITIES	8831	Fish Facilities	0
	89270	DAM	8713	Grounds Drainage Dams	300
Navy*	16430	LEVEES	8714	Levees and Dikes for Grounds Drainage	16
	87125	DYKE / DAM	8714	Levees and Dikes for Grounds Drainage	114
	87126	LEVEE AND/OR DIKE	8714	Levees and Dikes for Grounds Drainage	4
	87145	DREDGED SPOIL HANDLING FACILITY	8714	Levees and Dikes for Grounds Drainage	5

* Marine Corps and Navy dams are counted together and listed as Navy dams in this table.

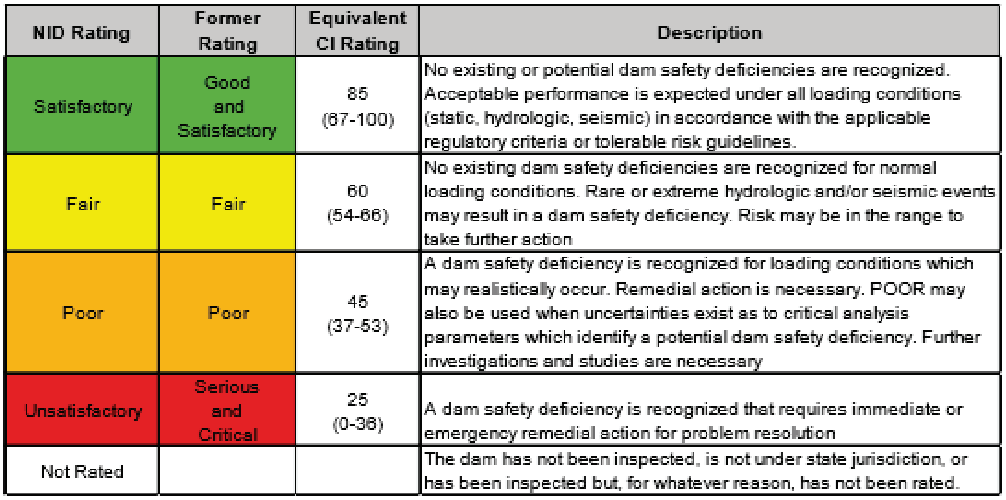
4.2.1 Army

Periodic inspections of Army dams are usually performed by the nearest USACE district. They are performed by ERDC or private consultants when USACE is unavailable or when special inspection techniques such as diving are required. The IMCOM Army Transportation Infrastructure Inspection Program Dam Inspection ERDC Program Manager is the point of contact for Army dam inspections. The Army dam inspections utilize the formal inspection sheets from FEMA 145 (Appendix F). The inspection reports adhere to the USACE report template, which is divided into Project information, Visual Inspection, and Recommendation and Cost sections. The reports may contain additional information such as photographs, repair action plans, and more included in appendices. The condition rating scale is the same as used by USACE (Table 3) (Foltz, Allen, and Werth 2018).

4.2.2 Navy

Formal inspections of Navy dams are performed by USACE, in-house labor, or contractors. These inspections are managed by the Expeditionary Warfare Center, Navy Dam Safety Inspection Program (NDSIP) manager or the project engineer of the Naval Facilities Engineering Command. USACE Norfolk District is the primary POC for formal inspections. The low-hazard dams are scheduled to have formal inspections every 5 years whereas high- and significant-hazard dams have formal inspections every 3 years. The structure of the Navy inspection reports is comparable to the Army reports. The recommendations and cost section makes suggestions for maintenance and repair actions and includes "rough order of magnitude" estimates for these expenses, which come from the inspector's expertise and experience. The Navy, like the Army, utilizes the inspection sheets from FEMA 145 and appendices in the inspection reports. However, the Navy condition rating scale includes a numerical condition index rating along with the NID condition ratings, as seen in Table 12 (Allen, Foltz, and Werth 2018).

Table 12. Navy condition rating scale (Allen, Foltz, and Werth 2018).



NID Rating	Former Rating	Equivalent CI Rating	Description
Satisfactory	Good and Satisfactory	85 (67-100)	No existing or potential dam safety deficiencies are recognized. Acceptable performance is expected under all loading conditions (static, hydrologic, seismic) in accordance with the applicable regulatory criteria or tolerable risk guidelines.
Fair	Fair	60 (54-66)	No existing dam safety deficiencies are recognized for normal loading conditions. Rare or extreme hydrologic and/or seismic events may result in a dam safety deficiency. Risk may be in the range to take further action
Poor	Poor	45 (37-53)	A dam safety deficiency is recognized for loading conditions which may realistically occur. Remedial action is necessary. POOR may also be used when uncertainties exist as to critical analysis parameters which identify a potential dam safety deficiency. Further investigations and studies are necessary
Unsatisfactory	Serious and Critical	25 (0-36)	A dam safety deficiency is recognized that requires immediate or emergency remedial action for problem resolution
Not Rated			The dam has not been inspected, is not under state jurisdiction, or has been inspected but, for whatever reason, has not been rated.

4.2.3 Marine Corps

The eight dams of the Marine Corps are managed similarly to the Navy dams as they were once considered part of the Navy inventory. The dam safety inspection procedure follows federal guidelines, except for the frequency of inspections. The Marine Corps inspects its dams every 2 years whereas dams are only required to be formally inspected every 3 years. The periodic inspection program and the appointment of a dam safety officer for each dam is managed by installation commanders. The USACE Norfolk district is primarily chosen to conduct dam inspections, and the inspections follow the same rating scheme as the Navy (Allen, Foltz, and Werth 2018).

4.2.4 Air Force

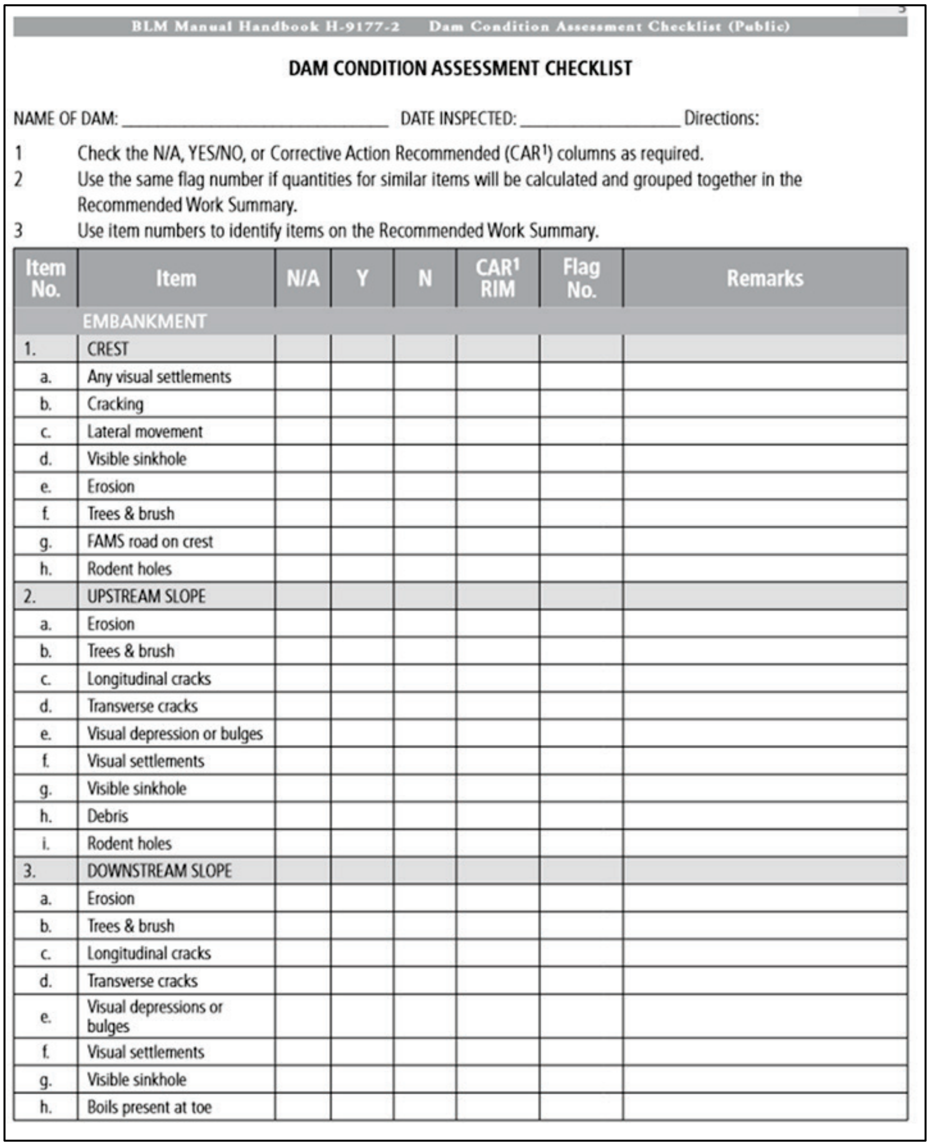
The Air Force usually employs the nearest USACE district to perform dam inspections. However, the Air Force bases may contract out other facilities or firms for dam inspections. The inspection reports comply with Engineer Regulation (ER) 1110-2-1156 but do not require a specific form for periodic inspections. Instead, the inspectors determine the structure and content of the reports. A unique element added to the Air Force reports is survey data. The other military branches did not include this in their reports (Allen, Foltz, and Werth 2018).

4.3 Other methods and technologies

4.3.1 Bureau of Land Management (BLM)

The BLM dam inspection checklist consists of criteria comparable to that of the FEMA 145 forms as shown below in Figure 19. For example, the crest criteria listed in the BLM checklist include any visual settlements, cracking, lateral movement, visible sinkhole, erosion, trees and brush, road on crest, and rodent holes (Bureau of Land Management 2006). The FEMA 145 sheet lists the following distresses for the crest: surface cracking, cave in, animal burrow, low area(s), horizontal alignment, ruts and/or puddles, vegetation condition.

Figure 19. Sample of BLM Dam Condition Assessment Checklist (BLM 2006).



BLM Manual Handbook H-9177-2 Dam Condition Assessment Checklist (Public)

DAM CONDITION ASSESSMENT CHECKLIST

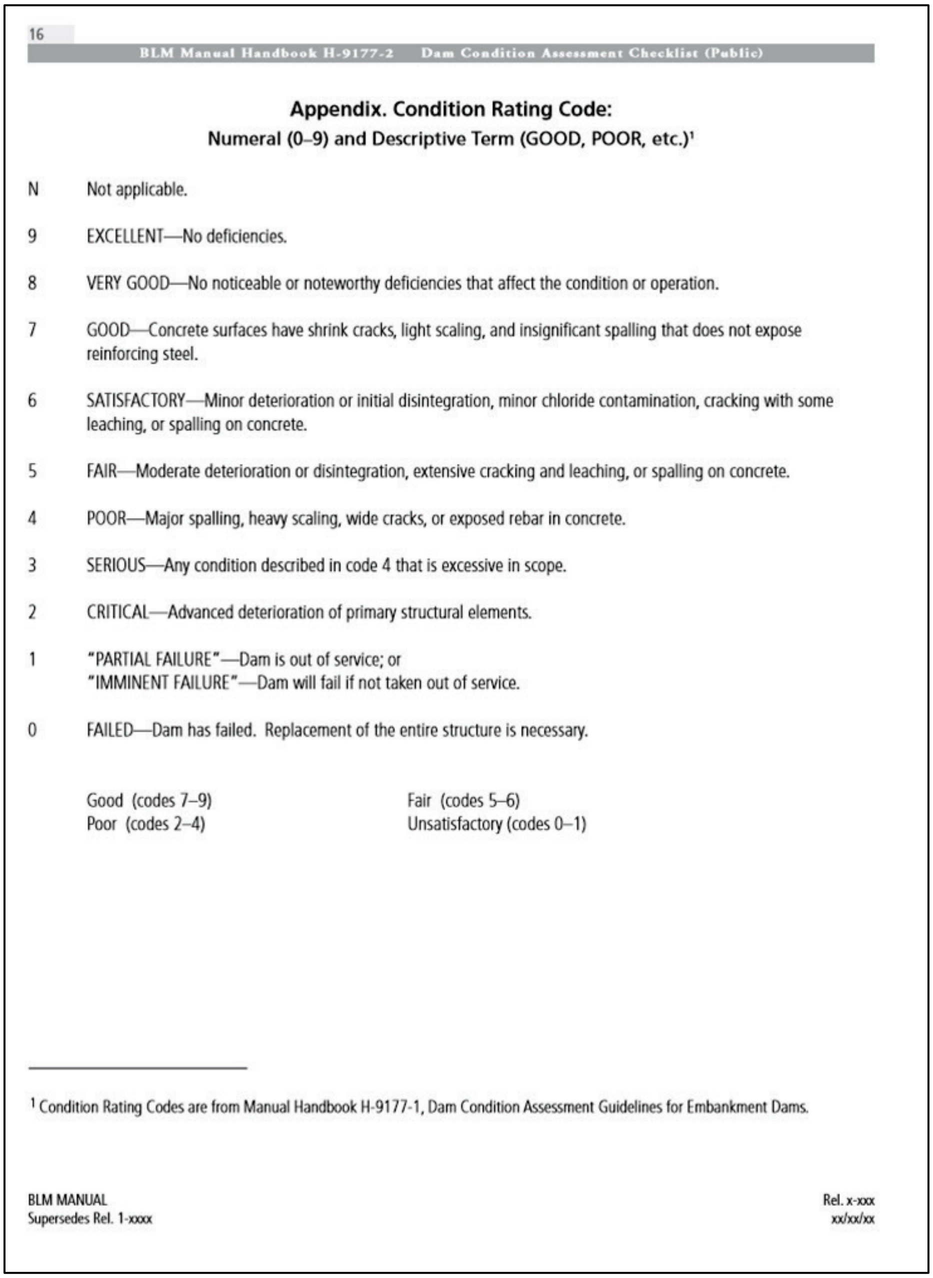
NAME OF DAM: ______________________ DATE INSPECTED: ______________ Directions:

1 Check the N/A, YES/NO, or Corrective Action Recommended (CAR[1]) columns as required.
2 Use the same flag number if quantities for similar items will be calculated and grouped together in the Recommended Work Summary.
3 Use item numbers to identify items on the Recommended Work Summary.

Item No.	Item	N/A	Y	N	CAR[1] RIM	Flag No.	Remarks
	EMBANKMENT						
1.	CREST						
a.	Any visual settlements						
b.	Cracking						
c.	Lateral movement						
d.	Visible sinkhole						
e.	Erosion						
f.	Trees & brush						
g.	FAMS road on crest						
h.	Rodent holes						
2.	UPSTREAM SLOPE						
a.	Erosion						
b.	Trees & brush						
c.	Longitudinal cracks						
d.	Transverse cracks						
e.	Visual depression or bulges						
f.	Visual settlements						
g.	Visible sinkhole						
h.	Debris						
i.	Rodent holes						
3.	DOWNSTREAM SLOPE						
a.	Erosion						
b.	Trees & brush						
c.	Longitudinal cracks						
d.	Transverse cracks						
e.	Visual depressions or bulges						
f.	Visual settlements						
g.	Visible sinkhole						
h.	Boils present at toe						

However, the BLM overall dam condition rating scale differs from the USACE overall dam condition rating scale mentioned above in Figure 19. Instead of rating the dam's condition on a scale of 1–5 (1=critical, 5=satisfactory), BLM rates the dam on a scale of 0–9 (0=failed, 9=excellent) as shown below in Figure 20. The BLM scale does, however, incorporate all the same descriptive terms as used in the USACE scale such as critical, serious, poor, fair, and satisfactory. The BLM scale seems to list specific deficiencies, in contrast to the USACE scale, which has a more general description of deficiencies for each dam condition rating classification.

Figure 20. BLM Overall Dam Condition Rating Scale (BLM 2006).



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BLM Manual Handbook H-9177-2 Dam Condition Assessment Checklist (Public)

Appendix. Condition Rating Code:

Numeral (0–9) and Descriptive Term (GOOD, POOR, etc.)[1]

N	Not applicable.
9	EXCELLENT—No deficiencies.
8	VERY GOOD—No noticeable or noteworthy deficiencies that affect the condition or operation.
7	GOOD—Concrete surfaces have shrink cracks, light scaling, and insignificant spalling that does not expose reinforcing steel.
6	SATISFACTORY—Minor deterioration or initial disintegration, minor chloride contamination, cracking with some leaching, or spalling on concrete.
5	FAIR—Moderate deterioration or disintegration, extensive cracking and leaching, or spalling on concrete.
4	POOR—Major spalling, heavy scaling, wide cracks, or exposed rebar in concrete.
3	SERIOUS—Any condition described in code 4 that is excessive in scope.
2	CRITICAL—Advanced deterioration of primary structural elements.
1	"PARTIAL FAILURE"—Dam is out of service; or "IMMINENT FAILURE"—Dam will fail if not taken out of service.
0	FAILED—Dam has failed. Replacement of the entire structure is necessary.

Good (codes 7–9)
Poor (codes 2–4)
Fair (codes 5–6)
Unsatisfactory (codes 0–1)

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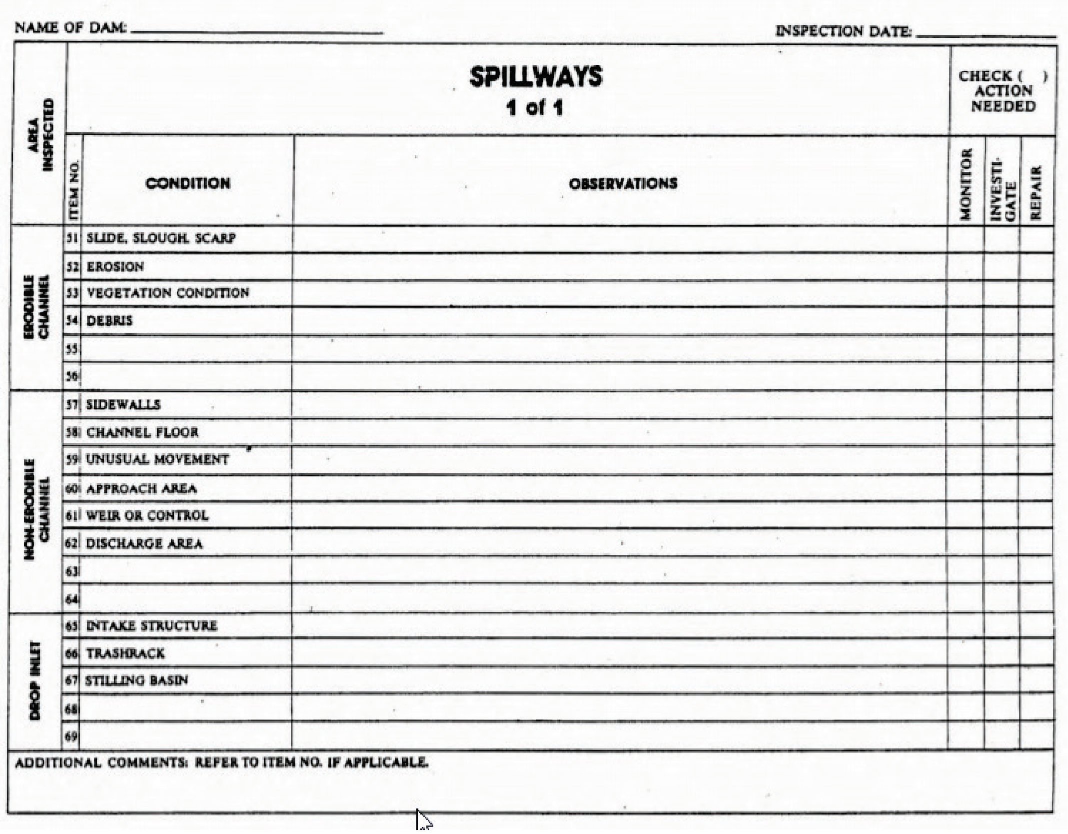
[1] Condition Rating Codes are from Manual Handbook H-9177-1, Dam Condition Assessment Guidelines for Embankment Dams.

BLM MANUAL
Supersedes Rel. 1-xxxx

Rel. x-xxx
xx/xx/xx

In *An Owners Guidance Manual for the Inspection and Maintenance of Dams in New York State, 1987*, the New York State Department of Environmental Conservation utilizes dam inspection forms nearly identical to the FEMA 145 inspection sheets as shown in Figure 21 below.

Figure 21. New York State Department of Environmental Conservation Inspection Form example (NYS 1987).



NAME OF DAM: ______________ INSPECTION DATE: ______________

SPILLWAYS

1 of 1

AREA INSPECTED	ITEM NO.	CONDITION	OBSERVATIONS	CHECK ( ) ACTION NEEDED		
				MONITOR	INVESTI-GATE	REPAIR
ERODIBLE CHANNEL	51	SLIDE, SLOUGH, SCARP				
	52	EROSION				
	53	VEGETATION CONDITION				
	54	DEBRIS				
	55					
	56					
NON-ERODIBLE CHANNEL	57	SIDEWALLS				
	58	CHANNEL FLOOR				
	59	UNUSUAL MOVEMENT				
	60	APPROACH AREA				
	61	WEIR OR CONTROL				
	62	DISCHARGE AREA				
	63					
	64					
DROP INLET	65	INTAKE STRUCTURE				
	66	TRASHRACK				
	67	STILLING BASIN				
	68					
	69					

ADDITIONAL COMMENTS: REFER TO ITEM NO. IF APPLICABLE.

4.3.2 GIS data collection applications

In March 2019, the Environmental Systems Research Institute (ESRI) released the Dam Safety add-in feature for the ArcGIS Pro 2.2-2.4 software. This add-in consists of maps and applications that enable one to store inventory dam information, prepare and manage dam inspections, inspect dam locations, and monitor dam inspections. Dam Safety includes the Dam Inspection Survey application, where one can inspect upstream reservoirs, downstream hazards, and more. This application contains some dam information (i.e., contact information of the dam owner/operator, emergency action plan, instructions for dam operation, etc.) as well as a series of questions concerning the dam components. Dam inspectors may also use this feature to record measurements and store photos of the site (ESRI 2019) and (ESRI 2020).

The similarities between the Environmental Systems Research Institute, Inc., (ESRI) Dam Safety add-in software to the proposed water control structure SMS methodology include the capacity to store inventory and inspection information and to display geospatial information. However, the proposed SMS tool will also include information regarding levees and dikes in addition to dams integrated into DoD inventory and facility classification systems and a condition-rating assessment with a condition-prediction modeling tool that will aid in constructing a work prioritization agenda. The ESRI Dam Safety add-in differs from the SMS tool by having the capability to manage/monitor dam inspections, and it includes the Dam Inspection Survey application, which enables access to the emergency action plan and dam operation instructions. The Dam Inspection Survey may be comparable to the SMS inspection scheme in the way that there is a standard array of questions or criteria that are to be investigated for each dam.

4.3.3 Dam safety monitoring

DamWatch® is a monitoring and management software for dams, levees, and other hydrologic infrastructure developed by USEngineering Solutions in 2009. It helps users to predict, identify, prepare for, manage, and record environmental events that may threaten the structural integrity/function of dams/levees. One can monitor the status of a dam/levee in actual time and be alerted via phone, email, fax, etc., when an event necessitates emergency action plans to be implemented. This software includes a collection of database and geospatial information and can store files and data such as plans, emergency action plans, inspections, reports, photos, and more (USEngineering Solutions Corp. n.d.) and (USEngineering Solutions Corp. 2017). According to an email on January 29, 2020, from Joseph Scannell, CEO of USEngineering Solutions, U.S. state and federal agencies such as the USACE currently monitor and manage more than 15,000 dams.

DamWatch and the proposed SMS methodology are similar by both having the ability to store inspection data and having geospatial capabilities. However, DamWatch also includes real-time monitoring and sends emergency response notifications. Furthermore, DamWatch also stores information such as plans and reports. As mentioned above, the proposed SMS tool will have the water control structures integrated into DoD inventory and facility classification systems and a condition rating assessment with a condition prediction modeling tool that will aid in constructing a work prioritization agenda, as well as a standard inspection rating methodology for the water control structures.

After reviewing the features of the ESRI Dam Safety application and DamWatch, it needs to be determined how to integrate these tools/match their capabilities in the SMS such as the management/monitoring of inspections, real-time monitoring of the water control structures, emergency alerts, and more. The DoD would benefit considerably by encompassing these additional capabilities in the SMS and have a well-rounded approach to accomplish efficient and economical management of its water control structures.

4.4 Levee inspection standards

4.4.1 Code of Federal Regulations (CFR)

Generic levee inspection standards are outlined in 33 CFR § 208.10 (33 CFR § 208.10: Local Flood Protection Works n.d.). Inspections are closely tied to maintenance procedures. While no clear distinction is made in this document between periodic and routine maintenance procedures, it outlines that the superintendent, head of maintenance and inspections, shall

- Submit a semiannual report to the District Engineer covering inspection, maintenance, and operation of protective works including levees
- Be available at all times to promptly ensure the completion of any maintenance measures or repairs which the District Engineer deems necessary
- Ensure the following maintenance measures are taken immediately prior to the beginning of the flood season, immediately following each major high-water period, and otherwise at intervals not exceeding 90 days:
  - Promoting the growth of sod
  - Exterminating burrowing animals
  - Mowing of the grass and weeds
  - Removal of wild growth and drift deposits
  - Repair of damage caused by erosion or other forces
  - Retarding bank erosion by planting of willows or other suitable growth on areas riverward of the levees
  - No unusual settlement, sloughing, or material loss of grade or levee cross section has taken place
  - No caving has occurred on either the land side or the river side of the levee which might affect the stability of the levee section

  - No seepage, saturated areas, or sand boils are occurring
  - Toe drainage systems and pressure relief wells are in good working condition, and that such facilities are not becoming clogged
  - Drains through the levees and gates on said drains are in good working condition
  - No revetment work or riprap has been displaced, washed out, or removed
  - No action is being taken, such as burning grass and weeds during inappropriate seasons, which will retard or destroy the growth of sod
  - Access roads to and on the levee are being properly maintained
  - Cattle guards and gates are in good condition
  - Crown of levee is shaped to drain readily, and roadway thereon, if any, is well shaped and maintained
  - There is no unauthorized grazing or vehicular traffic on the levees
  - Encroachments are not being made on the levee right-of-way which might endanger the structure or hinder its proper and efficient functioning during times of emergency.

4.4.2 USACE Levee Inspection Program

The Levee Safety Program of USACE expands on the CFR and provides more precise inspection standards and timelines. Inspectors follow the USACE “Flood Damage Reduction Segment/System Inspection Report” inspection sheets (U.S. Army Corps of Engineers 2008b). It comprises a detailed outline of levee components, 125 specific items dealing with operation and maintenance of levee embankments, floodwalls, interior drainage, pump stations, and channels. The components and overall system are labeled as being acceptable (A), minimally acceptable (M), or unacceptable (U), and the descriptions for those classifications are listed in Tables 13 and 14. This report also distinguishes between routine and periodic inspections. Appendix G consists of these inspection sheets for levees.

Routine Inspections (RIs) are conducted on a yearly basis for all levees in the Levee Safety Program. The purpose of these inspections is to verify proper maintenance, owner preparedness, and component operation. More detailed Periodic Inspections (PIs) are conducted every 5 years and entail data collection, field inspections, and a final report to summarize findings and recommend areas for further evaluation. The purpose of PIs is to evaluate the operational adequacy, structural stability, and safety of the structure, and these are used as the basis of risk assessments. Per the USACE Policy Guidance Letter on Periodic Inspection, "inspections shall be scheduled to allow for sponsor and maintainer participation. Because the PI checklist includes the RI checklist, the PI shall be scheduled to replace the RI for that system for that year" (U.S. Army Corps of Engineers 2008a). This policy letter builds upon P.L. 84-99 (U.S. Congress 1955) and contains a wealth of references chronicling the development of federal inspection regulations.

USACE utilizes the Levee Inspection System (LIS) to assist levee inspectors when conducting these inspections, documenting conditions, and generating reports. This information is shared with the NLD. LIS consists of a mobile application that provides tools to help inspection teams collect data during field visits. It also includes a web application for generating standardized reports and managing finalized inspections.

Table 13. Overall segment/system ratings (USACE 2008b).

Acceptable System	Minimally Acceptable System	Unacceptable System
All items or components are rated as Acceptable.	One or more items are rated as Minimally Acceptable or one or more items are rated as Unacceptable and an engineering determination concludes that the Unacceptable items would not prevent the segment/system from performing as intended during the next flood event.	One or more items are rated as Unacceptable and would prevent the segment/system from performing as intended, or a serious deficiency noted in past inspections (which had previously resulted in a minimally acceptable system rating) has not been corrected within the established timeframe, not to exceed 2 years.

Table 14. Individual item/component ratings (USACE 2008b).

Acceptable Item	Minimally Acceptable Item	Unacceptable Item
The inspected item is in satisfactory condition, with no deficiencies, and will function as intended during the next flood event.	The inspected item has one or more minor deficiencies that need to be corrected. The minor deficiency or deficiencies will not seriously impair the functioning of the item as intended during the next flood event.	The inspected item has one or more serious deficiencies that need to be corrected. The serious deficiency or deficiencies will seriously impair the functioning of the item as intended during the next flood event.

5 Proposed Inspection Rating Methodology for Sustainment Management System (SMS) Implementation

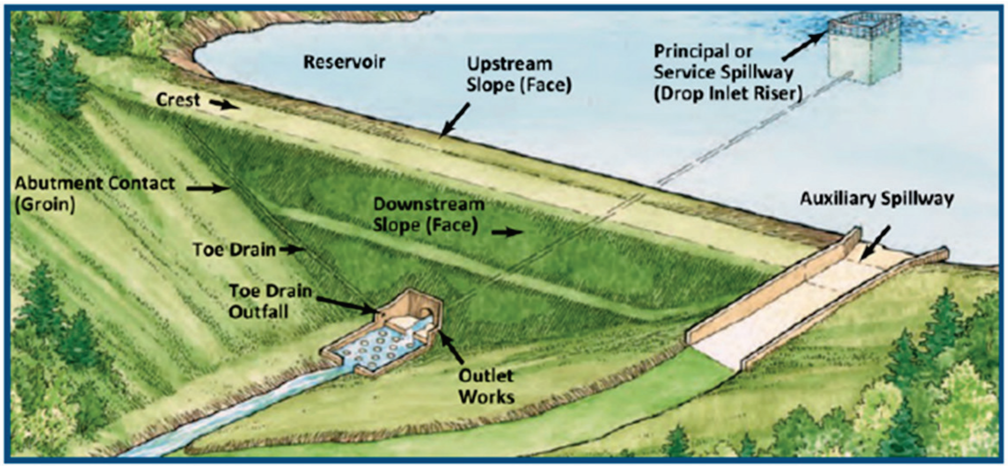
5.1 Components of dams, levees, and dikes

Because dams, levees, and dikes share many similar components, the SMS database will contain one catalog of components for the water retention structures instead of three. The components to be included in the SMS component catalog are listed below in Table 15. Figure 22 illustrates some of these components.

Table 15. Dam, levee, and dike components.

Crest	Spillway Discharge Area	Gate	Control Mechanism
Upstream Face	Stilling Basin	Floodwall	
Downstream Face	Piezometer	Outlet Pipe	Trash Racks
Body	Survey Monument	Outlet Tower	Staff Gauge
Downstream Toe Area	Inclinometer	Spillway Approach Area	Observation Well
Groin	Access Roads	Spillway Channel Floor	Sump/Wet Well
Abutments	Safety and Security Devices	Spillway Sidewalls	Culverts
Reservoir Slopes	Relief Wells	Weir	Intake Structure
Foundation	Concrete Surface	Conduit	Revetments
Toe Drain	Masonry Surface	Valves	Pumps
Foundation Drain	Concrete Monolith	Closure	Trash Booms

Figure 22. Dam component overview (USFS and FEMA 2016).



5.2 Proposed inspection ratings

The dam inspections forms used by USACE (Appendix F) contains both quantitative and qualitative observations to assign inspection ratings to the components of the structures. However, when comparing the inspection sheets of the dams to the condition rating tables (Appendix E), it is evident that there are some discrepancies between the components and distresses organized on the inspection sheets vs. the condition rating tables. Furthermore, there are not clear distinctions between the extents and the severities of the distresses on the components. Therefore, it was decided that the inspection rating scale would be reorganized to provide standard criterion for each distress observed in the inspection assessment for the purpose of SMS integration. However, the proposed rating scales are not meant to entirely replace the current inspection procedures. In fact, the proposed rating scales are based on the information from the existing dam and levee condition ratings.

Each distress is broken down into different extents and can either be quantitative or qualitative, depending on the case. Next, the extent is classified as either low (L), medium (M), or high (H) severity as described in Table 16. The definitions are modified versions of the current USACE definitions in the dam condition rating scale. Tables 17 through 26 provides an example set of inspection rating tables containing the descriptions of the extent and severity ratings for the distresses acting on the crest component. A comprehensive list of inspection rating tables for each component is included in Appendix I. Please note that these tables have not been finalized. Research is underway to determine the appropriate extents and severity ratings for each distress.

Table 16. Severity levels for component distresses.

Severity Level	Description
L	Minor deficiency exists under normal loading conditions but does not require further significant engineering analysis. Increased maintenance or monitoring may be necessary. Repairs are recommended, but priority is low.
M	Moderate deficiency exists under normal operating conditions and requires further engineering analysis. Repairs shall be carried out with moderate haste.
H	Major deficiency exists under normal operating conditions, affecting the structural integrity of the dam/dam operations. Dam failure is imminent, and immediate remedial action is imperative.

Table 17. Crest vegetation.

Diameter (in.)		
0 to ≤6	>6 and ≤12	> 12
L	M	H

Table 18. Animal burrows.

Depth (in.)		
0 to ≤6	>6 and ≤12	> 12
L	M	H

Table 19. Erosion-earth.

Severity Level	Description
L	Small bare areas/areas of sparse vegetation; Minor ruts/puddles
M	Substantial bare areas; Channels <6 in. deep
H	Channels >6 in. deep; Major loss of material that could allow overtopping with slight rise in reservoir level

Table 20. Unusual movement-earth.

Severity Level	Description
L	Undulating crest elevations; crest width <12 in.
M	Settling or shifted alignment/reduced crest width
H	Overtopping or evidence of

Table 21. Unusual movement-concrete/masonry.

Width of Displacement (in.)	Length of Displacement (ft)	
	≤x	>x
≤x	L	L
>x	L	L
≤x	L	M
>x	L	M
≤x	L	M
>x	M	H

Table 22. Unusual movement-concrete/masonry.

Severity Level	Depth (in.)
L	0 to ≤6
M	> 6 and ≤12
H	> 12

Table 23. Voids/sinkholes.

Depth (ft)	Diameter (ft)	
	≤1	>1
0 to ≤y	L	M
>y and ≤z	M	M
> z	M	H

Table 24. Transverse cracking-earth.

	Depth (in.)	
Length (ft)	≤6	>6
0 to ≤y	L	M
>y and ≤z	L	M
> z	M	H

Depth in.)	Width (in.)	Length (ft)	
		≤x	>x
≤z	≤y	L	M
	>y	L	M
>z	≤y	M	M
	>y	H	H

Relation to reservoir level	Length (ft)	Depth (in.)	
		≤x	>x
Above	≤x	L	L
	>x	L	L
At	≤x	L	M
	>x	M	M
Below	≤x	M	M
	>x	H	H

Table 25. Longitudinal cracking-earth.

Length (ft)	Depth (in.)	
	≤6	>6
0 to ≤y	L	M
>y and ≤z	L	M
> z	M	H

Depth (in.)	Width (in.)	Length (ft)	
		≤x	>x
≤z	≤y	L	M
	>y	L	M
>z	≤y	M	M
	>y	H	H

Do cracks curve?	Length (ft)	Depth (in.)	
		≤6	>6
No	≤x	L	L
	>x	M	M
Yes	≤x	M	H
	>x	H	H

Table 26. Drying cracking-earth.

Length (ft)	Depth (in.)	
	≤6	>x6
0 to ≤y	L	M
>y and ≤z	L	M
> z	M	H

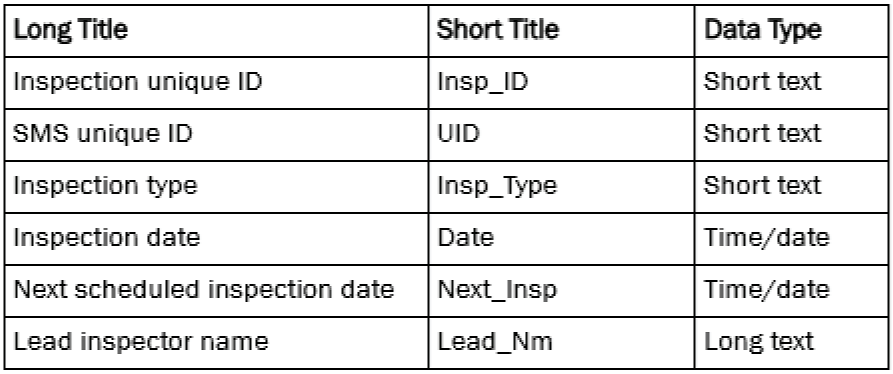
Depth (in.)	Width (in.)	Length (ft)	
		≤x	>x
≤z	≤y	L	M
	>y	L	M
>z	≤y	M	M
	>y	H	H

These rating scales will be implemented in the SMS tool to enable inspectors to input inspection data and track the history of the dam components' condition with ease.

5.3 Inspection data in the SMS

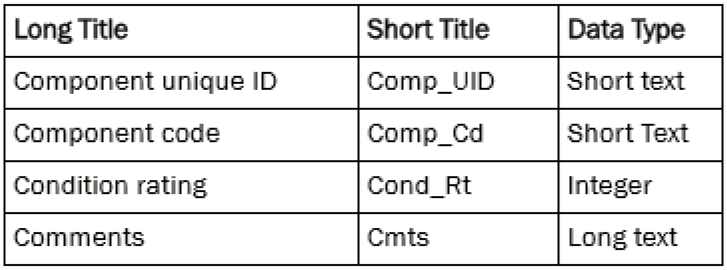
The inspection data imported into the SMS may include either formal or intermediate inspection data. According to the methods proposed in "Sustainment Management System Dams Inspection Module," the inspection observations will be entered into an inspection template and are linked to specific features in the SMS component catalog. The record of each structure would contain the inspection data grouped together by date. Photos, drawings, and special inspection reports would also be linked to the SMS database's inspection data. The inspection template is divided into the front matter, inspection observations and related condition ratings, and the resultant repair recommendations sections. Table 27 lists the front matter, which is designed to uniquely identify each inspection in the SMS database. In the database, each element should be linked to an inspection record. Table 28 contains the inspection data fields for each component (Foltz, Allen, and Werth 2018).

Table 27. Front matter data fields (Foltz, Allen, and Werth 2018).



Long Title	Short Title	Data Type
Inspection unique ID	Insp_ID	Short text
SMS unique ID	UID	Short text
Inspection type	Insp_Type	Short text
Inspection date	Date	Time/date
Next scheduled inspection date	Next_Insp	Time/date
Lead inspector name	Lead_Nm	Long text

Table 28 . Component inspection data fields (Foltz, Allen, and Werth 2018).



Long Title	Short Title	Data Type
Component unique ID	Comp_UID	Short text
Component code	Comp_Cd	Short Text
Condition rating	Cond_Rt	Integer
Comments	Cmts	Long text

6 Risk Assessment Considerations

The inspection methodology presented in this report does not explicitly consider risk or function in determining the condition of dams, dikes, or levees. A component that is insufficient for its design purpose can be rated in good condition if it is free of physical defects. The same condition rating is given to components of dams regardless of the hazard classification of the dam. This conforms to the methodology used by other SMS modules and serves the OSD intended purpose in providing an objective measure of condition that is comparable across asset classes. Risk is therefore not necessary in arriving at an objective condition rating. However, some aspects of a complete SMS for dams would benefit from, if not require, explicit quantitative estimation of risks.

There are both advantages and drawbacks to explicit risk consideration for dam safety management. The biggest argument in favor of a formal process is that the dam safety community already considers risk to be a fundamental product of their efforts. Risk consideration therefore heavily influences the outputs of engineers intimately involved in DoD dam safety management. A formal method would aid in one of the most fundamental aspects of the ESMS — consistent reporting across all DoD and across asset classes — via standardization of inspection results and interpretation thereof.

6.1 The case against risk consideration

First and foremost, there is reason to believe that the ability to estimate the risks associated with many aspects of dam safety is either limited or that the effort involved in generating useful risk analysis outweighs the value of the results (especially for many DoD low-risk dams).

First, all dams are custom-built structures, which inherently complicates the use of statistical modeling based on common components to extract useful values. Also, some components of dams do not display age-based degradation including the most common component of DoD dams (earth embankments). Many components do exhibit well-known *infant mortality* curves. However, this knowledge is not especially relevant to the DoD inventory of older dams and is difficult to turn into a work plan. The most relevant model for many components may turn out to be a static random failure chance, which is essentially what is produced by USACE methods when a value is estimated for the overall failure probability of a single dam in a specific condition.

6.2 The case in favor of risk consideration

FEMA has suggested a value of 0.3 statistical lives lost as an upper bound for a low- or significant-hazard dam. FEMA has suggested a value of ~$7M for use in calculating the economic consequence of a statistical life loss. This implies that a low-hazard dam might pose an economic consequence of failure equal to $2.1M. The total replacement value for the DoD real property portfolio of water retaining structures is estimated at approximately $2B, or approximately $3M per structure. This implies that the maximum life safety risk for a DoD dam could be an appreciable fraction of the replacement value of the structure.

Life loss is a factor in dam safety, even for low-hazard dams. More people have died in the past several decades because of failures of low-hazard dams than have died because of high-hazard dams failures. The primary cause of this is the large number of low-hazard dams. Clearly, life safety is not an insignificant factor in the operation of a low-hazard dam. Neglecting this consideration removes a substantial incentive for the DoD to improve the condition of its existing dams.

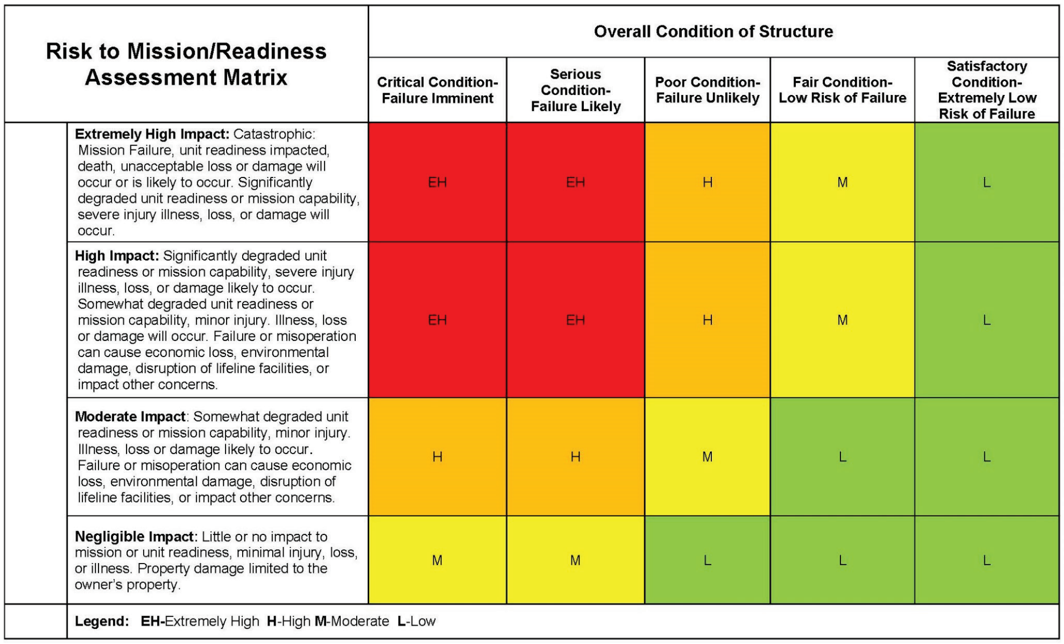
6.3 Reality – informal consideration of risk is a current feature of DoD dam management

Risk-informed analysis and decision making is already a common feature of DoD dam management. Stakeholders representing DoD services indicated that it is common practice to prioritize repairs and maintenance for high-hazard dams over significant- and low-hazard dams. Implicit in these efforts is the idea that higher hazard classification dams pose a greater risk, and the lower conditions imply higher failure probability. The rationale is informal and qualitative as opposed to formal and quantitative. However, it does demonstrate stakeholders' willingness to use risk-informed analysis on some level.

There may also be a systematic bias in current practices, as inspectors and engineers use their own judgment when interpreting the relative severity of defects and the priority of repairs. Engineers have an incentive to decrease the reported condition of dams they believe pose a greater risk in the event of failure. This tendency has been observed in a wide variety of contexts, and removing this subjective influence is a major goal of other SMS systems. In the current context, this not a negative, as the bias present reflects engineering judgment, which is used in place of a systematic risk analysis method.

Many services already use formal processes to manage risk in a wide variety of business lines. Most relevant to this discussion, the Army has produced a risk assessment matrix that is somewhat similar in background to the USACE Periodic Risk Assessment (PRA) decision method (Figure 23). This process is largely similar in conception and execution to the process proposed below. Close alignment with this sort of decision support method was a key factor in creation of the proposed risk-informed method in this report such that it may be blended relatively seamlessly into existing stakeholder business processes.

Figure 23. Army risk analysis rubric (U.S. Army HQDA G9, Dam Safety Officer).



Risk to Mission/Readiness Assessment Matrix	Overall Condition of Structure				
	Critical Condition-Failure Imminent	Serious Condition-Failure Likely	Poor Condition-Failure Unlikely	Fair Condition-Low Risk of Failure	Satisfactory Condition-Extremely Low Risk of Failure
Extremely High Impact: Catastrophic: Mission Failure, unit readiness impacted, death, unacceptable loss or damage will occur or is likely to occur. Significantly degraded unit readiness or mission capability, severe injury illness, loss, or damage will occur.	EH	EH	H	M	L
High Impact: Significantly degraded unit readiness or mission capability, severe injury illness, loss, or damage likely to occur. Somewhat degraded unit readiness or mission capability, minor injury. Illness, loss or damage will occur. Failure or misoperation can cause economic loss, environmental damage, disruption of lifeline facilities, or impact other concerns.	EH	EH	H	M	L
Moderate Impact: Somewhat degraded unit readiness or mission capability, minor injury. Illness, loss or damage likely to occur. Failure or misoperation can cause economic loss, environmental damage, disruption of lifeline facilities, or impact other concerns.	H	H	M	L	L
Negligible Impact: Little or no impact to mission or unit readiness, minimal injury, loss, or illness. Property damage limited to the owner's property.	M	M	L	L	L
Legend: **EH-**Extremely High **H**-High **M**-Moderate **L**-Low					

6.4 Proposal for a using a risk-condition matrix as a proxy for repair prioritization

Proposed here is a condition rating system and work prioritization scheme in which the primary source of information is the team of engineers doing periodic dam inspections. This method would apply to dams, dikes, and levees that do not warrant a formal risk analysis, such as low-hazard or non-NID dams. Although risk is explicitly addressed during this process, the results should *not* be interpreted as a risk analysis but rather a portfolio-prioritization score for work planning within the ESMS. Consideration of risk is given only so that the results are more easily comparable to USACE PRA and to work planning schemes in other ESMS domains.

No changes to the current inspection procedures are needed, but additional data would be required via a standardized reporting format. These values would include an overall condition rating of the dam similar to the direct-rating method used in BUILDER SMS, calibrated to the existing NID condition rating scale. Individual deficiencies would be tracked according to the inspection methodology presented in this report. Inspectors would supply the estimated costs to repair each item aided by a common database of standard values for equipment and labor maintained by the ESMS.

These data would supplement certain dam-specific stored values, which would be generated either by formal risk analysis by dam inspectors or from cached values created in a separate research effort. These values would include the estimated probability and consequence of failure of the dam. Depending on the specific dam in question, these values could be generated by the USACE method of PRA (e.g., for NID reportable dams) or standardized values (e.g., non-NID dams, levees).

All these data would then be used to construct a Condition – Hazard matrix for each dam in the inventory, where each point in the matrix represents a calculated value for the rate of risk assumed by the dam owners for keeping the dam in that status. The repair costs supplied by the inspectors would be used to determine the efficacy of each change in the condition-hazard status of the dam.

The primary advantage of this would be the ability to calculate the Return on Investment (ROI) for each repair action without building a comprehensive deterioration model, work planning algorithm, or standard repair action database. This ROI could be easily compared with maintenance and repair (M&R) projects generated in other ESMS domains, which would enable most of the functionality of a fully functional cross-domain work planning capability.

Table 29 shows how a dam could be classified according to its condition according to the NID data dictionary and the Hazard Classification of the dam. For each combination there is a presumed overall Probability of Failure ($\boldsymbol{PF_{i,j}}$) and Consequence of Failure ($\boldsymbol{CF_{i,j}}$), where $\boldsymbol{i}$ and $\boldsymbol{j}$ refer to the condition rating (row number) and Hazard Classification (column number) respectively. The assumptions needed to create this chart are that the failure probability and consequence of failure depend on known factors, and random variables are appropriate in this case.

Table 29. Proposed hazard – condition matrix.

	High Hazard	Significant Hazard	Low Hazard	Non-NID Dams	Levees	Dikes
Satisfactory Condition	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$
Fair Condition	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$
Poor Condition	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$
Unsatisfactory Condition	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$

Note that

$$CF_{i,j} = \Sigma PRV + SLL * SVL$$

- ΣPRV is the sum of the replacement value of the dam *and* all property destroyed during a failure
- SLL is the Statistical Lives Lost during a failure, idealized as the sum of the lives lost for each possible failure mode, multiplied by the mean lives lost during such a failure
- SVL is the Statistical Value of Human Life, which is generally regarded as the dollar value society would pay to avoid the loss of a single life. FEMA specifies certain sources and methods for determining SVL.

The consequence of failure, expressed in monetary terms, is equal to the sum of the replacement cost of the dam, all property destroyed in the failure, and the dollar value associated with the lives likely to be lost in a failure. The total risk posed by a dam can be calculated by multiplying the factors PF and CF together.

For each pair of observed condition and Hazard Classification, there are 14 possible outcomes for sustainment including

- maintain the current Hazard Classification and condition
- move to one of the 11 other possible Hazard Classification/condition states
- remove the dam
- modify the dam or change operating parameters such that it is no longer reportable in the NID Hazard Classifications.

For example, if a high-hazard dam is found to be in “Fair” condition, owners have the choice of either improving the condition to “Satisfactory,” letting it degrade to a lower condition, or modifying the dam or its operating parameters to move the dam to another Hazard Class. Reducing the dam to a non-NID state or removing the dam entirely is also an option. Each of these options has an implied cost in time and money associated with it. Note the special case where none of the inputs to the chart change and the dam remains in the same Hazard Class and condition. Depending on the exact condition state of the dam, this may or may not require resources to sustain the condition of the dam.

If the overall state of a dam is expressed in this way, a useful metric can be extracted from the factors PF (Probability of Failure) and CF (Consequence of Failure). PF is expressed in terms of likelihood per unit of time, usually an expected number of failures per calendar year. The factor $PF * CF$ is therefore equal to the total risk assumed by the dam owners for each year of operation. If each cell in the matrix is populated with values for PF and CF, then the relative difference between the assumed rates of risk accumulation can be calculated between and two condition states. This is an important value, since it allows the calculation of a rate of return on investment for the dollars used to affect the change in condition.

Assuming a constant inflation rate, stable condition rating after the repair work, and a discrete asset lifespan (or at least a finite analysis period),

$$ROI = \frac{\left(PF_{i,j} * CF_{i,j} - PF_{p,q} * CF_{p,q}\right) * \left(\frac{1-(1+r)^{-n}}{r}\right)}{Cost} : 1$$

where

$PF_{i,j}$ = Probability of Failure, given condition state and hazard classification (i,f) before repairs
$CF_{p,q}$ = Consequence of Failure, given condition state and hazard classification (i,f) before repairs

$PF_{p,q}$ = Probability of Failure given condition state and hazard classification (p,q) which results from the repair actions taken

$PF_{p,q}CF_{p,q}$ = Consequence of Failure, given condition state and hazard classification (p,q) which results from the repair actions taken

$PF_{p,q}CF_{p,q}\ r$ = inflation rate, n = asset lifespan.

6.4.1 Possible avenue for development: repair standards

The ESMS has two basic objectives for reporting condition: The FCI and the SMS Condition Index. FCI is generally seen as being relative to standards since it represents the deferred maintenance with respect to a defined minimum condition standard. An SMS condition index generally takes advantage of condition prediction, work planning, and project prioritization algorithms to create projects based on meeting some set of criteria such as maximized ROI and budget limits. Since FCI is supposed to be a common picture across DoD services, a common repair standard should also be created for dam assets.

Table 30 below shows a suggested common repair standard for DOD dams, where the red line indicates the minimum condition for a dam in each Hazard Classification.

Table 30. A hypothetical repair standards chart.

	High Hazard	Significant Hazard	Low hazard
Satisfactory Condition	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$
Fair Condition	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$
Poor Condition	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$
Unsatisfactory Condition	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$	$PF_{i,j}$ $CF_{i,j}$

For example, a Significant Hazard dam in Fair condition would be considered to meet the condition standards for the purpose of FCI reporting and would receive an FCI of 100 no matter what repair actions are recommended. However, Fair condition would imply an SMS condition index below 100 as well as some amount of identified deficiencies and associated repair actions. The only logical grouping of repair actions in that case would be to include all those necessary to improve the condition of the dam to Satisfactory.

The ESMS would therefore require up to two sets of M&R work plans to be provided by inspectors: one to calculate the FCI and the other to generate an SMS condition rating and work plan. Note that this would also address the OSD and the DoD request for a system to inform dam owners as to when to seek outside expertise on dam M&R issues. Any dam that obtained a rating above the red line would presumably not need additional investigation. Engineers conducting periodic inspections could also leave notes to base personnel as to what (new or progressing) deficiencies found in an intermediate inspection would lower the overall condition rating of the dam, triggering expert investigations.

Obviously, a decreased standard for repair may pose a special risk to the owner of the dam in the event of failure. In a general sense, a dam owner may defer maintenance on a dam if there is a reasonable economic justification for doing so. Depending on the implementation of this proposal, the economic justification implied by the risk matrix may or may not suffice to allow a lower repair standard. As it currently stands, all DoD services set a repair standard of *as-built-condition*, which is practical in lieu of a detailed economic justification for a lower standard.

6.4.2 A hypothetical method of work prioritization based on the proposed risk matrix

Assume that a Significant Hazard dam is inspected and found to be in poor condition due to an emergency spillway design that is inadequate for the Probable Maximum Flood but otherwise lacks significant failure indicators. Assume the use of the simple case where the failure probability and consequence are simple functions of condition rating and Hazard Class. Therefore, $PF_{Poor,Significant} = \frac{1}{25}$, and assume a reasonable value of $CF_{Poor,Significant} = \$2{,}000{,}000$.

1. Do nothing.
2. Spend $500,000 to improve the spillway to handle a 100-year frequency flood.
3. Remove $1,000,000 of real property from the inundation zone.
4. Remove the dam.
5. Remediate all deficiencies until the overall condition is Satisfactory.

In Case 1, no initial cost is incurred. However, consider that floods approaching the maximum capacity of the spillway could damage the emergency spillway. Assume that a 25-year frequency flood (which is typically a large fraction of the 50-year flood; floods do not follow in proportion to their probability) would cause damage to the emergency spillway and push the dam into Unsatisfactory condition. It is therefore reasonable to assume a *return* of 1/25th of the difference between the condition state Unsatisfactory and Poor, but with the Hazard Class unchanged.

In Case 2, the cost associated with the M&R plan is $500,000. By incurring this cost, the expectation is that the probability of failure will decrease to at least 1/100, or the equivalent of either Satisfactory or Fair. The consequence of failure is unchanged, and use

$$PF_{Fair,Significant} = \frac{1}{100}$$

In Case 3, the cost is $1,000,000 to relocate all real property to outside the inundation zone. The probability of failure is unchanged, but hazard Classification can be lowered to Low from Significant. In this case, the consequence of failure is lowered to $CF_{Poor,Low} = \$500{,}000$. Note that the consequence of failure is reduced by *more* than the $1,000,000 of property removed from danger of flooding. This is reasonable since real property is often occupied and the risk to personnel must be considered even if the property is infrequently populated. If a value of $7,000,000 per SLL is used, this implies a reasonable 1/14 chance that inundation zone is populated during a failure. Note that an implied value of 0.07 SSL is well within the FEMA guidelines for a dam to not be considered High Hazard, but the value of the lives lost is significant to the calculation of return on M&R spending.

In Case 4, the dam is removed completely, and the stream is restored to its natural state. A few factors are at play when considering the cost of this action: the cost of labor and mobilization to breech the dam, the increased flood risks to downstream areas after the dam is removed, the negative effects of the removal of the reservoir on the morale and welfare of the surrounding area, and the effect on the local wildlife due to the dam removal.

The cost of breeching is a lump sum paid up front. The flood risk could be expressed by calculating the equivalent to the probability and consequence of failure for the unimproved channel relative to the overall flood risk with the dam still in place. The difference between these two would be expressed as an annual increase (or possible decrease) in the consequence of flood events, which would be amortized over the assumed lifespan and added to the return for ROI purposes. Environmental concerns may be included as either a single cost representing the decrease in utility of the surrounding land associated with a change in wildlife patterns or an annual opportunity cost associated with the decrease in wetlands available.

For the sake of comparison, assume that the flood risk associated with the breeched dam is completely removed but it costs $1,000,000 to breech, and there is an additional $1,000,000 of utility lost due to environmental degradation.

In Case 5, assume a total repair cost of $3,000,000 to eliminate all deficiencies and that the consequence of failure is unchanged.

In summary, the ROI for the various cases are the following:

1. Return = ($71,512/year)
2. ROI = 4.01:1
3. ROI = 1.54:1
4. ROI = 1.03:1
5. ROI = .68:1

This analysis presents that, of the three projects considered, the option to improve the condition of the dam yields the most for the given investment. The return on the do-nothing strategy yields an increase of $71K per year in assumed risk. Breeching the dam seems to offer little real return on investment, giving only 3% back from the initial investment over the 50-year analysis period. The three repair/modification projects would equate to a 6%, 1%, and -.7% yearly rate of return over the 50-year analysis period.

Note that the calculation of the return on the do-nothing strategy gives an interesting metric for *consequence of deferred maintenance*. The numbers suggest that doing nothing yields a negative return over the lifespan of the project due to the increased risk of condition degradation. It can be interpreted that any action that prevents the degradation of the condition of the dam for less than $71K per year would yield a positive return for the dam owners. Note the nominal 6% return on $500K spillway reconstruction implies that only $30K is returned each year to the owners. If the owner can maintain the current condition for $41K or less without conducting major M&R, then more than $30K of surplus value would be accrued, making it an economic alternative. This could be accomplished by maintaining pump equipment capable of assisting the spillways in passing unusually large floods safely.

All these projects would then be uploaded to the dam module of the ESMS. The project ROI would be compared to the ROI of all M&R work plans in the ESMS for the real property site and selected according to best-to-worst return for the base. If the base budget allowed for projects with rate of return of 6% or less, than project “b” would be added for budgeting in the current year. Else, the project would be listed as deferred maintenance and the FCI for the dam would be <100, and the cost of deferred maintenance would be equal to the project cost of “b”: $500,000. It would be wise to keep a record of such deferrals as the ROI calculation is an important step to show that valid economic reasons exist when safety issues are unfunded.

6.5 Possible data sources

Determination of the quantities PF and CF is the providence of authorities on dam inspection and remediation. It is assumed that CERL would need to seek outside advice for filling in the condition-hazard matrix both in general or for individual dams.

6.6 USACE Periodic Risk Assessment (PRA)

The current USACE Civil Works method of PRA translates well to this proposed method. Risk assessment is also conducive to comparison to other SMS methods since the standard SMS degradation curve is a close proxy to the overall risk of failure on a component level.

6.7 Infer all values from NID condition and hazard

One approach to risk would entail inferring logical values for all variables in the condition-hazard matrix, where each is a defined function of the observed condition and Hazard Classification. The values for PF and CF for each condition state and Hazard Classification would be determined through a separate research project, most probably executed by USACE-Institute for Water Resources-Risk Management Center. These would represent mean values and be tailored to the DoD portfolio of dams. Tables 31 and 32 show some reasonable starting values for the purpose of demonstration.

Table 31. Possible failure probability mapping to NID condition rating.

NID Condition Rating	Failure Probability Range (/year)	Nominal Failure Probability PF (/year)
Satisfactory	250+	1/1000
Fair	50-250	1/100
Poor	5-50	1/25
Unsatisfactory	0-5	1/2

Table 32. Possible consequence of failure mapping to NID hazard classification.

High Hazard	Significant Hazard	Low Hazard
PRV* + $5,000,000	PRV + $2,000,000	PRV + $500,000

*PRV=plant replacement value

Another approach would mix explicit risk assessment and inferred values. This approach was created based on the understanding that there is already some interest in DoD for using USACE periodic risk assessment for some DoD dams (at least, some of the High Hazard ones). If this were the case, the table of inferred values from above could be supplemented by values generated by USACE PRA.

- **High Hazard Dams:** Apply the USACE civil works method, including periodic risk assessment in all cases. Directly calculate failure probability and consequence of failure during each inspection.
- **Significant Hazard Dams:** Use presumed values according to the condition of the dam to determine failure probability. Apply USACE methods to determining the extent of the inundation zone. Sum the plant replacement value of real property in the inundation zone to arrive at consequence of failure.
- **Low Hazard, non-NID, and Levees:** Conduct separate research to determine working values for PF and CF for each condition state.

7 Conclusions and Recommendations

7.1 Conclusion

The ESMS improves DoD asset management by providing decision support for installations, allowing a more efficient allocation of resources through targeted investment in real assets. The primary advantage to an Enterprise solution to sustainment management is that investment strategies can be compared and optimized across disparate asset types, allowing DoD to consider its maintenance and repair spending holistically. The ESMS also provides a consistent method for the capture and reporting of condition information across all DoD services and asset types. The inspection methodology will enable the water control structures (WCS) module in providing the benefits of the ESMS to DoD customers.

Further development and research are needed to complete the WCS module. Initial Operating Capability of the WCS module will require a condition rating method that utilizes the inspection rating methodology to roll up a single facility level score from the inspection rating of the components. Depending on stakeholder preferences, this roll-up condition rating may make special consideration for the risk posed by water control structures. If so, the next phase of development would require expertise outside of ERDC-CERL. The Corps of Engineers Mandatory Center of Expertise of Dam Safety and Risk Analysis would provide the technical expertise for such a project, with the goal of providing DoD services a simplified rubric that allows the prioritization of M&R work across multiple asset types without the needed for significant incremental investment in specialized risk analysis but still giving due consideration of the safety considerations of maintaining water-retaining structures.

7.2 Recommendations

- Further development of a condition rating method based on the inspection methodology proposed in this report would support the OSD intent to create a Sustainment Management System for Water Retaining Structures. Full integration of the WCS module with the ESMS would also require consideration of work planning, prioritization, and forecasting models for Water Retaining Structures.

- It would be highly desirable to have an API for data within the USACE NID. It is proposed that USACE develop this API for the NID while ERDC-CERL maintains a secure data portal to the ESMS database.
- An updated estimation of the replacement values of the DoD inventory of dams, dikes, and levees would increase the accuracy and usefulness of resulting FCI values. Inventory information stored in the DoD real property system would require updates to reflect changes made.
- Re-alignment of the FAC and CAT codes pertinent to dams, dikes, and levees would aid in the consistency of the DoD inventory system. A new classification system for Water Retaining Structures is proposed in Chapter 3.
- A study of the actual sustainment cost factors of various FACs for DoD Water Control Structures would be beneficial, particularly if DoD does re-align its water control structures as proposed in this report. A key feature of this effort would be to align the sustainment cost with the inspections required for that particular asset, as well as any increased repair standard for higher hazard assets.
- A clear standard for linear segmentation of levees is needed to create a consistent inventory record across DoD. It is recommended that OSD republish its linear segmentation guidelines with specific rules for levee type assets. Proposed linear segmentation guidelines are listed in Appendix D.
- It is recommended that the Executive Configuration Support Panel for the Enterprise SMS advice on future resourcing for continuing development of the Water Control Structures module and on the relative breakout of program sustainment costs for this module amongst the relevant services.
- A proactive approach to integration of third-party tools for GIS data collection and dam safety monitoring will prevent duplication of efforts and optimize the DoD ROI in off-the-shelf software.

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Appendix A: Federal Definition of a Dam

The following definition for a dam is given in 33 U.S.C., Chapter 9, Subchapter VII, Section 467. Full text is available at http://uscode.house.gov/view.xhtml?path=/prelim@title33/chapter9/subchapter7&edition=prelim.

> **(3) Dam** The term “dam”—
>
> **(A)** 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—
>
> **(i)** is 25 feet or more in height from—
>
> **(I)** the natural bed of the stream channel or watercourse measured at the downstream toe of the barrier; or
>
> **(II)** 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 water storage elevation; or
>
> **(ii)** has an impounding capacity for maximum storage elevation of 50 acre-feet or more; but
>
> **(B)** does not include—
>
> **(i)** a levee; or
>
> **(ii)** a barrier described in subparagraph (A) that—
>
> **(I)** is 6 feet or less in height regardless of storage capacity; or
>
> **(II)** 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 (as determined by the Administrator).

Appendix B: Federal Definition of a Levee

FEMA and 44 CFR definition:

> The National Flood Insurance Program (NFIP) defines a levee in Title 44 CFR, Chapter 1, section 59.1 (44 CFR § 59.1: Definitions n.d.), as ‘a man-made structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water in order to reduce risk from temporary flooding.’ (FEMA 2016)
>
> The NFIP regulations define a levee system as ‘a flood protection system which consists of a levee, or levees, and associated structures, such as closure and drainage devices, which are constructed and operated in accordance with sound engineering practices.’

Also, see comprehensive federal definition in P.L. 113-121, title III (U.S. Congress 2014):

> “(A) IN GENERAL.—The term ‘levee’ means a manmade barrier (such as an embankment, floodwall, or other structure)—
>
> > “(i) the primary purpose of which is to provide hurricane, storm, or flood protection relating to seasonal high water, storm surges, precipitation, or other weather events; and
> > “(ii) that is normally subject to water loading for only a few days or weeks during a calendar year.
>
> “(B) INCLUSIONS.—The term ‘levee’ includes a levee system, including—
>
> > “(i) levees and canal structures that—
> >
> > > “(I) constrain water flows;
> > > “(II) are subject to more frequent water loading; and
> > > “(III) do not constitute a barrier across a watercourse; and
> >
> > “(ii) roadway and railroad embankments, but only to the extent that the embankments are integral to the performance of a flood damage reduction system.
>
> “(C) EXCLUSIONS.—The term ‘levee’ does not include—
>
> > “(i) a roadway or railroad embankment that is not integral to the performance of a flood damage reduction system;

> “(ii) a canal constructed completely within natural ground without any manmade structure (such as an embankment or retaining wall to retain water or a case in which water is retained only by natural ground);
> “(iii) a canal regulated by a Federal or State agency in a manner that ensures that applicable Federal safety criteria are met;
> “(iv) a levee or canal structure—
> “(I) that is not a part of a Federal flood damage reduction system;
> “(II) that is not recognized under the National Flood Insurance Program as providing protection from the 1-percent-annual-chance or greater flood;
> “(III) that is not greater than 3 feet high;
> “(IV) the population in the leveed area of which is less than 50 individuals; and
> “(V) the leveed area of which is less than 1,000 acres; or
> “(v) any shoreline protection or river bank protection system (such as revetments or barrier islands).

Levee definition in NCLS Report to Congress, page 33 (NCLS 2009):

> NCLS Definition of a Levee: A manmade barrier (embankment, floodwall, or structure) along a watercourse constructed for the primary purpose to provide hurricane, storm, and flood protection relating to seasonal high water, storm surges, precipitation, and other weather events; and that normally is subject to water loading for only a few days or weeks during a year.
>
> Levees also may be embankments, floodwalls, and structures that provide flood protection to lands below sea level and other lowlands and that may be subject to water loading for much, if not all, portions of the year, but that do not constitute barriers across watercourses or constrain water along canals.
>
> This levee definition does not apply to shoreline protection or riverbank protection systems such as revetments or barrier islands.

Appendix C: Proposed Component Catalog for Dams and Levees

Crest

The crest is the peak elevation of the body of the dam, starting from wherever the slope of the embankment returns to level or near level. The crest should be a single inventory item between each embankment, regardless if the crest is interrupted by a spillway or outlet works.

Upstream face

The upstream face consists of the visible part of the dam body that faces the upstream area. It will extend from the crest to the reservoir pool at its lowest elevation.

Downstream face

The downstream face consists of the visible part of the dam body that faces the downstream area. It will extend from the crest of the dam to the toe, defined as the point at which the embankment slope ends. The entire downstream slope from the left to the right groin area is part of the same component.

Body

The body of a dam, dike, or levee includes the mass of the structure that resists the force of water. Generally, everything not included as part of the crest, faces, groin, or foundation should be included as part of the dam body. Since this component is not visible, this component serves as a placeholder for defects observed indirectly via visible indicators.

Downstream toe area

The toe area is the region immediately downstream of the downstream face of the dam body. The toe should be considered to extend 50 ft beyond the edge of the downstream face in the direction of the flow of water, or as far as the inspector deems relevant for inspection purposes. The toe need not have been constructed or engineered to be considered a component of the dam.

Groin area

The groin is the intersection between the body of the dam and its abutments. This feature is assumed to extend 10 ft from the actual intersection onto both the abutment and the body.

Abutments

The abutments consist of un-engineered material that supports the left or right end of the body of a dam.

Reservoir slopes

The reservoir slopes consist of the natural or engineered slope adjacent to the reservoir that is not considered part of the upstream slope.

Foundation

The foundation should be included in the inventory of a dam, dike, or levee, even if the foundation is not an explicitly constructed or engineered feature. While the foundation cannot be inspected under normal conditions, indicators of distress in the foundation may appear. This component serves to provide a distinct object in the ESMS database to attach such observations.

Toe drain

A toe drain is any structure used to safely transmit water from within the toe of the dam to a location farther downstream.

Foundation drain

A toe drain is any structure used to safely transmit water from within the foundation, or anywhere within the body of the dam, to a location farther downstream.

Trash rack

A trash rack is typically a metal grate used to prevent debris from entering the outlet works. If there is more than one intake, or there are trash racks on both the outlet works as well as the spillway inlets, include all trash racks as the same component.

Trash boom

A trash boom is a floating object that spans the waterline between an intake structure and the rest of the reservoir. If there is more than one section of trash boom, include all sections as a single inventory component.

Intake structure

An intake structure is any structure that supports the intake for the outlet works for a dam. Include all appurtenant components of the structure, not including the actual intake itself in this component.

Conduit

A conduit is a circular, oval, or square cross-sectioned tube that transmits water, typically through an embankment. All conduit that forms a single channel should be inventoried as a single component, regardless if the channel is formed from several pieces laid end to end. The interior width or diameter (whichever is more) should not exceed 48 in. If it does, use the component type "Culvert."

Includes "Drop Inlet," "Drop Outlet," and "Outlet Pipe."

Valves

A valve controls the flow of water through a pipe. For inventory purposes, include all mechanical components that are there solely due to the existence of the valve, including control equipment.

Closure

A closure is a device used to restrict or stop the flow of water through the outlet works or spillway.

Control mechanism

A control mechanism is any mechanism used to control the opening and closing of gates or valves in the outlet works or spillway.

Outlet tower

An outlet tower is a structure that supports the outlet pipe or conduit. Include all appurtenant components of this structure not including the outlet itself.

Spillway approach area

The approach area of a spillway includes the transition from the reservoir area to the spillway channel. Judgment should be used to determine where the approach begins, but the approach should typically end where the spillway channel reaches a uniform cross section.

Spillway channel floor

The channel floor of a spillway consists of the part of the spillway proper (not including the approaches) with a level or near-level slope.

Spillway sidewalls

The sidewalls of a spillway consist of the part of the spillway with a significant slope that is also part of the spillway proper (not including the approaches).

Spillway discharge areas

The discharge area of a spillway is the portion downstream from the main channel of a spillway, but before the downstream channel where water dissipates energy. Judgment should dictate where the beginning or end of this component is.

Stilling basin

A stilling basin is a downstream area of the outlet works or spillway used to dissipate energy from the flow of water. Judgment should be used to determine the extent of what is considered the component but should generally includes the floor, sidewalls, and any energy-dissipating features of the basin, all inventoried under the same component.

Piezometer

A piezometer is a device for measuring the pressure of water within an embankment. If there is more than one piezometer present, create a separate component for each piezometer, such that inspection readings may be more easily tracked.

Observation well

An observation well is a well, constructed for the sole purpose of measuring the height of water in the well. Each observation well should be its own component.

Gates

A sluice gate is a water control mechanism that uses a sluice, or a vertically oriented plate, that spans the opening of the conduit to control the flow of water. The sluice plate is typically lifted vertically to open the channel and allow water to flow. Each gate should be its own component.

Staff gauge

A staff gauge measures the height of water from a fixed reference point. If there is more than one staff gauge, create a separate component for each gauge.

Weir

A weir is a channel restriction designed so that the flow of water through the weir can be determined via hydraulic analysis.

There is an infinite amount of possible designs for weirs, each with a different relationship between the flows of water with respect to the steady state height of water flowing through the weir. Specific instructions on how to convert inspection observations of weir flow into volumetric flow rates should be provided, considering that not all inspections (e.g., routine inspections) will be conducted by engineers.

Survey monument

A survey monument is any object used to permanently mark a survey point. A separate component should exist for each monument.

Inclinometer

An inclinometer measures the *tilt* of the area it is embedded in. An inclinometer may be installed horizontally or vertically.

Access roads

Access roads include all paved or unpaved roads that exist solely because of the existence of the dam or levee, including any road that straddles the crest.

An unpaved road that straddles the crest of a dam or levee need not be inventoried separately from the crest. A paved road should always be included as a separate inventory item.

Safety and security devices

Include all devices used to restrict access or prevent accidental entry to unsafe areas.

Relief wells

Relief wells remove water from an embankment to remove hydraulic pressure from the dam or levee. Wells of a common depth and capacity should be inventoried as a single component.

Concrete surface

A concrete surface covers a spillway channel, embankment face, or reservoir face for the purpose of erosion or seepage control. The entire surface should be considered a single component for inventory purposes. Joints between surfaces are considered subcomponents of the concrete surface itself.

Concrete monolith

Concrete monoliths are single poured sections of concrete that resist structural loads. Each monolith in a structural system should be its own component. Joints between monoliths are considered subcomponents of the monolith itself.

Culverts

A culvert is a steel, polymer, or concrete hollow section used to transmit water through an embankment.

For the purposes of this database, a culvert is any section with an inside width or greater than 48 in. but less than 20 ft. Smaller-size sections should be inventoried as a conduit. Larger sections may qualify as a bridge if there is the potential for vehicle traffic over the culvert.

Revetments

A revetment is an engineered object placed to support a natural slope. Judgment should be used to differentiate between a concrete surface and a revetment, based on the likely intended use.

Pump

A pump is a machine used to create a flow of water. A separate inventory component should be created for each district type of pump (e.g., horsepower, pump design, intake diameter).

Sump/Wet well

A sump/wet well is a well that is designed to remove water from a dam, dike, or levee, or the vicinity thereof. It may also be used to move water from one side of an embankment to the other, usually to the channel side of a levee.

Appendix D: Proposed Linear Segmentation Business Rules for Department of Defense (DoD)-Owned Levees

The OSD has issued guidance on how to report DoD-owned real property assets that are linear in nature. A linear structure is a structure that has a function that requires it to traverse land. The OSD intent is to give higher level personnel, including Congress, a clearer picture of the extent of the DoD real property portfolio by segmenting linear structures by relevant features and capabilities. The OSD guidance contains special instructions for several linear structure types such as rail track, roads, airfields, and pipes but does not have any specific instructions for levees. The following general rules for segmenting linear structures follow from *Department of Defense Guide for Segmenting Types of Linear Structures*.

1. Each linear structure asset is a real property asset.
2. Each linear structure asset has an RPUID.
3. Each linear structure asset is bound to one and only one real property site.
4. A linear structure asset contains one or more linear structure segments.
5. The real property dimension of a linear structure asset is the sum of the real property dimensions of that linear structure asset's segments.
6. A linear structure segment must be associated with one and only one RPUID.
7. A linear structure asset may be comprised of multiple Category Codes (CATCODEs).
8. Multiple linear structure assets of one Facility Analysis Category (FAC) may exist on a site if they are discontinuous or not connected.
9. Each linear structure asset begins at the installation boundary or point where DoD's interest begins as stipulated in easements, rights-of-way, etc.
10. The linear structure asset is segmented where a non-linear real property asset (a linear structure known as a node) is connected to the linear structure.
11. The linear structure asset is segmented where there are changes in the characteristics that affect capacity or delivery of a service or commodity such as installation date, diameter, type material, and type of service. Where this business rule comes into conflict with the methodology

provided in a USA-CERL produced sustainment management system for that as-set type, the USA-CERL published methodology will be used.

The following rules are proposed for assets in the inventory of the ESMS.

- With respect to Rule 8.

If a levee exists on both banks of a waterway, consider both sections to be part of a single real property asset.

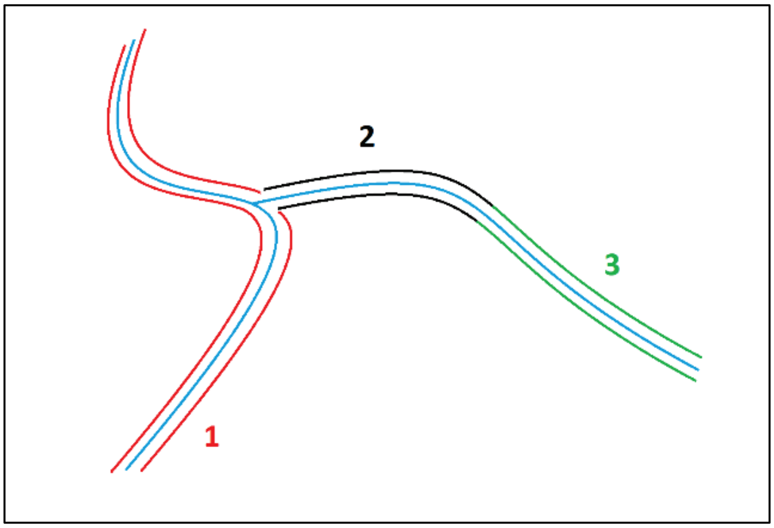
- With respect to Rule 10.

The delivery of service derived from a levee is generally not affected by typical non-linear structures that might appear in a levee.

- With respect to Rule 11.

Individual segments should be created such that each segment has the same (1) crest elevation, (2) construction type, (3) construction date, and (4) waterway. In addition, the left and right embankments should be separate segments. The figure below shows a single real property site with a levee along the banks of two rivers that join together downstream. All the segments would be inventoried as part of the same RPUID. However, the individual segments would become Level II inventory segments in the ESMS database while also being unique segments in the National Levee Database. Segments 2 and 3 differ in one of the four categories listed above. Therefore, they are different segments for this purpose, despite being on the same river (Figure D-1).

Figure D-1. Example linear segmentation of water control structure.

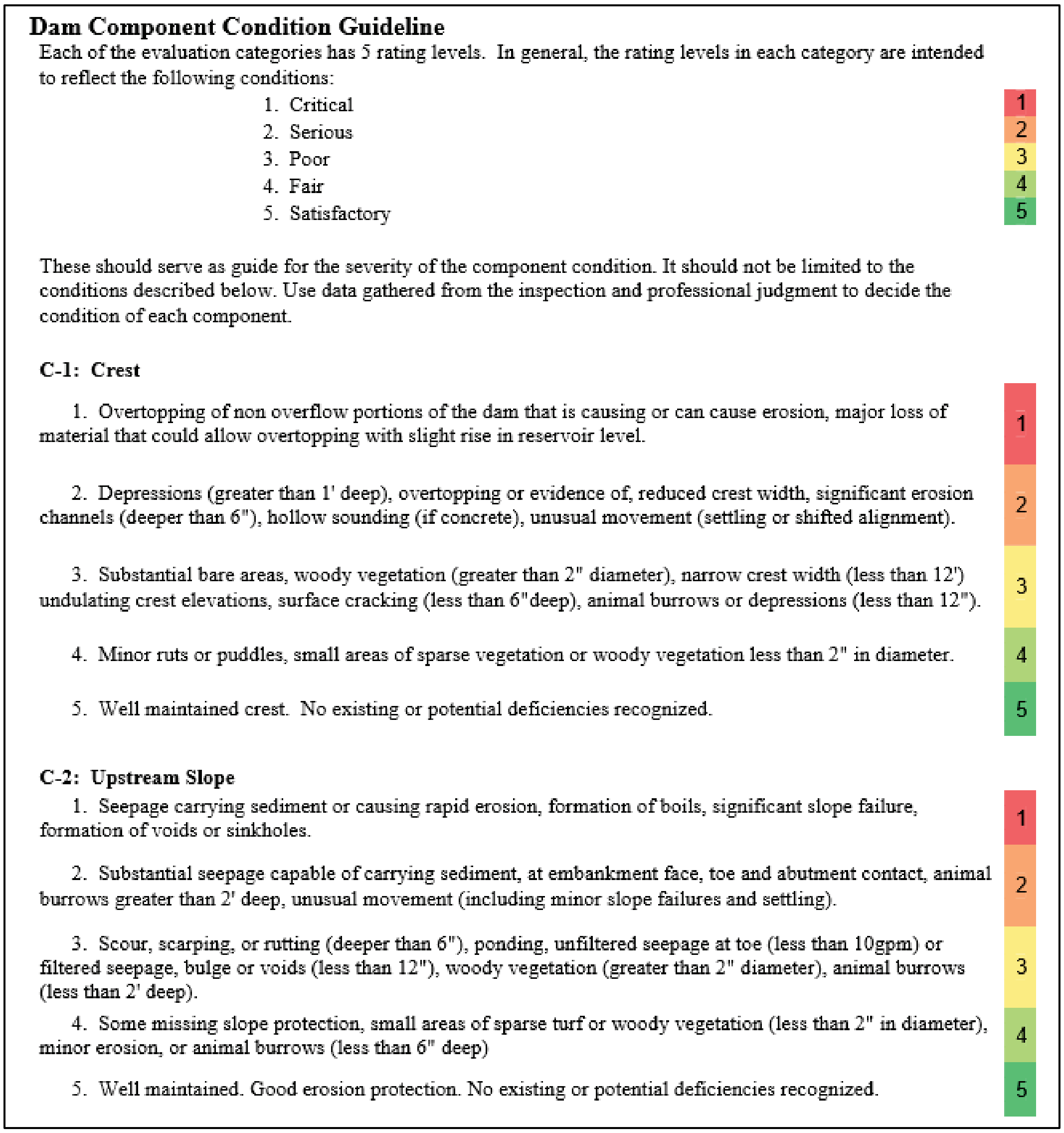


Applicable FAC Categories

MilDep	FAC	CAT CODE	CATCODE Long Name
Air Force	8714	871401	Dyke/Dam
Army	8714	16430	Levee
Navy	8714	16430	Levees

Appendix E: Current USACE Inspection Rating Scale-Dams

The following inspection rating scale for dams was found in the 2015 Periodic Dam Inspection Report for the Stillwell Dam in West Point, NY (Landers et al. 2015).



Dam Component Condition Guideline

Each of the evaluation categories has 5 rating levels. In general, the rating levels in each category are intended to reflect the following conditions:

1. Critical	1
2. Serious	2
3. Poor	3
4. Fair	4
5. Satisfactory	5

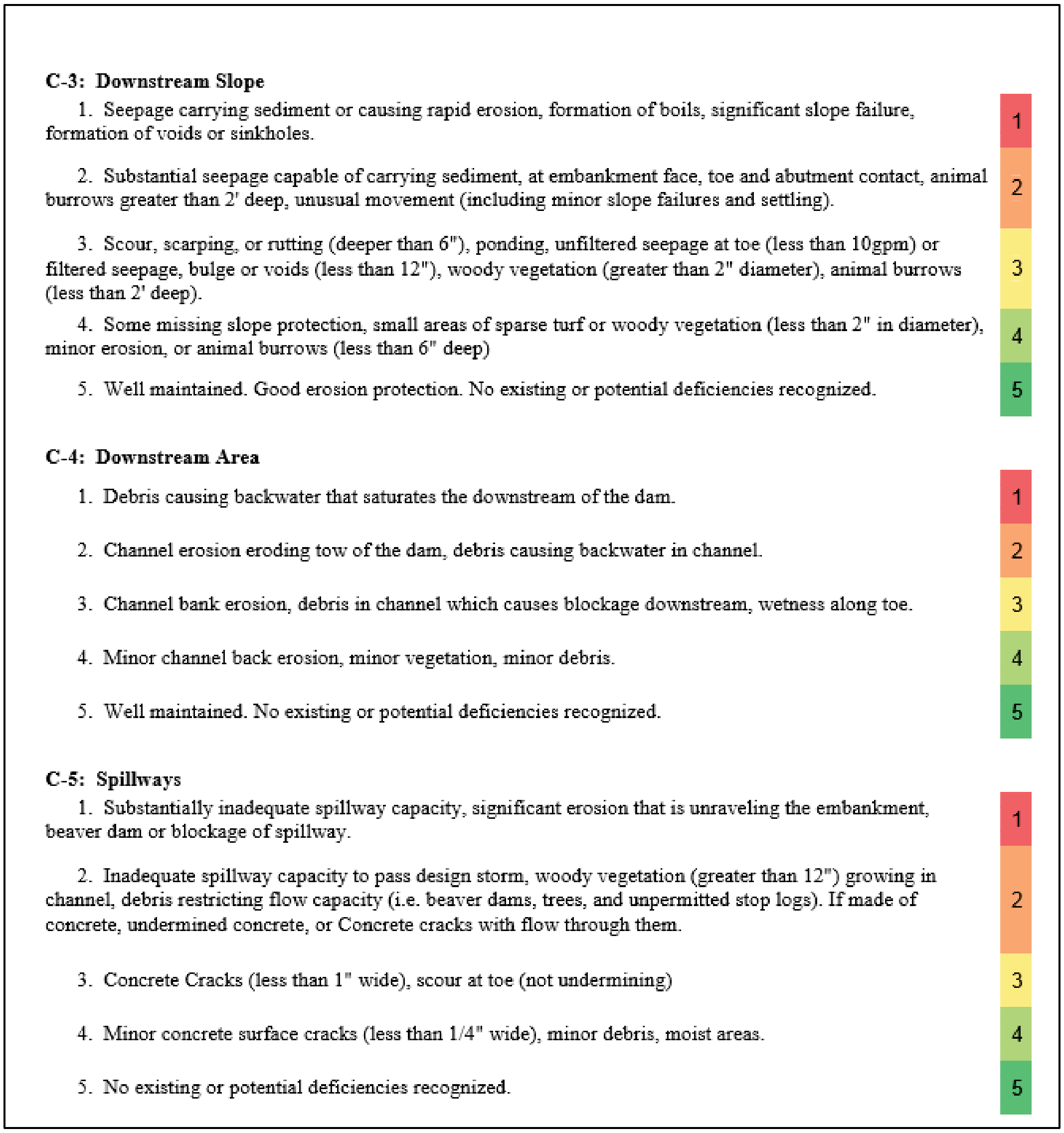
These should serve as guide for the severity of the component condition. It should not be limited to the conditions described below. Use data gathered from the inspection and professional judgment to decide the condition of each component.

C-1: Crest

1. Overtopping of non overflow portions of the dam that is causing or can cause erosion, major loss of material that could allow overtopping with slight rise in reservoir level.	1
2. Depressions (greater than 1' deep), overtopping or evidence of, reduced crest width, significant erosion channels (deeper than 6"), hollow sounding (if concrete), unusual movement (settling or shifted alignment).	2
3. Substantial bare areas, woody vegetation (greater than 2" diameter), narrow crest width (less than 12') undulating crest elevations, surface cracking (less than 6"deep), animal burrows or depressions (less than 12").	3
4. Minor ruts or puddles, small areas of sparse vegetation or woody vegetation less than 2" in diameter.	4
5. Well maintained crest. No existing or potential deficiencies recognized.	5

C-2: Upstream Slope

1. Seepage carrying sediment or causing rapid erosion, formation of boils, significant slope failure, formation of voids or sinkholes.	1
2. Substantial seepage capable of carrying sediment, at embankment face, toe and abutment contact, animal burrows greater than 2' deep, unusual movement (including minor slope failures and settling).	2
3. Scour, scarping, or rutting (deeper than 6"), ponding, unfiltered seepage at toe (less than 10gpm) or filtered seepage, bulge or voids (less than 12"), woody vegetation (greater than 2" diameter), animal burrows (less than 2' deep).	3
4. Some missing slope protection, small areas of sparse turf or woody vegetation (less than 2" in diameter), minor erosion, or animal burrows (less than 6" deep)	4
5. Well maintained. Good erosion protection. No existing or potential deficiencies recognized.	5



C-3: Downstream Slope

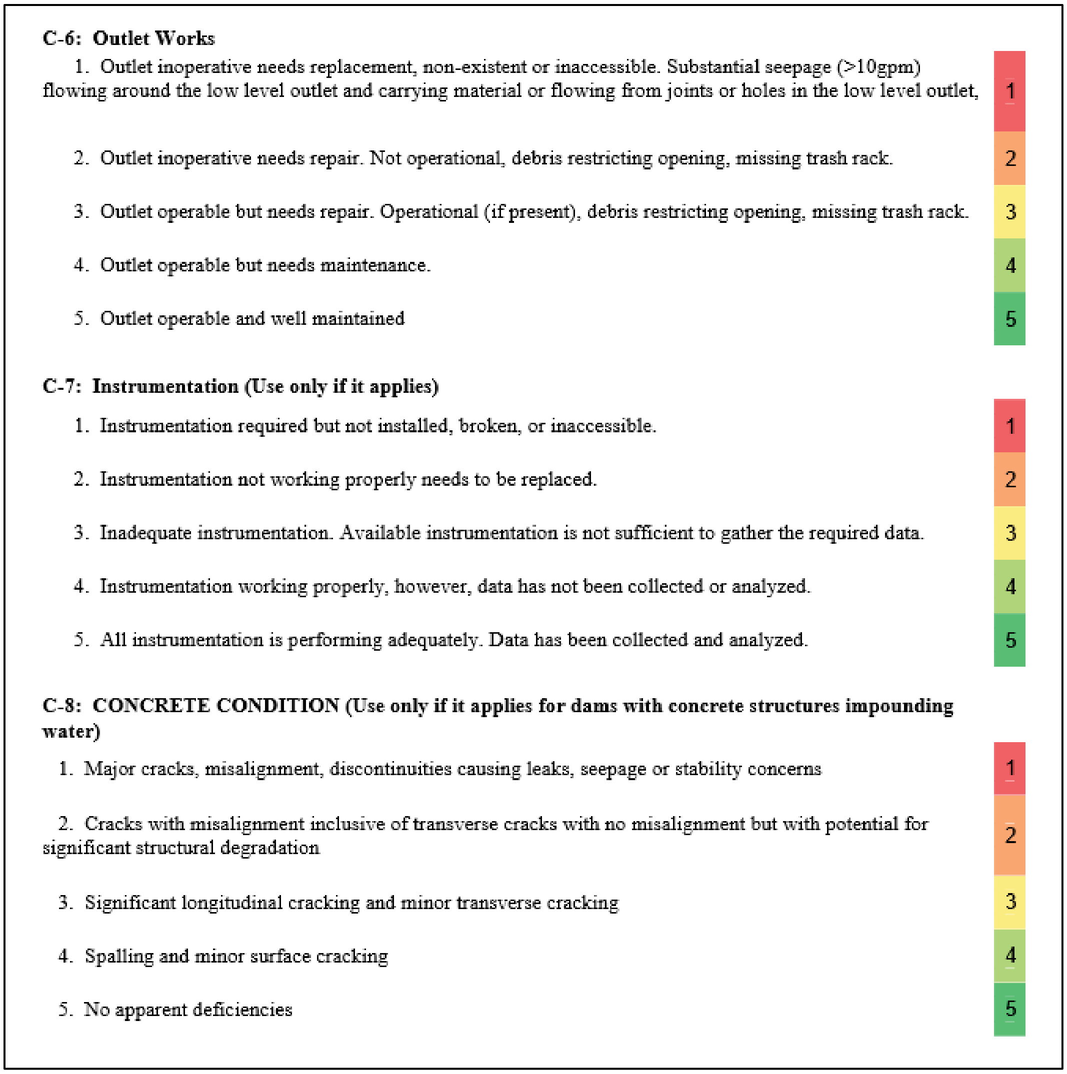
1. Seepage carrying sediment or causing rapid erosion, formation of boils, significant slope failure, formation of voids or sinkholes.	1
2. Substantial seepage capable of carrying sediment, at embankment face, toe and abutment contact, animal burrows greater than 2' deep, unusual movement (including minor slope failures and settling).	2
3. Scour, scarping, or rutting (deeper than 6"), ponding, unfiltered seepage at toe (less than 10gpm) or filtered seepage, bulge or voids (less than 12"), woody vegetation (greater than 2" diameter), animal burrows (less than 2' deep).	3
4. Some missing slope protection, small areas of sparse turf or woody vegetation (less than 2" in diameter), minor erosion, or animal burrows (less than 6" deep)	4
5. Well maintained. Good erosion protection. No existing or potential deficiencies recognized.	5

C-4: Downstream Area

1. Debris causing backwater that saturates the downstream of the dam.	1
2. Channel erosion eroding tow of the dam, debris causing backwater in channel.	2
3. Channel bank erosion, debris in channel which causes blockage downstream, wetness along toe.	3
4. Minor channel back erosion, minor vegetation, minor debris.	4
5. Well maintained. No existing or potential deficiencies recognized.	5

C-5: Spillways

1. Substantially inadequate spillway capacity, significant erosion that is unraveling the embankment, beaver dam or blockage of spillway.	1
2. Inadequate spillway capacity to pass design storm, woody vegetation (greater than 12") growing in channel, debris restricting flow capacity (i.e. beaver dams, trees, and unpermitted stop logs). If made of concrete, undermined concrete, or Concrete cracks with flow through them.	2
3. Concrete Cracks (less than 1" wide), scour at toe (not undermining)	3
4. Minor concrete surface cracks (less than 1/4" wide), minor debris, moist areas.	4
5. No existing or potential deficiencies recognized.	5



C-6: Outlet Works

1. Outlet inoperative needs replacement, non-existent or inaccessible. Substantial seepage (>10gpm) flowing around the low level outlet and carrying material or flowing from joints or holes in the low level outlet,	1
2. Outlet inoperative needs repair. Not operational, debris restricting opening, missing trash rack.	2
3. Outlet operable but needs repair. Operational (if present), debris restricting opening, missing trash rack.	3
4. Outlet operable but needs maintenance.	4
5. Outlet operable and well maintained	5

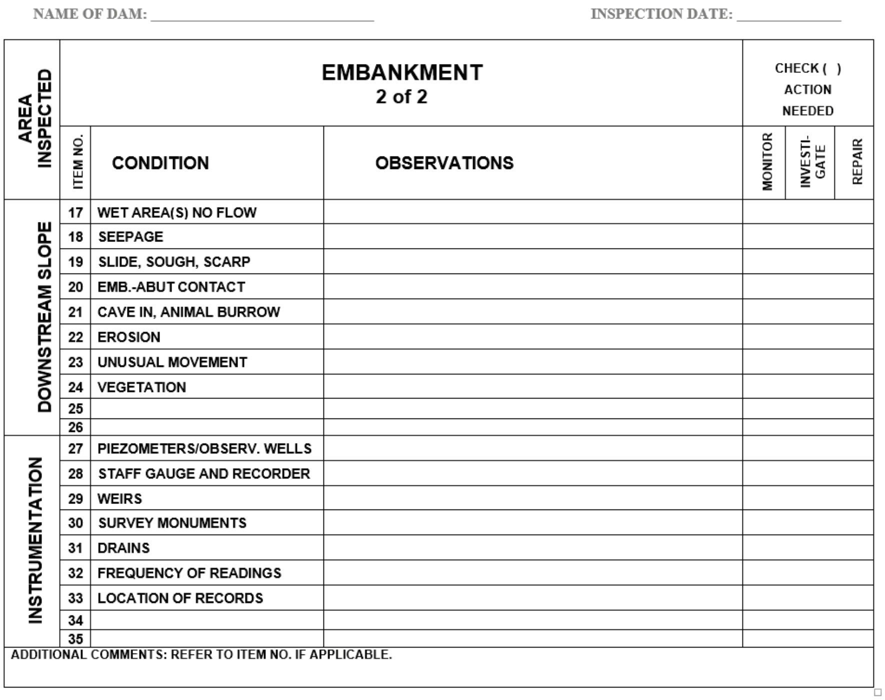
C-7: Instrumentation (Use only if it applies)

1. Instrumentation required but not installed, broken, or inaccessible.	1
2. Instrumentation not working properly needs to be replaced.	2
3. Inadequate instrumentation. Available instrumentation is not sufficient to gather the required data.	3
4. Instrumentation working properly, however, data has not been collected or analyzed.	4
5. All instrumentation is performing adequately. Data has been collected and analyzed.	5

C-8: CONCRETE CONDITION (Use only if it applies for dams with concrete structures impounding water)

1. Major cracks, misalignment, discontinuities causing leaks, seepage or stability concerns	1
2. Cracks with misalignment inclusive of transverse cracks with no misalignment but with potential for significant structural degradation	2
3. Significant longitudinal cracking and minor transverse cracking	3
4. Spalling and minor surface cracking	4
5. No apparent deficiencies	5

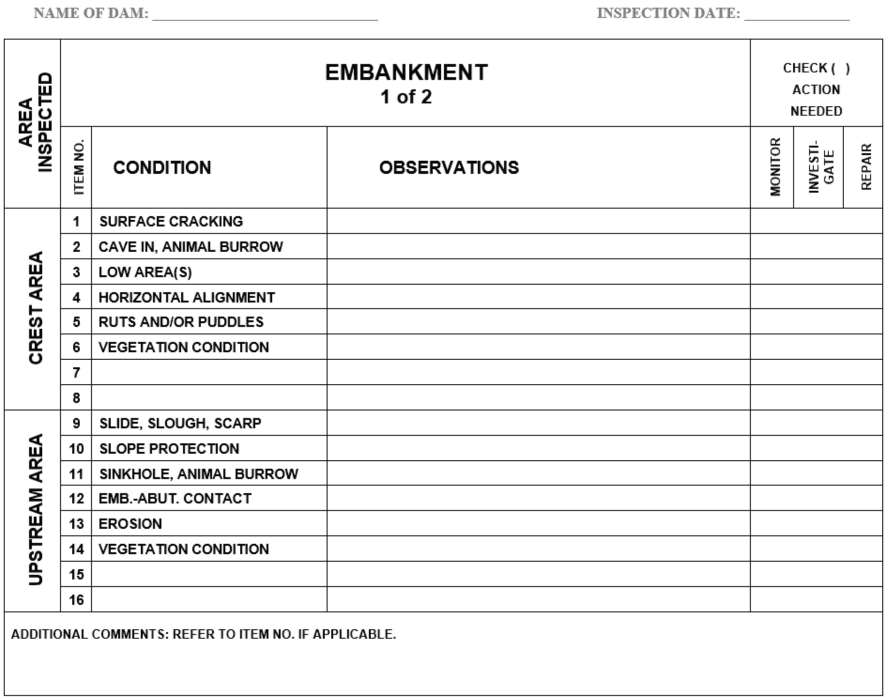
Appendix F: USACE Dam Inspection Forms



NAME OF DAM: ______________________________ INSPECTION DATE: ______________

AREA INSPECTED	EMBANKMENT 2 of 2			CHECK ( ) ACTION NEEDED		
	ITEM NO.	CONDITION	OBSERVATIONS	MONITOR	INVESTI-GATE	REPAIR
DOWNSTREAM SLOPE	17	WET AREA(S) NO FLOW				
	18	SEEPAGE				
	19	SLIDE, SOUGH, SCARP				
	20	EMB.-ABUT CONTACT				
	21	CAVE IN, ANIMAL BURROW				
	22	EROSION				
	23	UNUSUAL MOVEMENT				
	24	VEGETATION				
	25					
	26					
INSTRUMENTATION	27	PIEZOMETERS/OBSERV. WELLS				
	28	STAFF GAUGE AND RECORDER				
	29	WEIRS				
	30	SURVEY MONUMENTS				
	31	DRAINS				
	32	FREQUENCY OF READINGS				
	33	LOCATION OF RECORDS				
	34					
	35					

ADDITIONAL COMMENTS: REFER TO ITEM NO. IF APPLICABLE.



NAME OF DAM: ______________________________ INSPECTION DATE: ______________

AREA INSPECTED	EMBANKMENT 1 of 2			CHECK ( ) ACTION NEEDED		
	ITEM NO.	CONDITION	OBSERVATIONS	MONITOR	INVESTI-GATE	REPAIR
CREST AREA	1	SURFACE CRACKING				
	2	CAVE IN, ANIMAL BURROW				
	3	LOW AREA(S)				
	4	HORIZONTAL ALIGNMENT				
	5	RUTS AND/OR PUDDLES				
	6	VEGETATION CONDITION				
	7					
	8					
UPSTREAM AREA	9	SLIDE, SLOUGH, SCARP				
	10	SLOPE PROTECTION				
	11	SINKHOLE, ANIMAL BURROW				
	12	EMB.-ABUT. CONTACT				
	13	EROSION				
	14	VEGETATION CONDITION				
	15					
	16					

ADDITIONAL COMMENTS: REFER TO ITEM NO. IF APPLICABLE.

NAME OF DAM: ______________________________ INSPECTION DATE: ______________

AREA INSPECTED	DOWNSTREAM AREA AND MISC. 1 of 1			CHECK ( ) ACTION NEEDED		
	ITEM NO.	CONDITION	OBSERVATIONS	MONITOR	INVESTI-GATE	REPAIR
DOWNSTREAM AREA	36	ABUTMENT LEAKAGE				
	37	FOUNDATION SEEPAGE				
	38	SLIDE, SLOUGH, SCARP				
	39	DRAINAGE SYSTEM				
	40					
	41					
	42	DOWNTREAM HAZARD DESCRIPTION				
	43	DATE OF LAST UPDATE OF EMERGENCY ACTION PLAN				
MISCELLANEOUS	44	RESERVOIR SLPOES				
	45	ACCESS ROADS				
	46	SECURITY DEVICES				
	47					
	48					
	49					
	50					

ADDITIONAL COMMENTS: REFER TO ITEM NO. IF APPLICABLE.

NAME OF DAM: ______________________________ INSPECTION DATE: ______________

AREA INSPECTED	SPILLWAYS 1 of 1			CHECK ( ) ACTION NEEDED		
	ITEM NO.	CONDITION	OBSERVATIONS	MONITOR	INVESTI-GATE	REPAIR
ERODIBLE CHANNEL	51	SLIDE, SLOUGH, SCARP				
	52	EROSION				
	53	VEGETATION CONDITION				
	54	DEBRIS				
	55					
	56					
NON-ERODIBLE CHANNEL	57	SIDEWALLS				
	58	CHANNEL FLOOR				
	59	UNUSUAL MOVEMENT				
	60	APPROACH AREA				
	61	WEIR OR CONTROL				
	62	DISCHARGE AREA				
	63					
	64					
DROP INLET	65	INTAKE STRUCTURE				
	66	TRASHRACK				
	67	STILLING BASIN				
	68					
	69					

ADDITIONAL COMMENTS: REFER TO ITEM NO. IF APPLICABLE.

NAME OF DAM: ______________________________ INSPECTION DATE: ______________

AREA INSPECTED	OUTLET WORKS 1 of 1			CHECK ( ) ACTION NEEDED		
	ITEM NO.	CONDITION	OBSERVATIONS	MONITOR	INVESTI-GATE	REPAIR
OUTLET WORKS	70	INTAKE STRUCTURE				
	71	TRASKRACK				
	72	STILLING BASIN				
	73	PRIMARY CLOSURE				
	74	SECONDARY CLOSURE				
	75	OUTLET PIPE				
	76	OUTLET TOWER				
	78	EROSION ALONG DAM TOE				
	79	SEEPAGE				
	80	UNUSUAL MOVEMENT				
	81					
	82					
	83					

ADDITIONAL COMMENTS: REFER TO ITEM NO. IF APPLICABLE.

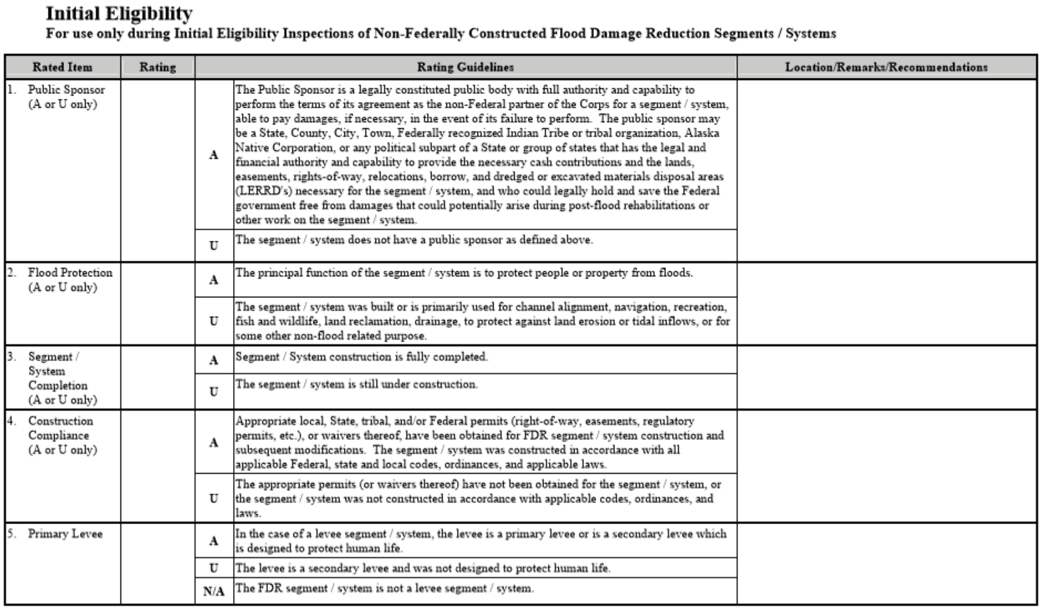
NAME OF DAM: ______________________________ INSPECTION DATE: ______________

AREA INSPECTED	CONCRETE/MASONRY DAMS 1 of 1			CHECK ( ) ACTION NEEDED		
	ITEM NO.	CONDITION	OBSERVATIONS	MONITOR	INVESTI-GATE	REPAIR
UPSTREAM FACE	84	SURFACE CONDITIONS				
	85	CONDITION OF JOINTS				
	86	UNUSUAL MOVEMENT				
	87	ABUTMENT DAM CONTACTS				
	88					
	89					
DOWNSTREAM FACE	90	SURFACE CONDITIONS				
	91	CONDITION OF JOINTS				
	92	UNUSUAL MOVEMENT				
	93	ABUTMENT DAM CONTACTS				
	94	DRAINS				
	95	LEAKAGE				
	96					
CREST	97	SURFACE CONDITIONS				
	98	HORIZONTAL ALIGNMENT				
	99	VERTICAL ALIGNMENT				
	100	CONDITION OF JOINTS				
	101	UNUSUAL MOVEMENTS				
	102					

ADDITIONAL COMMENTS: REFER TO ITEM NO. IF APPLICABLE.

Appendix G: Current USACE Levee Inspection Sheets

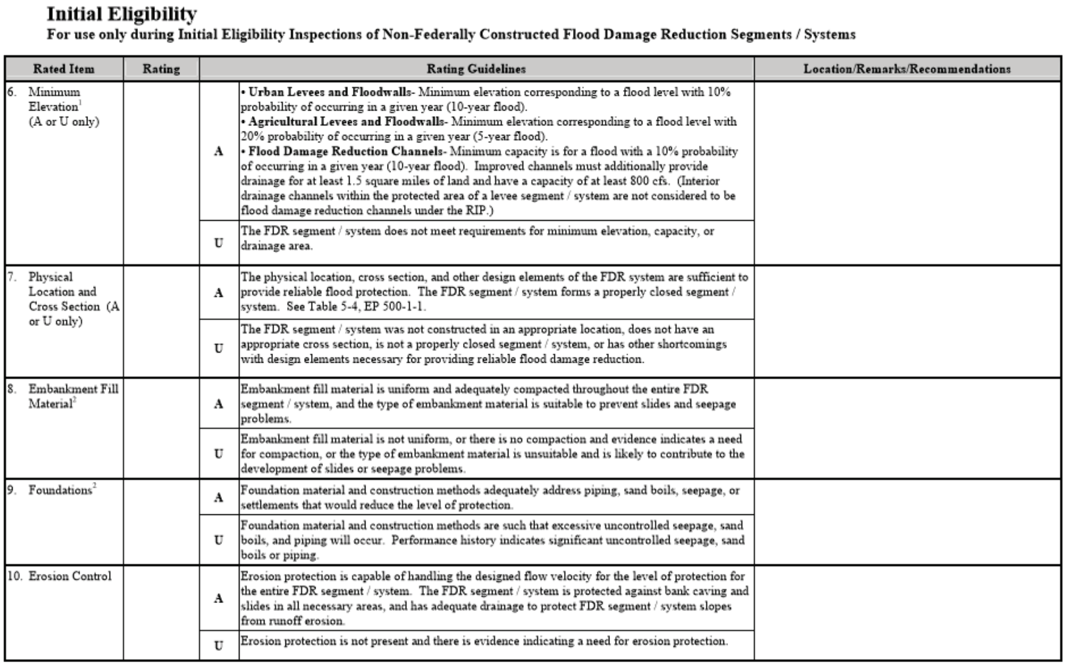
The levee condition rating scale was found in the flood damage reduction segment/system inspection report in the USACE Digital Library (U.S. Army Corps of Engineers 2008b).



Initial Eligibility

For use only during Initial Eligibility Inspections of Non-Federally Constructed Flood Damage Reduction Segments / Systems

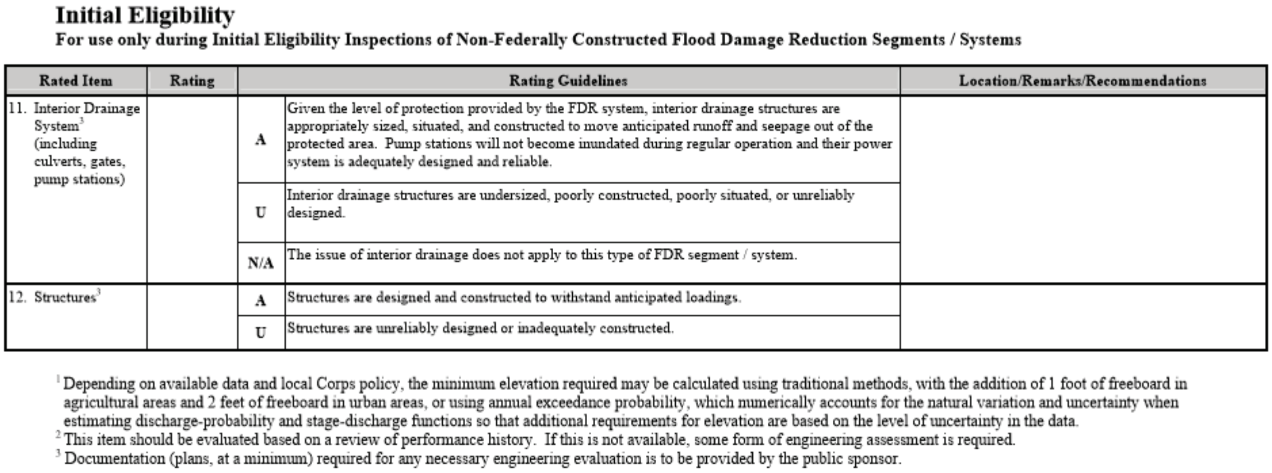
Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
1. Public Sponsor (A or U only)		**A**	The Public Sponsor is a legally constituted public body with full authority and capability to perform the terms of its agreement as the non-Federal partner of the Corps for a segment / system, able to pay damages, if necessary, in the event of its failure to perform. The public sponsor may be a State, County, City, Town, Federally recognized Indian Tribe or tribal organization, Alaska Native Corporation, or any political subpart of a State or group of states that has the legal and financial authority and capability to provide the necessary cash contributions and the lands, easements, rights-of-way, relocations, borrow, and dredged or excavated materials disposal areas (LERRD's) necessary for the segment / system, and who could legally hold and save the Federal government free from damages that could potentially arise during post-flood rehabilitations or other work on the segment / system.	
		U	The segment / system does not have a public sponsor as defined above.	
2. Flood Protection (A or U only)		**A**	The principal function of the segment / system is to protect people or property from floods.	
		U	The segment / system was built or is primarily used for channel alignment, navigation, recreation, fish and wildlife, land reclamation, drainage, to protect against land erosion or tidal inflows, or for some other non-flood related purpose.	
3. Segment / System Completion (A or U only)		**A**	Segment / System construction is fully completed.	
		U	The segment / system is still under construction.	
4. Construction Compliance (A or U only)		**A**	Appropriate local, State, tribal, and/or Federal permits (right-of-way, easements, regulatory permits, etc.), or waivers thereof, have been obtained for FDR segment / system construction and subsequent modifications. The segment / system was constructed in accordance with all applicable Federal, state and local codes, ordinances, and applicable laws.	
		U	The appropriate permits (or waivers thereof) have not been obtained for the segment / system, or the segment / system was not constructed in accordance with applicable codes, ordinances, and laws.	
5. Primary Levee		**A**	In the case of a levee segment / system, the levee is a primary levee or is a secondary levee which is designed to protect human life.	
		U	The levee is a secondary levee and was not designed to protect human life.	
		N/A	The FDR segment / system is not a levee segment / system.	



Initial Eligibility

For use only during Initial Eligibility Inspections of Non-Federally Constructed Flood Damage Reduction Segments / Systems

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
6. Minimum Elevation[1] (A or U only)		**A**	• **Urban Levees and Floodwalls**- Minimum elevation corresponding to a flood level with 10% probability of occurring in a given year (10-year flood). • **Agricultural Levees and Floodwalls**- Minimum elevation corresponding to a flood level with 20% probability of occurring in a given year (5-year flood). • **Flood Damage Reduction Channels**- Minimum capacity is for a flood with a 10% probability of occurring in a given year (10-year flood). Improved channels must additionally provide drainage for at least 1.5 square miles of land and have a capacity of at least 800 cfs. (Interior drainage channels within the protected area of a levee segment / system are not considered to be flood damage reduction channels under the RIP.)	
		U	The FDR segment / system does not meet requirements for minimum elevation, capacity, or drainage area.	
7. Physical Location and Cross Section (A or U only)		**A**	The physical location, cross section, and other design elements of the FDR system are sufficient to provide reliable flood protection. The FDR segment / system forms a properly closed segment / system. See Table 5-4, EP 500-1-1.	
		U	The FDR segment / system was not constructed in an appropriate location, does not have an appropriate cross section, is not a properly closed segment / system, or has other shortcomings with design elements necessary for providing reliable flood damage reduction.	
8. Embankment Fill Material[2]		**A**	Embankment fill material is uniform and adequately compacted throughout the entire FDR segment / system, and the type of embankment material is suitable to prevent slides and seepage problems.	
		U	Embankment fill material is not uniform, or there is no compaction and evidence indicates a need for compaction, or the type of embankment material is unsuitable and is likely to contribute to the development of slides or seepage problems.	
9. Foundations[2]		**A**	Foundation material and construction methods adequately address piping, sand boils, seepage, or settlements that would reduce the level of protection.	
		U	Foundation material and construction methods are such that excessive uncontrolled seepage, sand boils, and piping will occur. Performance history indicates significant uncontrolled seepage, sand boils or piping.	
10. Erosion Control		**A**	Erosion protection is capable of handling the designed flow velocity for the level of protection for the entire FDR segment / system. The FDR segment / system is protected against bank caving and slides in all necessary areas, and has adequate drainage to protect FDR segment / system slopes from runoff erosion.	
		U	Erosion protection is not present and there is evidence indicating a need for erosion protection.	



Initial Eligibility

For use only during Initial Eligibility Inspections of Non-Federally Constructed Flood Damage Reduction Segments / Systems

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
11. Interior Drainage System[3] (including culverts, gates, pump stations)		**A**	Given the level of protection provided by the FDR system, interior drainage structures are appropriately sized, situated, and constructed to move anticipated runoff and seepage out of the protected area. Pump stations will not become inundated during regular operation and their power system is adequately designed and reliable.	
		U	Interior drainage structures are undersized, poorly constructed, poorly situated, or unreliably designed.	
		N/A	The issue of interior drainage does not apply to this type of FDR segment / system.	
12. Structures[3]		**A**	Structures are designed and constructed to withstand anticipated loadings.	
		U	Structures are unreliably designed or inadequately constructed.	

[1] Depending on available data and local Corps policy, the minimum elevation required may be calculated using traditional methods, with the addition of 1 foot of freeboard in agricultural areas and 2 feet of freeboard in urban areas, or using annual exceedance probability, which numerically accounts for the natural variation and uncertainty when estimating discharge-probability and stage-discharge functions so that additional requirements for elevation are based on the level of uncertainty in the data.

[2] This item should be evaluated based on a review of performance history. If this is not available, some form of engineering assessment is required.

[3] Documentation (plans, at a minimum) required for any necessary engineering evaluation is to be provided by the public sponsor.

General Items for All Flood Damage Reduction Segments / Systems

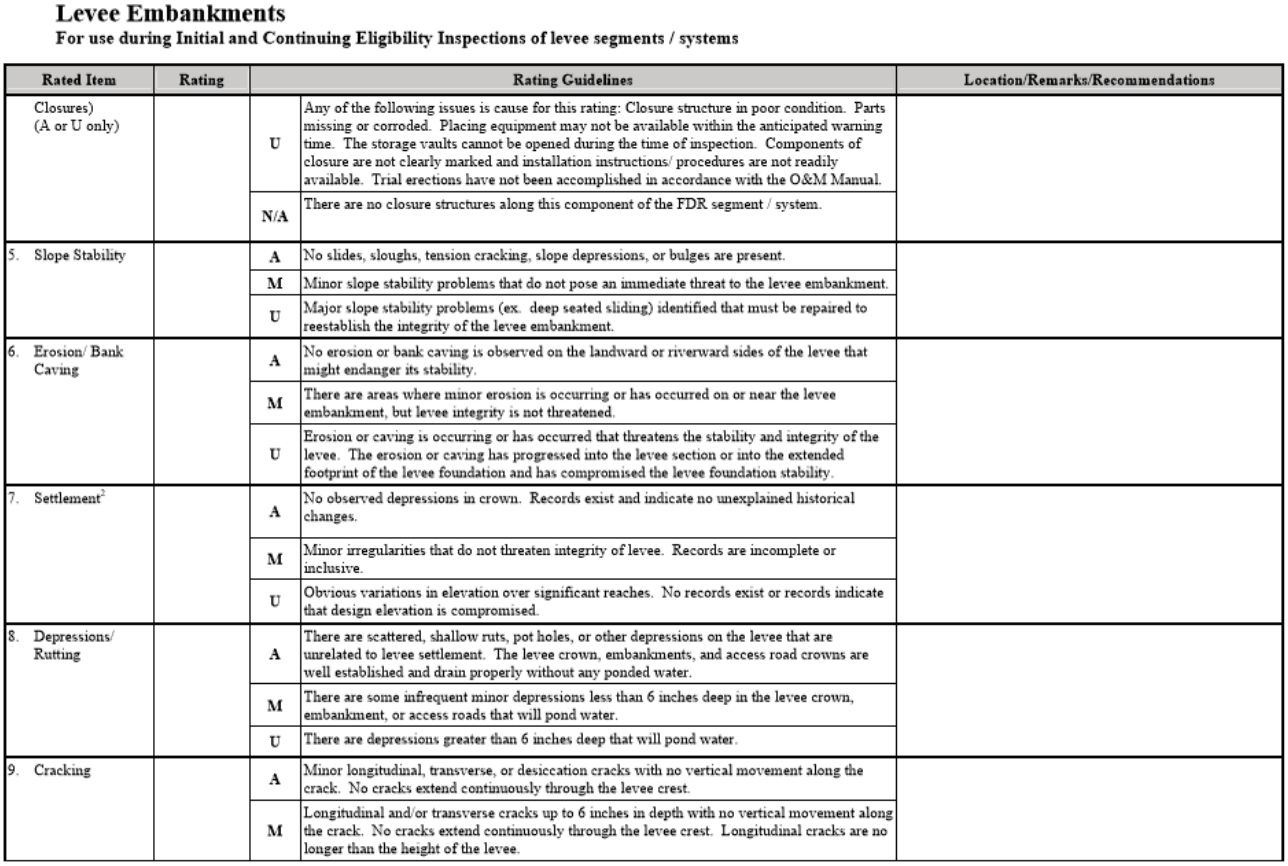
For use during all inspections of all Flood Damage Reduction Segments / Systems

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
1. Operations and Maintenance Manuals		A	Levee Owner's Manual, O&M Manuals, and/or manufacturer's operating instructions are present.	
		M	Sponsor manuals are lost or missing or out of date; however, sponsor will obtain manuals prior to next scheduled inspection.	
		U	Sponsor has not obtained lost or missing manuals identified during previous inspection.	
2. Emergency Supplies and Equipment (A or M only)		A	The sponsor maintains a stockpile of sandbags, shovels, and other flood fight supplies which will adequately supply all needs for the initial days of a flood fight. Sponsor determines required quantity of supplies after consulting with inspector.	
		M	The sponsor does not maintain an adequate supply of flood fighting materials as part of their preparedness activities.	
3. Flood Preparedness and Training (A or M only)		A	Sponsor has a written system-specific flood response plan and a solid understanding of how to operate, maintain, and staff the FDR system during a flood. Sponsor maintains a list of emergency contact information for appropriate personnel and other emergency response agencies.	
		M	The sponsor maintains a good working knowledge of flood response activities, but documentation of system-specific emergency procedures and emergency contact personnel is insufficient or out of date.	

Levee Embankments

For use during Initial and Continuing Eligibility Inspections of levee segments / systems

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
1. Unwanted Vegetation Growth[1]		A	The levee has little or no unwanted vegetation (trees, bush, or undesirable weeds), except for vegetation that is properly contained and/or situated on overbuilt sections, such that the mandatory 3-foot root-free zone is preserved around the levee profile. The levee has been recently mowed. The vegetation-free zone extends 15 feet from both the landside and riverside toes of the levee to the centerline of the tree. If the levee access easement doesn't extend to the described limits, then the vegetation-free zone must be maintained to the easement limits. Reference EM 1110-2-301 or Corps policy for regional vegetation variance.	
		M	Minimal vegetation growth (brush, weeds, or trees 2 inches in diameter or smaller) is present within the zones described above. This vegetation must be removed but does not currently threaten the operation or integrity of the levee.	
		U	Significant vegetation growth (brush, weeds, or any trees greater than 2 inches in diameter) is present within the zones described above and must to be removed to reestablish or ascertain levee integrity.	
2. Sod Cover		A	There is good coverage of sod over the levee.	
		M	Approximately 25% of the sod cover is missing or damaged over a significant portion or over significant portions of the levee embankment. This may be the result of over-grazing or feeding on the levee, unauthorized vehicular traffic, chemical or insect problems, or burning during inappropriate seasons.	
		U	Over 50% of the sod cover is missing or damaged over a significant portion or portions of the levee embankment.	
		N/A	Surface protection is provided by other means.	
3. Encroachments		A	No trash, debris, unauthorized farming activity, structures, excavations, or other obstructions present within the easement area. Encroachments have been previously reviewed by the Corps, and it was determined that they do not diminish proper functioning of the levee.	
		M	Trash, debris, unauthorized farming activity, structures, excavations, or other obstructions present, or inappropriate activities noted that should be corrected but will not inhibit operations and maintenance or emergency operations. Encroachments have not been reviewed by the Corps.	
		U	Unauthorized encroachments or inappropriate activities noted are likely to inhibit operations and maintenance, emergency operations, or negatively impact the integrity of the levee.	
4. Closure Structures (Stop Log, Earthen Closures, Gates, or Sandbag		A	Closure structure in good repair. Placing equipment, stoplogs, and other materials are readily available at all times. Components are clearly marked and installation instructions/ procedures readily available. Trial erections have been accomplished in accordance with the O&M Manual.	



Levee Embankments

For use during Initial and Continuing Eligibility Inspections of levee segments / systems

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
Closures) (A or U only)		U	Any of the following issues is cause for this rating: Closure structure in poor condition. Parts missing or corroded. Placing equipment may not be available within the anticipated warning time. The storage vaults cannot be opened during the time of inspection. Components of closure are not clearly marked and installation instructions/ procedures are not readily available. Trial erections have not been accomplished in accordance with the O&M Manual.	
		N/A	There are no closure structures along this component of the FDR segment / system.	
5. Slope Stability		A	No slides, sloughs, tension cracking, slope depressions, or bulges are present.	
		M	Minor slope stability problems that do not pose an immediate threat to the levee embankment.	
		U	Major slope stability problems (ex. deep seated sliding) identified that must be repaired to reestablish the integrity of the levee embankment.	
6. Erosion/ Bank Caving		A	No erosion or bank caving is observed on the landward or riverward sides of the levee that might endanger its stability.	
		M	There are areas where minor erosion is occurring or has occurred on or near the levee embankment, but levee integrity is not threatened.	
		U	Erosion or caving is occurring or has occurred that threatens the stability and integrity of the levee. The erosion or caving has progressed into the levee section or into the extended footprint of the levee foundation and has compromised the levee foundation stability.	
7. Settlement[2]		A	No observed depressions in crown. Records exist and indicate no unexplained historical changes.	
		M	Minor irregularities that do not threaten integrity of levee. Records are incomplete or inclusive.	
		U	Obvious variations in elevation over significant reaches. No records exist or records indicate that design elevation is compromised.	
8. Depressions/ Rutting		A	There are scattered, shallow ruts, pot holes, or other depressions on the levee that are unrelated to levee settlement. The levee crown, embankments, and access road crowns are well established and drain properly without any ponded water.	
		M	There are some infrequent minor depressions less than 6 inches deep in the levee crown, embankment, or access roads that will pond water.	
		U	There are depressions greater than 6 inches deep that will pond water.	
9. Cracking		A	Minor longitudinal, transverse, or desiccation cracks with no vertical movement along the crack. No cracks extend continuously through the levee crest.	
		M	Longitudinal and/or transverse cracks up to 6 inches in depth with no vertical movement along the crack. No cracks extend continuously through the levee crest. Longitudinal cracks are no longer than the height of the levee.	

Levee Embankments

For use during Initial and Continuing Eligibility Inspections of levee segments / systems

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
		U	Cracks exceed 6 inches in depth. Longitudinal cracks are longer than the height of the levee and/or exhibit vertical movement along the crack. Transverse cracks extend through the entire levee width.	
10. Animal Control		**A**	Continuous animal burrow control program in place that includes the elimination of active burrowing and the filling in of existing burrows.	
		M	The existing animal burrow control program needs to be improved. Several burrows are present which may lead to seepage or slope stability problems, and they require immediate attention.	
		U	Animal burrow control program is not effective or is nonexistent. Significant maintenance is required to fill existing burrows, and the levee will not provide reliable flood protection until this maintenance is complete.	
11. Culverts/ Discharge Pipes[3] (This item includes both concrete and corrugated metal pipes.)		**A**	There are no breaks, holes, cracks in the discharge pipes/ culverts that would result in significant water leakage. The pipe shape is still essentially circular. All joints appear to be closed and the soil tight. Corrugated metal pipes, if present, are in good condition with 100% of the original coating still in place (either asphalt or galvanizing) or have been relined with appropriate material, which is still in good condition. Condition of pipes has been verified using television camera video taping or visual inspection methods within the past five years, and the report for every pipe is available for review by the inspector.	
		M	There are a small number of corrosion pinholes or cracks that could leak water and need to be repaired, but the entire length of pipe is still structurally sound and is not in danger of collapsing. Pipe shape may be ovalized in some locations but does not appear to be approaching a curvature reversal. A limited number of joints may have opened and soil loss may be beginning. Any open joints should be repaired prior to the next inspection. Corrugated metal pipes, if present, may be showing corrosion and pinholes but there are no areas with total section loss. Condition of pipes has been verified using television camera video taping or visual inspection methods within the past five years, and the report for every pipe is available for review by the inspector.	
		U	Culvert has deterioration and/or has significant leakage; it is in danger of collapsing or as already begun to collapse. Corrugated metal pipes have suffered 100% section loss in the invert. HOWEVER: Even if pipes appear to be in good condition, as judged by an external visual inspection, an Unacceptable Rating will be assigned if the condition of pipes has not been verified using television camera video taping or visual inspection methods within the past five years, and reports for all pipes are not available for review by the inspector.	
		N/A	There are no discharge pipes/ culverts.	
12. Riprap Revetments &		**A**	No riprap displacement or stone degradation that could pose an immediate threat to the integrity of channel bank. Riprap intact with no woody vegetation present.	

Levee Embankments

For use during Initial and Continuing Eligibility Inspections of levee segments / systems

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
Bank Protection		**M**	Minor riprap displacement or stone degradation that could pose an immediate threat to the integrity of the channel bank. Unwanted vegetation must be cleared or sprayed with an appropriate herbicide.	
		U	Significant riprap displacement, exposure of bedding, or stone degradation observed. Scour activity is undercutting banks, eroding embankments, or impairing channel flows by causing turbulence or shoaling. Rock protection is hidden by dense brush, trees, or grasses.	
		N/A	There is no riprap protecting this feature of the segment / system, or riprap is discussed in another section.	
13. Revetments other than Riprap		**A**	Existing revetment protection is properly maintained, undamaged, and clearly visible.	
		M	Minor revetment displacement or deterioration that does not pose an immediate threat to the integrity of the levee. Unwanted vegetation must be cleared or sprayed with an appropriate herbicide.	
		U	Significant revetment displacement, deterioration, or exposure of bedding observed. Scour activity is undercutting banks, eroding embankments, or impairing channel flows by causing turbulence or shoaling. Revetment protection is hidden by dense brush and trees.	
		N/A	There are no such revetments protecting this feature of the segment / system.	
14. Underseepage Relief Wells/ Toe Drainage Systems		**A**	Toe drainage systems and pressure relief wells necessary for maintaining FDR segment / system stability during high water functioned properly during the last flood event and no sediment is observed in horizontal system (if applicable). Nothing is observed which would indicate that the drainage systems won't function properly during the next flood, and maintenance records indicate regular cleaning. Wells have been pumped tested within the past 5 years and documentation is provided.	
		M	Toe drainage systems or pressure relief wells are damaged and may become clogged if they are not repaired. Maintenance records are incomplete or indicate irregular cleaning and pump testing.	
		U	Toe drainage systems or pressure relief wells necessary for maintaining FDR segment / system stability during flood events have fallen into disrepair or have become clogged. No maintenance records. No documentation of the required pump testing.	
		N/A	There are no relief wells/ toe drainage systems along this component of the FDR segment / system.	
15. Seepage		**A**	No evidence or history of unrepaired seepage, saturated areas, or boils.	
		M	Evidence or history of minor unrepaired seepage or small saturated areas at or beyond the landside toe but not on the landward slope of levee. No evidence of soil transport.	
		U	Evidence or history of active seepage, extensive saturated areas, or boils.	

Floodwalls

For use during Initial and Continuing Eligibility Inspections of all floodwalls

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
1. Unwanted Vegetation Growth[1]		**A**	A grass-only or paved zone is maintained on both sides of the floodwall, free of all trees, brush, and undesirable weeds. The vegetation-free zone extends 15 feet from both the land and riverside of the floodwall, at ground-level, to the centerline of the tree. Additionally, an 8-foot root-free zone is maintained around the entire structure, including the floodwall toe, heel, and any toe-drains. If the floodwall access easement doesn't extend to the described limits, then the vegetation-free zone must be maintained to the easement limits. Reference EM 1110-2-301 and/or Corps policy for regional vegetation variance.	
		M	Minimal vegetation growth (brush, weeds, or trees 2 inches in diameter or smaller) is present within the zones described above. This vegetation must be removed but does not currently threaten the operation or integrity of the floodwall.	
		U	Significant vegetation growth (brush, weeds, or any trees greater than 2 inches in diameter) is present within the zones described above. This vegetation threatens the operation or integrity of the floodwall and must be removed.	
2. Encroachments		**A**	No trash, debris, unauthorized structures, excavations, or other obstructions present within the easement area. Encroachments have been previously reviewed by the Corps, and it was determined that they do not diminish proper functioning of the floodwall.	
		M	Trash, debris, unauthorized structures, excavations, or other obstructions present, or inappropriate activities noted that should be corrected but will not inhibit operations and maintenance or emergency operations. Encroachments have not been reviewed by the Corps.	
		U	Unauthorized encroachments or inappropriate activities noted are likely to inhibit operations and maintenance, emergency operations, or negatively impact the integrity of the floodwall.	
3. Closure Structures (Stop Log Closures and Gates) (A or U only)		**A**	Closure structure in good repair. Placing equipment, stoplogs, and other materials are readily available at all times. Components are clearly marked and installation instructions/ procedures readily available. Trial erections have been accomplished in accordance with the O&M Manual.	
		U	Any of the following issues is cause for this rating: Closure structure in poor condition. Parts missing or corroded. Placing equipment may not be available within the anticipated warning time. The storage vaults cannot be opened during the time of inspection. Components of closure are not clearly marked and installation instructions/ procedures are not readily available. Trial erections have not been accomplished in accordance with the O&M Manual.	
		N/A	There are no closure structures along this component of the FDR segment / system.	
4. Concrete Surfaces		**A**	Negligible spalling, scaling or cracking. If the concrete surface is weathered or holds moisture, it is still satisfactory but should be seal coated to prevent freeze/ thaw damage.	
		M	Spalling, scaling, and open cracking present, but the immediate integrity or performance of the structure is not threatened. Reinforcing steel may be exposed. Repairs/ sealing is necessary to prevent additional damage during periods of thawing and freezing.	

Floodwalls

For use during Initial and Continuing Eligibility Inspections of all floodwalls

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
		U	Surface deterioration or deep cracks present that may result in an unreliable structure. Any surface deterioration that exposes the sheet piling or lies adjacent to monolith joints may indicate underlying reinforcement corrosion and is unacceptable.	
5. Tilting, Sliding or Settlement of Concrete Structures[2]		**A**	There are no significant areas of tilting, sliding, or settlement that would endanger the integrity of the structure.	
		M	There are areas of tilting, sliding, or settlement (either active or inactive) that need to be repaired. The maximum offset, either laterally or vertically, does not exceed 2 inches unless the movement can be shown to be no longer actively occurring. The integrity of the structure is not in danger.	
		U	There are areas of tilting, sliding, or settlement (either active or inactive) that threaten the structure's integrity and performance. Any movement that has resulted in failure of the waterstop (possibly identified by daylight visible through the joint) is unacceptable. Differential movement of greater than 2 inches between any two adjacent monoliths, either laterally or vertically, is unacceptable unless it can be shown that the movement is no longer active. Also, if the floodwall is of I-wall construction, then any visible or measurable tilting of the wall toward the protected side that has created an open horizontal crack on the riverside base of a monolith is unacceptable.	
6. Foundation of Concrete Structures[1]		**A**	No active erosion, scouring, or bank caving that might endanger the structure's stability.	
		M	There are areas where the ground is eroding towards the base of the structure. Efforts need to be taken to slow and repair this erosion, but it is not judged to be close enough to the structure or to be progressing rapidly enough to affect structural stability before the next inspection. For the purposes of inspection, the erosion or scour is not closer to the riverside face of the wall than twice the floodwall's underground base width if the wall is of L-wall or T-wall construction; or if the wall is of sheetpile or I-wall construction, the erosion is not closer than twice the wall's visible height. Additionally, rate of erosion is such that the wall is expected to remain stabile until the next inspection.	
		U	Erosion or bank caving observed that is closer to the wall than the limits described above, or is outside these limits but may lead to structural instabilities before the next inspection. Additionally, if the floodwall is of I-wall or sheetpile construction, the foundation is unacceptable if any turf, soil or pavement material got washed away from the landside of the I-wall as the result of a previous overtopping event.	
7. Monolith Joints		**A**	The joint material is in good condition. The exterior joint sealant is intact and cracking/ desiccation is minimal. Joint filler material and/or waterstop is not visible at any point.	
		M	The joint material has appreciable deterioration to the point where joint filler material and/or waterstop is visible in some locations. This needs to be repaired or replaced to prevent spalling and cracking during freeze/ thaw cycles, and to ensure water tightness of the joint.	

Floodwalls

For use during Initial and Continuing Eligibility Inspections of all floodwalls

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
		U	The joint material is severely deteriorated or the concrete adjacent to the monolith joints has spalled and cracked, damaging the waterstop; in either case damage has occurred to the point where it is apparent that the joint is no longer watertight and will not provide the intended level of protection during a flood.	
		N/A	There are no monolith joints in the floodwall.	
8. Underseepage Relief Wells/ Toe Drainage Systems		**A**	Toe drainage systems and pressure relief wells necessary for maintaining FDR segment / system stability during high water functioned properly during the last flood event and no sediment is observed in horizontal system (if applicable). Nothing is observed which would indicate that the drainage systems won't function properly during the next flood, and maintenance records indicate regular cleaning. Wells have been pumped tested within the past 5 years and documentation is provided.	
		M	Toe drainage systems or pressure relief wells are damaged and may become clogged if they are not repaired. Maintenance records are incomplete or indicate irregular cleaning and pump testing.	
		U	Toe drainage systems or pressure relief wells necessary for maintaining FDR segment / system stability during flood events have fallen into disrepair or have become clogged. No maintenance records. No documentation of the required pump testing.	
		N/A	There are no relief wells/ toe drainage systems along this component of the FDR segment / system.	
9. Seepage		**A**	No evidence or history of unrepaired seepage, saturated areas, or boils.	
		M	Evidence or history of minor unrepaired seepage or small saturated areas at or beyond the landside toe but not on the landward slope of levee. No evidence of soil transport.	
		U	Evidence or history of active seepage, extensive saturated areas, or boils.	

[1] Inspectors must have as-built drawings available during the inspection so that the lateral distance to the heel and toe of the floodwalls can be determined in the field.

[2] The sponsor should be monitoring any observed movement to verify whether the movement is active or inactive.

Interior Drainage System

For use during Initial and Continuing Eligibility Inspections of interior drainage systems

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
1. Vegetation and Obstructions		A	No obstructions, vegetation, debris, or sediment accumulation noted within interior drainage channels or blocking the culverts, inlets, or discharge areas. Concrete joints and weep holes are free of grass and weeds.	
		M	Obstructions, vegetation, debris, or sediment are minor and have not impaired channel flow capacity or blocked more than 10% of any culvert openings, but should be removed. A limited volume of grass and weeds may be present in concrete channel joints and weep holes.	
		U	Obstructions, vegetation, debris, or sediment have impaired the channel flow capacity or blocked more than 10% of a culvert opening. Sediment and debris removal required to re-establish flow capacity.	
2. Encroachments		A	No trash, debris, unauthorized structures, excavations, or other obstructions present within the easement area. Encroachments have been previously reviewed by the Corps, and it was determined that they do not diminish proper functioning of the interior drainage system.	
		M	Trash, debris, unauthorized structures, excavations, or other obstructions present, or inappropriate activities noted that should be corrected but will not inhibit operations and maintenance or emergency operations. Encroachments have not been reviewed by the Corps.	
		U	Unauthorized encroachments or inappropriate activities noted are likely to inhibit operations and maintenance, emergency operations, or negatively impact the integrity of this component of the interior drainage system.	
3. Ponding Areas		A	No trash, debris, structures, or other obstructions present within the ponding areas. Sediment deposits do not exceed 10% of capacity.	
		M	Trash, debris, excavations, structures, or other obstructions present, or inappropriate activities that will not inhibit operations and maintenance. Sediment deposits do not exceed 30% of capacity.	
		U	Trash, debris, excavations, structures, or other obstructions, or other encroachments or activities noted that will inhibit operations, maintenance, or emergency work. Sediment deposits exceeds 30% of capacity.	
		N/A	There are no ponding areas associated with the interior drainage system.	
4. Fencing and Gates[1]		A	Fencing is in good condition and provides protection against falling or unauthorized access. Gates open and close freely, locks are in place, and there is little corrosion on metal parts.	
		M	Fencing or gates are damaged or corroded but appear to be maintainable. Locks may be missing or damaged.	
		U	Fencing and gates are damaged or corroded to the point that replacement is required, or potentially dangerous features are not secured.	
		N/A	There are no features noted that require safety fencing.	
5. Concrete Surfaces (Such as gate		A	Negligible spalling, scaling or cracking. If the concrete surface is weathered or holds moisture, it is still satisfactory but should be seal coated to prevent freeze/ thaw damage.	

Interior Drainage System

For use during Initial and Continuing Eligibility Inspections of interior drainage systems

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
wells, outfalls, intakes, or culverts)		M	Spalling, scaling, and open cracking present, but the immediate integrity or performance of the structure is not threatened. Reinforcing steel may be exposed. Repairs/ sealing is necessary to prevent additional damage during periods of thawing and freezing.	
		U	Surface deterioration or deep cracks present that may result in an unreliable structure. Any surface deterioration that exposes the sheet piling or lies adjacent to monolith joints may indicate underlying reinforcement corrosion and is unacceptable.	
		N/A	There are no concrete items in the interior drainage system.	
6. Tilting, Sliding or Settlement of Concrete and Sheet Pile Structures[2] (Such as gate wells, outfalls, intakes, or culverts)		A	There are no significant areas of tilting, sliding, or settlement that would endanger the integrity of the structure.	
		M	There are areas of tilting, sliding, or settlement (either active or inactive) that need to be repaired. The maximum offset, either laterally or vertically, does not exceed 2 inches unless the movement can be shown to be no longer actively occurring. The integrity of the structure is not in danger.	
		U	There are areas of tilting, sliding, or settlement (either active or inactive) that threaten the structure's integrity and performance. Any movement that has resulted in failure of the waterstop (possibly identified by daylight visible through the joint) is unacceptable. Differential movement of greater than 2 inches between any two adjacent monoliths, either laterally or vertically, is unacceptable unless it can be shown that the movement is no longer active. Also, if the floodwall is of I-wall construction, then any visible or measurable tilting of the wall toward the protected side that has created an open horizontal crack on the riverside base of a monolith is unacceptable.	
		N/A	There are no concrete items in the interior drainage system.	
7. Foundation of Concrete Structures[3] (Such as culverts, inlet and discharge structures, or gatewells.)		A	No active erosion, scouring, or bank caving that might endanger the structure's stability.	
		M	There are areas where the ground is eroding towards the base of the structure. Efforts need to be taken to slow and repair this erosion, but it is not judged to be close enough to the structure or to be progressing rapidly enough to affect structural stability before the next inspection. The rate of erosion is such that the structure is expected to remain stabile until the next inspection.	
		U	Erosion or bank caving observed that may lead to structural instabilities before the next inspection.	
		N/A	There are no concrete items in the interior drainage system.	
8. Monolith Joints		A	The joint material is in good condition. The exterior joint sealant is intact and cracking/ desiccation is minimal. Joint filler material and/or waterstop is not visible at any point.	
		M	The joint material has appreciable deterioration to the point where joint filler material and/or waterstop is visible in some locations. This needs to be repaired or replaced to prevent spalling and cracking during freeze/ thaw cycles, and to ensure water tightness of the joint.	

Interior Drainage System

For use during Initial and Continuing Eligibility Inspections of interior drainage systems

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
		U	The joint material is severely deteriorated or the concrete adjacent to the monolith joints has spalled and cracked, damaging the waterstop; in either case damage has occurred to the point where it is apparent that the joint is no longer watertight and will not provide the intended level of protection during a flood.	
		N/A	There are no monolith joints in the interior drainage system.	
9. Culverts/ Discharge Pipes[4]		A	There are no breaks, holes, cracks in the discharge pipes/ culverts that would result in significant water leakage. The pipe shape is still essentially circular. All joints appear to be closed and the soil tight. Corrugated metal pipes, if present, are in good condition with 100% of the original coating still in place (either asphalt or galvanizing) or have been relined with appropriate material, which is still in good condition. Condition of pipes has been verified using television camera video taping or visual inspection methods within the past five years, and the report for every pipe is available for review by the inspector.	
		M	There are a small number of corrosion pinholes or cracks that could leak water and need to be repaired, but the entire length of pipe is still structurally sound and is not in danger of collapsing. Pipe shape may be ovalized in some locations but does not appear to be approaching a curvature reversal. A limited number of joints may have opened and soil loss may be beginning. Any open joints should be repaired prior to the next inspection. Corrugated metal pipes, if present, may be showing corrosion and pinholes but there are no areas with total section loss. Condition of pipes has been verified using television camera video taping or visual inspection methods within the past five years, and the report for every pipe is available for review by the inspector.	
		U	Culvert has deterioration and/or has significant leakage; it is in danger of collapsing or as already begun to collapse. Corrugated metal pipes have suffered 100% section loss in the invert. HOWEVER: Even if pipes appear to be in good condition, as judged by an external visual inspection, an Unacceptable Rating will be assigned if the condition of pipes has not been verified using television camera video taping or visual inspection methods within the past five years, and reports for all pipes are not available for review by the inspector.	
		N/A	There are no discharge pipes/ culverts.	
10. Sluice / Slide Gates[5]		A	Gates open and close freely to a tight seal or minor leakage. Gate operators are in good working condition and are properly maintained. Sill is free of sediment and other obstructions. Gates and lifters have been maintained and are free of corrosion. Documentation provided during the inspection.	
		M	Gates and/or operators have been damaged or have minor corrosion, and open and close with resistance or binding. Leakage quantity is controllable, but maintenance is required. Sill is free of sediment and other obstructions.	
		U	Gates do not open or close and/or operators do not function. Gate, stem, lifter and/or guides may be damaged or have major corrosion.	
		N/A	There are no sluice/ slide gates.	

Interior Drainage System

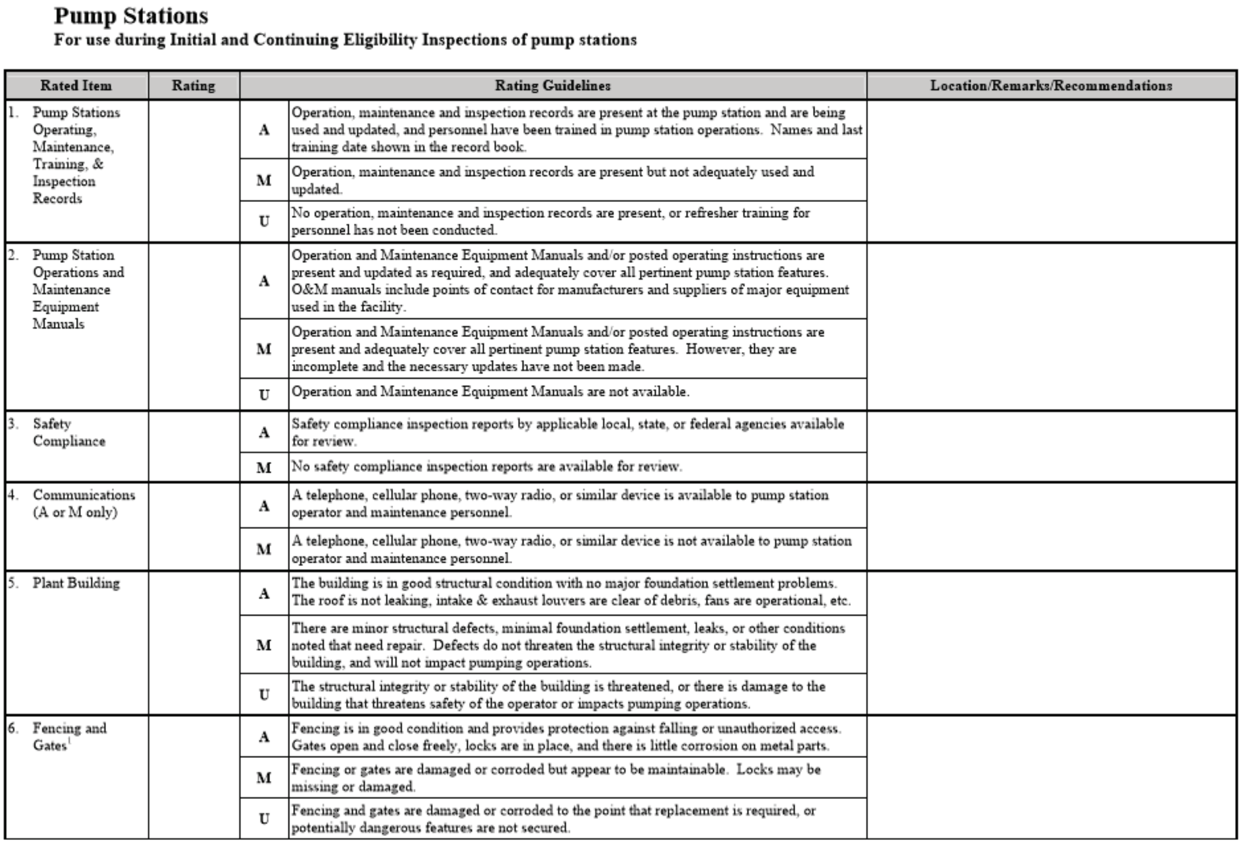
For use during Initial and Continuing Eligibility Inspections of interior drainage systems

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
11. Flap Gates/ Flap Valves/ Pinch Valves[1]		**A**	Gates/ valves open and close easily with minimal leakage, have no corrosion damage, and have been exercised and lubricated as required.	
		M	Gates/ valves will not fully open or close because of obstructions that can be easily removed, or have minor corrosion damage that requires maintenance.	
		U	Gates/ valves are missing, have been damaged, or have deteriorated to the point that they need to be replaced.	
		N/A	There are no flap gates.	
12. Trash Racks (non-mechanical)		**A**	Trash racks are fastened in place and properly maintained.	
		M	Trash racks are in place but are unfastened or have bent bars that allow debris to enter into the pipe or pump station, bars are corroded to the point that up to 10% of the sectional area may be lost. Repair or replacement is required.	
		U	Trash racks are missing or damaged to the extent that they are no longer functional and must be replaced. (For example, more than 10% of the sectional area may be lost.)	
		N/A	There are no trash racks, or they are covered in the pump stations section of the report.	
13. Other Metallic Items		**A**	All metal parts are protected from corrosion damage and show no rust, damage, or deterioration that would cause a safety concern.	
		M	Corrosion seen on metallic parts appears to be maintainable.	
		U	Metallic parts are severely corroded and require replacement to prevent failure, equipment damage, or safety issues.	
		N/A	There are no other significant metallic items.	
14. Riprap Revetments of Inlet/ Discharge Areas		**A**	No riprap displacement or stone degradation that could pose an immediate threat to the integrity of channel bank. Riprap intact with no woody vegetation present.	
		M	Minor riprap displacement or stone degradation that could pose an immediate threat to the integrity of the channel bank. Unwanted vegetation must be cleared or sprayed with an appropriate herbicide.	
		U	Significant riprap displacement, exposure of bedding, or stone degradation observed. Scour activity is undercutting banks, eroding embankments, or impairing channel flows by causing turbulence or shoaling. Rock protection is hidden by dense brush, trees, or grasses.	
		N/A	There is no riprap protecting this feature of the segment / system, or riprap is discussed in another section.	
15. Revetments other than Riprap		**A**	No riprap displacement or stone degradation that could pose an immediate threat to the integrity of channel bank. Riprap intact with no woody vegetation present.	

Interior Drainage System

For use during Initial and Continuing Eligibility Inspections of interior drainage systems

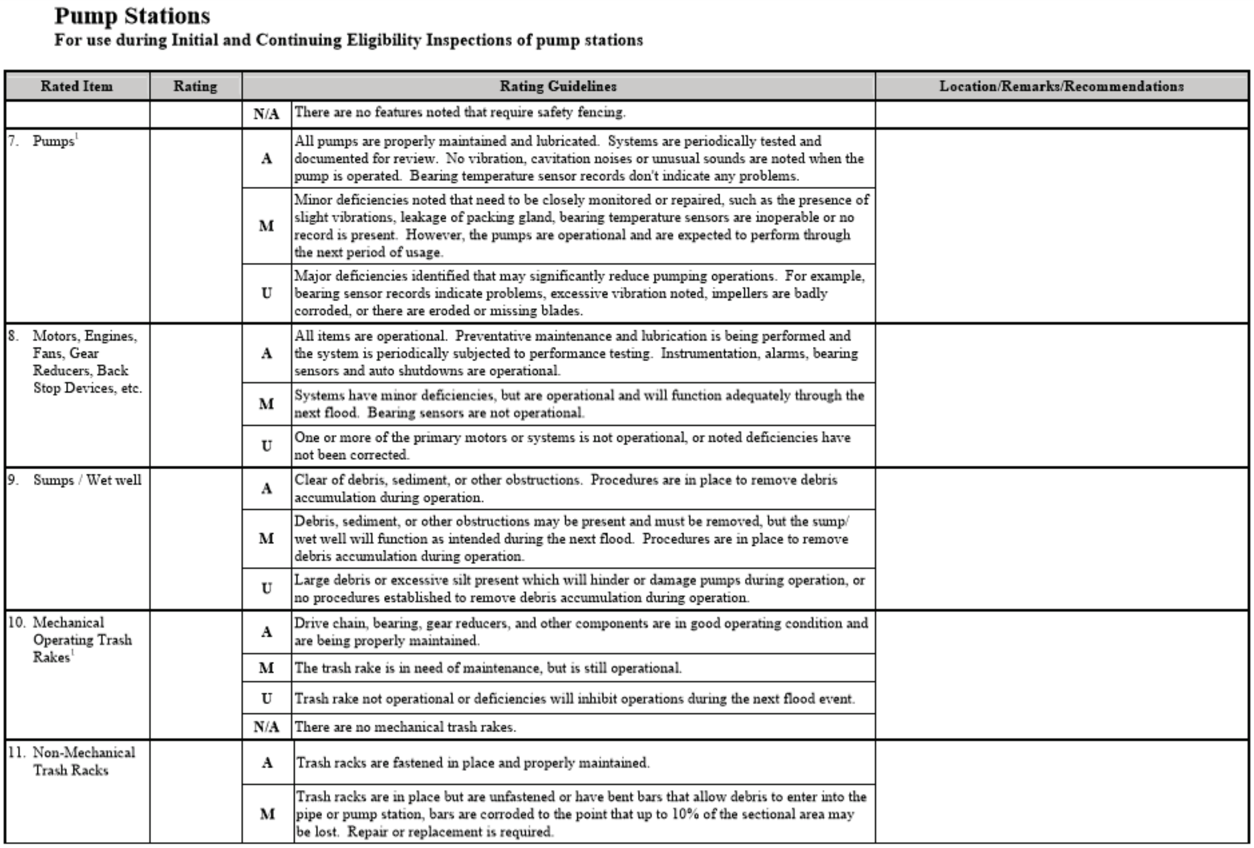
Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
		M	Minor riprap displacement or stone degradation that could pose an immediate threat to the integrity of the channel bank. Unwanted vegetation must be cleared or sprayed with an appropriate herbicide.	
		U	Significant riprap displacement, exposure of bedding, or stone degradation observed. Scour activity is undercutting banks, eroding embankments, or impairing channel flows by causing turbulence or shoaling. Rock protection is hidden by dense brush, trees, or grasses.	
		N/A	There are no such revetments protecting this feature of the segment / system.	



Pump Stations

For use during Initial and Continuing Eligibility Inspections of pump stations

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
1. Pump Stations Operating, Maintenance, Training, & Inspection Records		A	Operation, maintenance and inspection records are present at the pump station and are being used and updated, and personnel have been trained in pump station operations. Names and last training date shown in the record book.	
		M	Operation, maintenance and inspection records are present but not adequately used and updated.	
		U	No operation, maintenance and inspection records are present, or refresher training for personnel has not been conducted.	
2. Pump Station Operations and Maintenance Equipment Manuals		A	Operation and Maintenance Equipment Manuals and/or posted operating instructions are present and updated as required, and adequately cover all pertinent pump station features. O&M manuals include points of contact for manufacturers and suppliers of major equipment used in the facility.	
		M	Operation and Maintenance Equipment Manuals and/or posted operating instructions are present and adequately cover all pertinent pump station features. However, they are incomplete and the necessary updates have not been made.	
		U	Operation and Maintenance Equipment Manuals are not available.	
3. Safety Compliance		A	Safety compliance inspection reports by applicable local, state, or federal agencies available for review.	
		M	No safety compliance inspection reports are available for review.	
4. Communications (A or M only)		A	A telephone, cellular phone, two-way radio, or similar device is available to pump station operator and maintenance personnel.	
		M	A telephone, cellular phone, two-way radio, or similar device is not available to pump station operator and maintenance personnel.	
5. Plant Building		A	The building is in good structural condition with no major foundation settlement problems. The roof is not leaking, intake & exhaust louvers are clear of debris, fans are operational, etc.	
		M	There are minor structural defects, minimal foundation settlement, leaks, or other conditions noted that need repair. Defects do not threaten the structural integrity or stability of the building, and will not impact pumping operations.	
		U	The structural integrity or stability of the building is threatened, or there is damage to the building that threatens safety of the operator or impacts pumping operations.	
6. Fencing and Gates[1]		A	Fencing is in good condition and provides protection against falling or unauthorized access. Gates open and close freely, locks are in place, and there is little corrosion on metal parts.	
		M	Fencing or gates are damaged or corroded but appear to be maintainable. Locks may be missing or damaged.	
		U	Fencing and gates are damaged or corroded to the point that replacement is required, or potentially dangerous features are not secured.	



Pump Stations

For use during Initial and Continuing Eligibility Inspections of pump stations

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
		N/A	There are no features noted that require safety fencing.	
7. Pumps[1]		A	All pumps are properly maintained and lubricated. Systems are periodically tested and documented for review. No vibration, cavitation noises or unusual sounds are noted when the pump is operated. Bearing temperature sensor records don't indicate any problems.	
		M	Minor deficiencies noted that need to be closely monitored or repaired, such as the presence of slight vibrations, leakage of packing gland, bearing temperature sensors are inoperable or no record is present. However, the pumps are operational and are expected to perform through the next period of usage.	
		U	Major deficiencies identified that may significantly reduce pumping operations. For example, bearing sensor records indicate problems, excessive vibration noted, impellers are badly corroded, or there are eroded or missing blades.	
8. Motors, Engines, Fans, Gear Reducers, Back Stop Devices, etc.		A	All items are operational. Preventative maintenance and lubrication is being performed and the system is periodically subjected to performance testing. Instrumentation, alarms, bearing sensors and auto shutdowns are operational.	
		M	Systems have minor deficiencies, but are operational and will function adequately through the next flood. Bearing sensors are not operational.	
		U	One or more of the primary motors or systems is not operational, or noted deficiencies have not been corrected.	
9. Sumps / Wet well		A	Clear of debris, sediment, or other obstructions. Procedures are in place to remove debris accumulation during operation.	
		M	Debris, sediment, or other obstructions may be present and must be removed, but the sump/ wet well will function as intended during the next flood. Procedures are in place to remove debris accumulation during operation.	
		U	Large debris or excessive silt present which will hinder or damage pumps during operation, or no procedures established to remove debris accumulation during operation.	
10. Mechanical Operating Trash Rakes[1]		A	Drive chain, bearing, gear reducers, and other components are in good operating condition and are being properly maintained.	
		M	The trash rake is in need of maintenance, but is still operational.	
		U	Trash rake not operational or deficiencies will inhibit operations during the next flood event.	
		N/A	There are no mechanical trash rakes.	
11. Non-Mechanical Trash Racks		A	Trash racks are fastened in place and properly maintained.	
		M	Trash racks are in place but are unfastened or have bent bars that allow debris to enter into the pipe or pump station, bars are corroded to the point that up to 10% of the sectional area may be lost. Repair or replacement is required.	

Pump Stations

For use during Initial and Continuing Eligibility Inspections of pump stations

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
		U	Trash racks are missing or damaged to the extent that they are no longer functional and must be replaced. (For example, more than 10% of the sectional area may be lost.)	
		N/A	There are no trash racks, or they are covered in the pump stations section of the report.	
12. Fuel System for Pump Engines		**A**	Fuel system is operational, day tank present and operational, fuel fresh and rotated regularly.	
		M	Fuel system is operational and of adequate capacity, but day tank is missing or fuel is not fresh and rotated regularly.	
		U	Fuel system not functional.	
		N/A	No fuel system.	
13. Power Source		**A**	The normal power source and backup generators, if installed, are operational, properly exercised and well maintained. Surge protection, grounding, lightning protection, transformers, and automatic/manual transfer of main power to backup system is working.	
		M	Normal power source and backup units, if applicable, are operational with minor discrepancies or maintenance, inspection and exercising record is present but not up to date. Preventative maintenance or repairs are required.	
		U	Normal power source or generators are not operational and must be repaired; or generator, if required, is not on site.	
14. Electrical Systems[2]		**A**	Operational and maintained free of damage, corrosion, and debris. Preventative maintenance and system testing is being performed periodically.	
		M	Operational with minor discrepancies. Preventative maintenance or repairs are required, but the components are expected to function adequately during the next flood event.	
		U	Components of the electrical system will not function adequately during the next flood event and must be replaced.	
15. Megger Testing on Pump Motors and Critical Power Cables		**A**	Results of megger tests on pump motors or critical power cables show that the insulation meets manufacturer's or industry standards. Tested within the last year.	
		M	Megger testing not conducted within the past year. If megger tests on pump motors indicate that insulation resistance is below the manufacturer's or industry standard, but the resistance can be corrected with proper application of heat, this is minimally acceptable. (The application of heat does not relate to critical power cables.)	
		U	Megger tests not conducted within past two years, or tests indicate that insulation resistance is low enough that the equipment will not be able to meet design standards of operation; or evidence of arcing or shorting is detected visually.	

Pump Stations

For use during Initial and Continuing Eligibility Inspections of pump stations

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
16. Enclosures, Panels, Conduit and Ducts		**A**	All enclosures, panels, conduits, and ducts are protected from corrosion damage and show no rust, damage, or deterioration that would cause a safety concern.	
		M	Minor surface corrosion which appears to be maintainable. Cleaning and painting required.	
		U	Severely corroded and must be replaced to prevent failure, equipment damage, or safety issues.	
17. Intake and Discharge Pipelines		**A**	Intake and discharge pipelines have no corrosion and paint is intact, except for minor touch up required. Pipe couplings and anchors have no leakage or corrosion.	
		M	Intake and discharge pipelines have minor corrosion and repair and painting is required. Pipe coupling with anchors have minor leakage, corrosion and require bolts to be tightened.	
		U	Intake and discharge pipelines have major corrosion and replacement is required. Pipe coupling with anchors have major leakage and is heavily corroded and requires replacement.	
18. Sluice/ Slide Gates[3]		**A**	Gates open and close freely to a tight seal or minor leakage. Gate operators are in good working condition and are properly maintained. Sill is free of sediment and other obstructions. Gates and lifters have been maintained and are free of corrosion. Documentation provided during the inspection.	
		M	Gates and/or operators have been damaged or have minor corrosion, and open and close with resistance or binding. Leakage quantity is controllable, but maintenance is required. Sill is free of sediment and other obstructions.	
		U	Gates do not open or close and/or operators do not function. Gate, stem, lifter and/or guides may be damaged or have major corrosion.	
		N/A	There are no sluice/ slide gates.	
19. Flap Gates/ Flap Valves/ Pinch Valves[1]		**A**	Gates/ valves open and close easily with minimal leakage, have no corrosion damage, and have been exercised and lubricated as required.	
		M	Gates/ valves will not fully open or close because of obstructions that can be easily removed, or have minor corrosion damage that requires maintenance.	
		U	Gates/ valves are missing, have been damaged, or have deteriorated to the point that they need to be replaced.	
		N/A	There are no gates on discharge lines from pump station.	
20. Cranes[1]		**A**	Cranes operational and have been inspected and load tested in accordance with applicable standards within the last year. Documentation is on hand.	

Pump Stations

For use during Initial and Continuing Eligibility Inspections of pump stations

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
		M	Cranes have not been inspected or operationally tested within the past year, or there are visible signs of corrosion, oil leakage, etc, requiring maintenance.	
		U	Cranes are not operational, and this may prevent the pump station from functioning as required. No documentation available on cranes.	
		N/A	There are no cranes.	
21. Other Metallic Items (Equipment, Ladders, Platform Anchors, etc)		**A**	All metal parts are protected from corrosion damage and show no rust, damage, or deterioration that would cause a safety concern.	
		M	Corrosion seen on metallic parts appears to be maintainable.	
		U	Metallic parts are severely corroded and require replacement to prevent failure, equipment damage, or safety issues.	
		N/A	There are no other significant metallic items.	

Flood Damage Reduction Channels

For use during Initial and Continuing Eligibility Inspections of flood damage reduction channels

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
1. Vegetation and Obstructions		**A**	No obstructions, vegetation, debris, or sediment accumulation within the channel. Concrete channel joints and weep holes are free of grass and weeds.	
		M	Obstructions (including log jams), vegetation, debris, or sediment are minor and have not impaired channel flow capacity, but should be removed. Sediment shoals have not developed to the extent that they can support vegetation other than non-aquatic grasses. A limited volume of grass and weeds may be present in concrete channel joints and weep holes.	
		U	Obstructions (including log jams), vegetation, debris or sediment have impaired the channel flow capacity. Sediment shoals are well established and support woody and/or brushy vegetation. Sediment and debris removal required to re-establish flow capacity.	
2. Shoaling[1] (sediment deposition)		**A**	No shoaling or minor, non-vegetated shoaling is present.	
		M	More widespread vegetated and non-vegetated shoaling is present. Non-aquatic grasses are present on shoal. No trees or brush is present on shoal, and channel flow is not significantly reduced. Sediment and debris removal recommended.	
		U	Shoaling is well established, stabilized by saplings, brush, or other vegetation. Shoals are diverting flow to channel walls. Channel flow capacity is reduced and maintenance is required.	
3. Encroachments		**A**	No trash, debris, unauthorized structures, excavations, or other obstructions present within the easement area. Encroachments have been previously reviewed by the Corps, and it was determined that they do not diminish proper functioning of the channel.	
		M	Trash, debris, unauthorized structures, excavations, or other obstructions present, or inappropriate activities noted that should be corrected but will not inhibit operations and maintenance or emergency operations. Encroachments have not been reviewed by the Corps.	
		U	Unauthorized encroachments or inappropriate activities noted are likely to inhibit operations and maintenance, emergency operations, or negatively impact the integrity of the channel.	
4. Erosion		**A**	No head cutting or horizontal deviation observed.	
		M	Head cutting and horizontal deviation evident, but is less than 1 foot from the designed grade or cross section.	
		U	Head cutting and horizontal deviation of more than 1 foot from the designed grade or cross section. Corrective actions required to stop or slow erosion.	
5. Concrete Surfaces		**A**	Negligible spalling, scaling or cracking. If the concrete surface is weathered or holds moisture, it is still satisfactory but should be seal coated to prevent freeze/ thaw damage.	
		M	Spalling, scaling, and open cracking present, but the immediate integrity or performance of the structure is not threatened. Reinforcing steel may be exposed. Repairs/ sealing is necessary to prevent additional damage during periods of thawing and freezing.	

Flood Damage Reduction Channels

For use during Initial and Continuing Eligibility Inspections of flood damage reduction channels

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
		U	Surface deterioration or deep cracks present that may result in an unreliable structure. Any surface deterioration that exposes the sheet piling or lies adjacent to monolith joints may indicate underlying reinforcement corrosion and is unacceptable.	
		N/A	There are no concrete items in the channel.	
6. Tilting, Sliding or Settlement of Concrete Structures[2]		**A**	There are no significant areas of tilting, sliding, or settlement that would endanger the integrity of the structure.	
		M	There are areas of tilting, sliding, or settlement (either active or inactive) that need to be repaired. The maximum offset, either laterally or vertically, does not exceed 2 inches unless the movement can be shown to be no longer actively occurring. The integrity of the structure is not in danger.	
		U	There are areas of tilting, sliding, or settlement (either active or inactive) that threaten the structure's integrity and performance. Any movement that has resulted in failure of the waterstop (possibly identified by daylight visible through the joint) is unacceptable. Differential movement of greater than 2 inches between any two adjacent monoliths, either laterally or vertically, is unacceptable unless it can be shown that the movement is no longer active. Also, if the floodwall is of I-wall construction, then any visible or measurable tilting of the wall toward the protected side that has created an open horizontal crack on the riverside base of a monolith is unacceptable.	
		N/A	There are no concrete items in the channel.	
7. Foundation of Concrete Structures[3]		**A**	No active erosion, scouring, or bank caving that might endanger the structure's stability.	
		M	There are areas where the ground is eroding towards the base of the structure. Efforts need to be taken to slow and repair this erosion, but it is not judged to be close enough to the structure or to be progressing rapidly enough to affect structural stability before the next inspection. For the purposes of inspection, the erosion or scour is not closer to the riverside face of the wall than twice the floodwall's underground base width if the wall is of L-wall or T-wall construction; or if the wall is of sheetpile or I-wall construction, the erosion is not closer than twice the wall's visible height. Additionally, rate of erosion is such that the wall is expected to remain stabile until the next inspection.	
		U	Erosion or bank caving observed that is closer to the wall than the limits described above, or is outside these limits but may lead to structural instabilities before the next inspection. Additionally, if the floodwall is of I-wall or sheetpile construction, the foundation is unacceptable if any turf, soil or pavement material got washed away from the landside of the I-wall as the result of a previous overtopping event.	
		N/A	There are no concrete items in the channel.	
8. Slab and Monolith Joints		**A**	The joint material is in good condition. The exterior joint sealant is intact and cracking/ desiccation is minimal. Joint filler material and/or waterstop is not visible at any point.	

Flood Damage Reduction Channels

For use during Initial and Continuing Eligibility Inspections of flood damage reduction channels

Rated Item	Rating	Rating Guidelines		Location/Remarks/Recommendations
		M	The joint material has appreciable deterioration to the point where joint filler material and/or waterstop is visible in some locations. This needs to be repaired or replaced to prevent spalling and cracking during freeze/ thaw cycles, and to ensure water tightness of the joint.	
		U	The joint material is severely deteriorated or the concrete adjacent to the monolith joints has spalled and cracked, damaging the waterstop; in either case damage has occurred to the point where it is apparent that the joint is no longer watertight and will not provide the intended level of protection during a flood.	
		N/A	There are no concrete items in the channel.	
9. Flap Gates/ Flap Valves/ Pinch Valves[4]		**A**	Gates/ valves open and close easily with minimal leakage, have no corrosion damage, and have been exercised and lubricated as required.	
		M	Gates/ valves will not fully open or close because of obstructions that can be easily removed, or have minor corrosion damage that requires maintenance.	
		U	Gates/ valves are missing, have been damaged, or have deteriorated to the point that they need to be replaced.	
		N/A	There are no flap gates.	
10. Riprap Revetments & Banks		**A**	No riprap displacement or stone degradation that could pose an immediate threat to the integrity of channel bank. Riprap intact with no woody vegetation present.	
		M	Minor riprap displacement or stone degradation that could pose an immediate threat to the integrity of the channel bank. Unwanted vegetation must be cleared or sprayed with an appropriate herbicide.	
		U	Significant riprap displacement, exposure of bedding, or stone degradation observed. Scour activity is undercutting banks, eroding embankments, or impairing channel flows by causing turbulence or shoaling. Rock protection is hidden by dense brush, trees, or grasses.	
		N/A	There is no riprap protecting this feature of the segment / system, or riprap is discussed in another section.	
11. Revetments other than Riprap		**A**	Existing revetment protection is properly maintained, undamaged, and clearly visible.	
		M	Minor revetment displacement or deterioration that does not pose an immediate threat to the integrity of the levee. Unwanted vegetation must be cleared or sprayed with an appropriate herbicide.	
		U	Significant revetment displacement, deterioration, or exposure of bedding observed. Scour activity is undercutting banks, eroding embankments, or impairing channel flows by causing turbulence or shoaling. Revetment protection is hidden by dense brush and trees.	
		N/A	There are no such revetments protecting this feature of the segment / system.	

Appendix H: Photos of Distresses

Figure H-1. Animal burrow (Quinn et al. 2016).

Figure H-2. Debris in inlet structure (Quinn et al. 2016).

Figure H-3. Low spot on dam crest (Ellithy, Rivera-Hernandez, and Abraham 2015).

Figure H-4. Concrete cracking on crest (Ellithy, Rivera-Hernandez, and Abraham 2015).

Figure H-5. Heavy vegetation on the downstream slope (Landers et al. 2015).

Figure H-6. Gallery seepage (Landers et al. 2015).

Figure H-7. Eroded concrete floor on spillway outlet (Landers et al. 2015).

Appendix I: Proposed Inspection Rating Tables

Crest

Vegetation

Diameter (in.)		
0 to ≤6	>6 and ≤12	> 12
L	M	H

Animal Burrows

Depth (in.)		
0 to ≤6	>6 and ≤12	> 12
L	M	H

Erosion-Earth

Severity Level	Description
L	Small bare areas/areas of sparse vegetation; Minor ruts/puddles
M	Substantial bare areas; Channels <6 in. deep
H	Channels >6 in. deep; Major loss of material that could allow overtopping with slight rise in reservoir level

Unusual Movement-Earth

Severity level	Description
L	Undulating crest elevations; crest width <12 in.
M	Settling or shifted alignment/reduced crest width
H	Overtopping or evidence of

Unusual Movement-Concrete/Masonry

Width of Displacement (in.)	Length of Displacement (ft)	
	≤x	>x
≤x	L	L
>x	L	L
≤x	L	M
>x	L	M
≤x	L	M
>x	M	H

Depression

Severity Level	Depth (in.)
L	0 to ≤6
M	> 6 and ≤12
H	> 12

Voids/Sinkholes

Depth (ft)	Diameter (ft)	
	≤1	>1
0 to ≤y	L	M
>y and ≤z	M	M
> z	M	H

Transverse Cracking-Earth

	Depth (in.)	
Length (ft)	≤6	>6
0 to ≤y	L	M
>y and ≤z	L	M
> z	M	H

Depth (in.)	Width (in.)	Length (ft)	
		≤x	>x
≤z	≤y	L	M
	>y	L	M
>z	≤y	M	M
	>y	H	H

Relation to Reservoir Level	Length (ft)	Depth (in.)	
		≤x	>x
Above	≤x	L	L
	>x	L	L
At	≤x	L	M
	>x	M	M
Below	≤x	M	M
	>x	H	H

Longitudinal Cracking-Earth

Length (ft)	Depth (in.)	
	≤6	>6
0 to ≤y	L	M
>y and ≤z	L	M
> z	M	H

Depth (in.)	Width (in.)	Length (ft)	
		≤x	>x
≤z	≤y	L	M
	>y	L	M
>z	≤y	M	M
	>y	H	H

Do Cracks Curve?	Length (ft)	Depth (in.)	
		≤6	>6
No	≤x	L	L
	>x	M	M
Yes	≤x	M	H
	>x	H	H

Drying Cracking-Earth

Length (ft)	Depth (in.)	
	≤6	>x6
0 to ≤y	L	M
>y and ≤z	L	M
> z	M	H

Depth (in.)	Width (in.)	Length (ft)	
		≤x	>x
≤z	≤y	L	M
	>y	L	M
>z	≤y	M	M
	>y	H	H

Upstream Face

Vegetation

Diameter (in.)		
0 to ≤2	>2 and ≤4	> 4
L	M	H

Animal Burrows

Depth (in.)		
0 to ≤6	>6 and ≤12	> 12
L	M	H

Erosion-Earth

Severity Level	Description
L	Small bare areas/areas of sparse vegetation; minor erosion
M	Scour, scarping, or rutting (>6 in.); substantial bare areas
H	Significant erosion; on the verge of sliding/sloughing

Unusual Movement-Earth

Severity level	Description
L	Little to no unusual movement
M	Minor slope failures & settling
H	Significant slope failure

Unusual Movement-Concrete/Masonry

Width of Displacement (in.)	Length of Displacement (ft)	
≤x	L	L
>x	L	L
>x	L	M
≤x	L	M

Bulge

Severity Level	Height (in.)
L	0 to ≤y
M	>y and ≤z
H	> z

*H if in wet area (can lead to massive sliding) (New York State/Department of Environmental Conservation 1987).

Depression

Severity Level	Depth (in.)
L	0 to ≤6
M	> 6 and ≤12
H	> 12

Voids/Sinkholes

Depth (ft)	Diameter (ft)	
	≤1	>1
0 to ≤y	L	M
>y and ≤z	M	M
> z	M	H

Longitudinal Cracking-Earth

	Depth (in.)	
Length (ft)	≤6	>6
0 to ≤y	L	M
>y and ≤z	L	M
> z	M	H

Depth (in.)	Width (in.)	Length (ft)	
		≤x	>x
≤z	≤y	L	M
	>y	L	M
>z	≤y	M	M
	>y	H	H

Seepage-Earth

Severity Level	Description
L	Moist, green areas
M	Unfiltered seepage or filtered seepage
H	Carrying sediment or causing rapid erosion; boil formed

Seepage-Concrete/Masonry

Severity Level	Description
L	Seepage increases as reservoir level increases
M	Increase in existing seepage/new seepage
H	Seepage with cloudy discharge/ is damaging concrete/masonry

Downstream Face

Vegetation

Diameter (in.)		
0 to ≤3	>3 and ≤6	> 6
L	M	H

Animal Burrows

Depth (in.)		
0 to ≤6	>6 and ≤12	> 12
L	M	H

Erosion-Earth

Severity Level	Description
L	Small bare areas/areas of sparse vegetation; Minor erosion
M	Scour, scarping, or rutting (>6 in.); Substantial bare areas
H	Significant erosion; On the verge of sliding/sloughing

Unusual Movement-Earth

Severity level	Description
L	Little to no unusual movement
M	Minor slope failures and settling
H	Significant slope failure

Unusual Movement-Concrete/Masonry

Width of Displacement (in.)	Length of Displacement (ft)	
	≤x	>x
≤x	L	L
>x	L	L
≤x	L	M
>x	L	M
≤x	L	M
>x	M	H

Bulge

Severity Level	Height (in.)
L	0 to ≤y
M	>y and ≤z
H	> z

*H if in wet area (can lead to massive sliding) (New York State/Department of Environmental Conservation 1987).

Depression

Severity Level	Depth (in.)
L	0 to ≤6
M	> 6 and ≤12
H	> 12

Longitudinal Cracking-Earth

	Depth (in.)	
Length (ft)	≤6	>6
0 to ≤y	L	M
>y and ≤z	L	M
> z	M	H

Depth (in.)	Width (in.)	Length (ft)	
		≤x	>x
≤z	≤y	L	M
	>y	L	M
>z	≤y	M	M
	>y	H	H

Voids/Sinkholes

Depth (ft)	Diameter (ft)	
	≤1	>1
0 to ≤y	L	M
>y and ≤z	M	M
> z	M	H

Seepage-Earth

Severity Level	Description
L	Moist, green areas
M	Unfiltered seepage or filtered seepage
H	Carrying sediment or causing rapid erosion; Boil formed

Seepage-Concrete/Masonry

Severity Level	Description
L	Seepage increases as reservoir level increases
M	Increase in existing seepage/new seepage
H	Seepage with cloudy discharge/ is damaging concrete/masonry

Body

Seepage-Earth

Severity Level	Description
L	Moist, green areas
M	Unfiltered seepage at toe (<10 gpm) or filtered seepage
H	Carrying sediment or causing rapid erosion; Boil formed

Seepage-Concrete/Masonry

Severity Level	Description
L	Seepage increases as reservoir level increases
M	Increase in existing seepage/new seepage
H	Seepage with cloudy discharge/ is damaging concrete/masonry

Downstream Toe Area

Vegetation

Diameter (in.)		
0 to ≤2	>2 and ≤4	> 4
L	M	H

Animal Burrows

Depth (in.)		
0 to ≤6	>6 and ≤12	> 12
L	M	H

Erosion-Earth

Severity Level	Description
L	Minor channel bank erosion
M	Moderate channel bank erosion
H	Channel erosion eroding toe of dam

Debris

Severity Level	Description
L	Minor; Little effect on flow
M	Causing blockage downstream or wetness along toe
H	Causing backwater in channel; Saturates downstream

Seepage-Earth

Severity Level	Description
L	Moist, green areas
M	Unfiltered seepage at toe (<10 gpm) or filtered seepage
H	Carrying sediment or causing rapid erosion; Boil formed

Bulge

Severity Level	Height (in.)
L	0 to ≤y
M	>y and ≤z
H	> z

*H if in wet area (can lead to massive sliding) (New York State/Department of Environmental Conservation 1987).

Groin Area

Seepage-earth

Severity Level	Description
L	Moist, green areas
M	Unfiltered seepage at toe (<10 gpm) or filtered seepage
H	Carrying sediment or causing rapid erosion

Seepage-Concrete/Masonry

Severity Level	Description
L	Seepage increases as reservoir level increases
M	Increase in existing seepage/new seepage
H	Seepage with cloudy discharge/ is damaging concrete/masonry

Erosion-Earth

Severity Level	Description
L	Small bare areas/areas of sparse vegetation; Minor erosion
M	Scour or rutting (>6 in.); Substantial bare areas
H	Significant erosion; On the verge of sliding/sloughing

Abutments

Seepage-Earth

Severity Level	Description
L	Moist, green areas
M	Unfiltered seepage at toe (<10 gpm) or filtered seepage
H	Carrying sediment or causing rapid erosion

Seepage-Concrete/Masonry

Severity Level	Description
L	Seepage increases as reservoir level increases
M	Increase in existing seepage/new seepage
H	Seepage with cloudy discharge/ is damaging concrete/masonry

Erosion

Severity Level	Description
L	Small bare areas/areas of sparse vegetation; Minor erosion
M	Scour or rutting (>6 in.); Substantial bare areas
H	Significant erosion; On the verge of sliding/sloughing

Vegetation

Diameter (in.)		
0 to ≤6	>6 and ≤12	> 12
L	M	H

Animal Burrows

Depth (in.)		
0 to ≤6	>6 and ≤12	> 12
L	M	H

Reservoir Slopes

Severity level	Description
L	No slides, sloughs, tension cracking, slope depressions, or bulges present
M	Minor slope stability problems that do not pose an immediate threat to the levee/dam embankment
H	Major slope stability problems (ex. deep seated sliding) identified that must be repaired to reestablish the integrity of the levee/dam embankment

Foundations

Seepage

Severity Level	Description
M	Some seepage, but does not appear to have sediment
H	Carrying sediment or causing rapid erosion; Sand boils formed

Unusual Movement

Severity Level	Description
M	Some settlement but does not appear to affect the structural integrity of the dam/levee
H	Evidence of movement threatens structural stability

Cracks

Length (ft)	Depth (in.)	
	≤6	>6
0 to ≤y	L	M
>y and ≤z	L	M
> z	M	H

Depth (in.)	Width (in.)	Length (ft)	
		≤x	>x
≤z	≤y	L	M
	>y	L	M
>z	≤y	M	M
	>y	H	H

Erosion (Not of Foundation itself, but surrounding Foundation that may affect its stability)

Severity Level	Description
L	Structural stability is not compromised by erosion, scouring, or bank caving
M	The ground is eroding towards the base of the foundation, but not close enough to it where it would affect the structural stability prior to the next inspection; Erosion needs to be mitigated
H	Structural stability is compromised or will be by the next inspection due to excessive erosion or bank caving

-See Concrete/Masonry Surface

Toe Drain

Severity level	Description
L	Functioned properly during the last flood event; No sediment in horizontal system; Appears drainage systems will function properly during the next flood event; Maintenance records document regular cleanings
M	Signs of deterioration; May become clogged if they are not repaired; Inadequate maintenance records and irregular cleaning
H	Severe deterioration or has become clogged; No maintenance records exist/can be found

Foundation Drain-holes or drainage blanket

Severity level	Description
L	Draining holes functioning properly/are not clogged; Small amount of impermeable blanket missing
H	Drainage holes carrying foundation material or has become clogged, reducing flows; Substantial amount of impermeable blankets missing

Trash Racks

Severity Level	Description
L	Good condition; Little/no debris entering intake
M	Fair condition but may need some maintenance; Little debris entering intake; Debris build-up outside of trash rack hasn't been disposed of in a timely manner
H	Trash rack is missing/severely damaged; Not preventing debris from entering intake

Trash Boom

Severity Level	Description
L	Good condition; Little/no debris entering intake
M	Fair condition but may need some maintenance; Little debris entering intake; Debris build-up outside of trash boom hasn't been disposed of in a timely manner
H	Trash boom is missing/severely damaged; Not preventing debris from entering intake

Intake Structure

Debris

Severity level	Description
L	No debris, sediment, or other possible obstructions; Debris accumulation is removed during operation
M	Debris, sediment, or other obstructions observed and needs to be removed, but does not affect functionality; Debris accumulation is removed during operation
H	Large debris is clogging the intake structure, which affects functionality; Debris accumulation is not removed during operation

Corrosion (Pipes)

Severity level	Description
L	No corrosion and paint is in good condition, but may need a minor touch up; Pipe couplings and anchors have no leakage or corrosion
M	Some corrosion; Needs repair and painting; Pipe coupling with anchors have insignificant leakage, corrosion, or bolts need to be tightened
H	Major corrosion; Needs to be replaced; Pipe coupling with anchors have significant leakage or corrosion and needs to be replaced

-See Concrete/Masonry Surface

Conduit

Corrosion

Severity level	Description
L	Corrosion damage protection present; No rust or deterioration that would affect safety is observed
M	Minor surface corrosion present; Needs cleaning and painting
H	Severe corrosion observed that affects functionality; Replacement is mandatory to prevent failure, safety hazards, or further equipment damage

Holes/Cracks

Severity level	Description
L	No apparent breaks, holes, cracks that would cause significant water leakage or threaten structural integrity; Conduit shape is conserved; Joints are closed and soil tight; Cameras or visual inspection methods have been used within the past 5 years to confirm condition, and the report for every conduit is readily available
M	Small amount of pinholes or cracks have the potential to leak water; Repair is necessary but structural integrity is not yet threatened; Conduit shape may be slightly altered in some locations; Some joints are not closed and soil loss is commencing, which warrants repair; Cameras or visual inspection methods have been used within the past 5 years to confirm condition, and the report for every conduit is readily available
H	Significant deterioration/leakage, where leakage is eroding the dam toe; Structural integrity is threatened; Cameras or visual inspection methods have not been used within the past five years to confirm condition, or the report for every conduit is not readily available

Valves

Severity level	Description
L	Opens and closes easily with minimal leakage; No corrosion damage; Lubricated properly
M	Does not fully open or close because of obstructions that can be easily removed; Minor corrosion damage that requires maintenance
H	Valves are missing, have been damaged, or have deteriorated to the point that they need to be replaced

Closure

Severity level	Description
L	No signs of damage; Placing equipment, stoplogs, installation instructions and procedures, etc. are always available; Components markings are evident;
H	Signs of damage (i.e., missing parts or corrosion); Placing equipment may not be available within the anticipated warning time or installation instructions and procedures are not immediately available; Unable to open storage vaults during inspection; Components markings are not evident;

Control Mechanism

Severity level	Description
L	Operable; Control stem, stem guides, support block, etc. in fair condition (i.e., no corrosion)
M	Operable but needs repair; Some corrosion
H	Inoperable; Parts need to be repaired or replaced

Outlet Pipe

Corrosion

Severity level	Description
L	Corrosion damage protection present; No rust or deterioration that would affect safety is observed
M	Minor surface corrosion present; Needs cleaning and painting
H	Severe corrosion observed that affects functionality; Replacement is mandatory to prevent failure, safety hazards, or further equipment damage

Holes/Cracks

Severity level	Description
L	No apparent breaks, holes, cracks that would cause significant water leakage or threaten structural integrity; Pipe shape is conserved (circular); Joints are closed and soil tight; Cameras or visual inspection methods have been used within the past five years to confirm condition, and the report for every conduit is readily available
M	Small amount of pinholes or cracks have the potential to leak water; Repair is necessary but structural integrity is not yet threatened; Pipe shape may be slightly ovalized in some locations but does not appear to be approaching a curvature reversal; Some joints are not closed and soil loss is commencing, which warrants repair; Cameras or visual inspection methods have been used within the past 5 years to confirm condition, and the report for every conduit is readily available
H	Significant deterioration/leakage, where leakage is eroding the dam toe; Structural integrity is threatened; Cameras or visual inspection methods have not been used within the past 5 years to confirm condition, or the report for every conduit is not readily available

Outlet Tower

-See Concrete/Masonry Surface

Spillway Approach Area

Debris

Severity Level	Description
L	Minor; Little effect on flow
M	Flow is restricted
H	Beaver dam or blockage

Inadequate Spillway Capacity

Severity Level	Spillway Capacity
L	Adequate
M	Doesn't pass design storm
H	Substantially inadequate

Severity Level	Spillway Capacity
L	Adequate
H	Doesn't pass design storm; Substantially inadequate

-See Concrete/Masonry Surface

Spillway Channel Floor

Inadequate Spillway Capacity

Severity Level	Spillway Capacity
L	Adequate
M	Doesn't pass design storm
H	Substantially inadequate

Severity Level	Spillway Capacity
L	Adequate
H	Doesn't pass design storm; Substantially inadequate

-See Concrete/Masonry Surface

Spillway Sidewalls

Inadequate Spillway Capacity

Severity Level	Spillway Capacity
L	Adequate
M	Doesn't pass design storm
H	Substantially inadequate

Severity Level	Spillway Capacity
L	Adequate
H	Doesn't pass design storm; Substantially inadequate

Erosion

Severity Level	Description
L	Little to no evidence of erosion alongside channel; Small bare areas
M	Moderate erosion alongside channel; No earth-slide into channel
H	Excessive erosion; Earth-slide causing concentrated flows and high flow velocities in channel

Vegetation (along side slopes)

Diameter (in.)		
0 to ≤6	>6 and ≤12	> 12
L	M	H

-See Concrete/Masonry Surface

Spillway Discharge Areas

Vegetation

Diameter (in.)		
0 to ≤6	>6 and ≤12	> 12
L	M	H

Animal Burrows

Depth (in.)		
0 to ≤6	>6 and ≤12	> 12
L	M	H

Erosion

Severity Level	Description
L	Little to no evidence of erosion
M	Scour at toe, not undermining
H	Concrete is undermined; Unraveling embankment

Inadequate Spillway Capacity

Severity Level	Spillway Capacity
L	Adequate
M	Doesn't pass design storm
H	Substantially inadequate

Severity Level	Spillway Capacity
L	Adequate
H	Doesn't pass design storm; Substantially inadequate

Debris

Severity Level	Description
L	Minor; Little effect on flow
M	Flow is restricted
H	Beaver dam or blockage

-See Concrete/Masonry Surface

Stilling Basin

-See Concrete/Masonry Surface

Piezometer

Severity level	Description
L	Working properly but data has not been collected or analyzed; Pipe/box has no signs of damage
M	Inadequate; Not sufficient to gather the required data; Pipe/box may have some damage such as cracks that does not threaten structural integrity
H	Needs to be replaced, or not installed, broken, or it is inaccessible

Observation Well

Severity level	Description
L	Working properly but data has not been collected or analyzed; Pipe/box has no signs of damage
M	Inadequate; Not sufficient to gather the required data; Pipe/box may have some damage such as cracks that does not threaten structural integrity
H	Needs to be replaced, or not installed, broken, or it is inaccessible

Staff Gauge

Severity level	Description
L	In good condition and clearly visible; Measurements usually taken and analyzed at appropriate frequency
M	Beginning to show signs of deterioration; Some numbers/tick marks starting to ware down; No debris/vegetation inhibiting visibility; Measurements are taken and analyzed at appropriate frequency
H	Broken; Numbers/tick marks no longer visible; Debris/vegetation inhibiting visibility; Measurements and analysis has been neglected

Weir

Severity level	Description
L	Working properly; Structure showing no signs of wear; Data has not been collected or analyzed
M	Structure showing signs of wear (erosion, cracks, etc.), but does not affect structural integrity; Not sufficient to gather the required data
H	Not working properly; Structural integrity is threatened; Needs to be replaced, broken, or it is inaccessible

Survey Monument

Severity level	Description
L	Survey monument undisturbed; Surface relatively easy to locate
M	Surface difficult to locate (covered with debris, vegetation, etc.); Contains cracks
H	Broken due to dam movement

Inclinometer

Severity level	Description
L	Working properly but data has not been analyzed
M	Inadequate; Not sufficient to gather the required data
H	Not working properly and needs to be replaced; Broken

Access Roads

Severity level	Description
L	Drains properly without any ponded water; Roads are accessible
M	There are some infrequent minor depressions less than 6 in. deep that will pond water; Roads are accessible
H	There are depressions greater than 6 in. deep that will pond water; Roads are inaccessible/overgrown with vegetation

Safety and Security Devices

Severity level	Description
L	Security gates and fences, buoys, warning signs in reservoir show no signs of damage and are clearly visible; Emergency action plan (EAP) readily available; Sirens are operable
M	Security gates and fences, buoys and warning signs in reservoir need repair; EAP readily available; sirens are operable
H	Security gates and fences, buoys and warning signs in reservoir need replacement; EAP not readily available/doesn't exist; sirens are inoperable

Relief Wells

Severity level	Description
L	Operated properly during the last flood event; No sediment in horizontal system; Appears the drainage systems will function properly during the next flood event; Maintenance records document regular cleaning; It has been recorded that the wells have been pumped tested within the past 5 years
M	Signs of deterioration; May become clogged if they are not repaired; Inadequate maintenance records and irregular cleaning and pump testing
H	Severe deterioration or has become clogged; No maintenance records exist/can be found including pump testing

Concrete Surface

Severity level	Description
L	Spalling and minor surface cracking
M	Significant longitudinal cracking, transverse cracking
H	Major cracks, misalignment, discontinuities causing leaks, seepage or stability concerns

Transverse Cracking

	Depth (in.)	
Length (ft)	≤6	>6
0 to ≤y	L	M
>y and ≤z	L	M
> z	M	H

Depth (in.)	Width (in.)	Length (ft)	
		≤x	>x
≤z	≤y	L	M
	>y	L	M
>z	≤y	M	M
	>y	H	H

Location	**Length (ft)**	**Depth (in.)**	
		≤x	**>x**
Crest	≤x	L	L
	>x	M	H
Upstream Face	≤x	L	M
	>x	M	H
Downstream Face	≤x	M	M
	>x	M	H
Abutments	≤x	L	M
	>x	M	H
Foundation	≤x	M	H
	>x	H	H

Longitudinal Cracking

	Depth (in.)	
Length (ft)	≤6	>6
0 to ≤y	L	M
>y and ≤z	L	M
> z	M	H

Depth (in.)	**Width (in.)**	**Length (ft)**	
		≤x	**>x**
≤z	≤y	L	M
	>y	L	M
>z	≤y	M	M
	>y	H	H

Location	**Length (ft)**	**Depth (in.)**	
		≤x	**>x**
Crest	≤x	L	L
	>x	L	L
Upstream Face	≤x	L	M
	>x	L	M
Downstream Face	≤x	M	M
	>x	M	H
Abutments	≤x	L	M
	>x	M	H
Foundation	≤x	M	H
	>x	H	H

Location	Length (ft)	Depth (in.)	
		≤x	>x
Structural	≤x	L	L
	>x	L	L
Along Joint	≤x	L	M
	>x	M	H

Spillway cracks, joints, and seepage

Severity Level	Concrete Cracks
L	Cracks <0.25 in. wide; No joint displacement; Joint sealant in good condition
M	Cracks <1in. wide; Joint displacement <0.5 in.; Joint sealant showing signs of ware
H	Weep holes plugged, causing seepage; Flow through cracks; Joint displacement wider >0.5 in.; Joint sealant missing

Spalling

Spall Pieces	Length (in.)	Width (in.)	
		≤x	>x
Tight: Cannot be easily removed (maybe a few pieces missing); No rebar exposed	≤x	L	L
	>x	L	L
Loose: Can be removed and some pieces are missing; If most or all pieces are missing, spall is shallow, less than 1 in.; Beginning to see rebar	≤x	L	M
	>x	M	M
Missing: Most or all pieces have been removed; Most of rebar has been exposed	≤x	M	M
	>x	H	H

Spall Pieces	Area (in.^{2})	Depth (in.)	
		≤x	>x
Tight: Cannot be easily removed (maybe a few pieces missing); No rebar exposed	≤x	L	L
	>x	L	L
Loose: Can be removed and some pieces are missing; If most or all pieces are missing, spall is shallow, less than 1 in.; Beginning to see rebar	≤x	L	M
	>x	M	M
Missing: Most or all pieces have been removed; Most of rebar has been exposed	≤x	M	M
	>x	H	H

Erosion

Area (in.2)	Depth (in.)	
	≤x	>x
≤x	L	L
>x	L	L
≤x	L	M
>x	M	M
≤x	M	M
>x	H	H

Severity Level	Area of surface erosion (in.^{2})
L	0 to ≤y
M	>y and ≤z
H	> z

Location	Area (in.2)	Depth (in.)	
		≤x	>x
Crest	≤x	L	L
	>x	L	L
Upstream slope	≤x	L	M
	>x	M	M
Downstream slope	≤x	M	M
Spillway	≤x	M	M
	>x	H	H
Abutments	≤x	L	M
	>x	M	H

Efflorescence

Area (yd2)	% of Concrete it spans	
	≤50	>50
≤x	L	L
>x	L	M
≤x	L	M
>x	M	M
≤x	M	H
>x	H	H

Delamination

Width (in.)	Length (ft)	
	≤x	>x
≤x	L	L
>x	L	L
≤x	L	M
>x	L	M
≤x	L	M
>x	M	H

Depth (in.)	Length (ft)	
	≤x	>x
≤x	L	L
>x	L	L
≤x	L	M
>x	L	M
≤x	L	M
>x	M	H

Depth (in.)	Width (in.)	Length (ft)	
		≤x	>x
≤z	≤y	L	M
	>y	L	M
>z	≤y	M	M
	>y	H	H

Sulfate attack

Area (yd^2)	% of Concrete/Masonry it spans	
	≤50	>50
≤x	L	L
>x	L	M
≤x	L	M
>x	M	M
≤x	M	H
>x	H	H

Reinforcement issues-Rebar section loss

Severity level	Description
L	0-x% of cross-sectional area lost
M	x-y% of cross-sectional area lost
H	>y% cross-sectional area lost

Hollow concrete

Severity Level	% of samples that are hollow
L	0 to ≤25
M	>25 and ≤50
H	> 50

Masonry Surface

Missing/loose stones

Severity Level	% of Missing/Loose Stones
L	0 to ≤25
M	>25 and ≤50
H	> 50

Area (yd.2)	% of Missing/Loose Stones	
	≤50	>50
≤x	L	L
>x	L	L
≤x	L	M
>x	M	M
≤x	M	M
>x	H	H

Cracks

Length (ft)	Depth (in.)	
	≤6	>6
0 to ≤y	L	M
>y and ≤z	L	M
> z	M	H

Location	Length (ft)	Depth (in.)	
		≤x	>x
Crest	≤x	L	L
	>x	L	L
Upstream slope	≤x	L	M
	>x	L	M
Downstream slope	≤x	M	M
	>x	M	H

Depth (in.)	Width (in.)	Length (ft)	
		≤x	>x
≤z	≤y	L	M
	>y	L	M
>z	≤y	M	M
	>y	H	H

Erosion

Severity Level	Area of surface erosion (in.^{2})
L	0 to ≤y
M	>y and ≤z
H	> z

Area (in.2)	Depth (in.)	
	≤x	>x
≤x	L	L
>x	L	L
≤x	L	M
>x	M	M
≤x	M	M
>x	H	H

Location	Area (in.^{2})	Depth (in.)	
		≤x	>x
Crest	≤x	L	L
	>x	L	L
Upstream slope	≤x	L	M
	>x	M	M
Downstream slope	≤x	M	M
	>x	H	H

Concrete Monolith

Joint Material/Sealant

Severity level	Description
L	Joint material and sealant are intact; Minor cracking/desiccation; Unable to see the joint filler material and/or waterstop
M	Joint material is deteriorating; Able to see joint filler material/waterstop; Repair or replacement is necessary to avoid concrete spalling and cracking during freeze/ thaw cycles and to maintain water tightness of the joint
H	Significant deterioration of joint material; Spalling or cracking of concrete adjacent to the joints; Waterstop is impaired; Joint ceases to be watertight, which will decrease performance and protection in a future flood event

Unusual Movement

Width of Displacement (in)	Length of Displacement (ft)	
	≤2	>2
≤2	L	M
>2	M	H

Severity Level	Description
L	No major areas indicating tilting, sliding, or settlement that threatens the structural integrity
M	Areas of tilting, sliding, or settlement do not quite threaten the structural integrity, yet warrant repair; Horizontal and vertical movement must be less than 2 in., unless it can be proved that movement is no longer happening
H	Tilting, sliding, or settlement threatens structural integrity; Waterstop no longer functional; Horizontal or vertical movement exceeds 2 in., unless it can be proved that movement is no longer happening; For I-wall types: tilting of the wall toward the protected side that has created an open horizontal crack on the upstream base of the monolith

-See Concrete Surface

Culverts

Vegetation

Severity Level	Description
L	No obstructions, including vegetation, debris, or sediment within interior drainage channels or clogging the culverts; Both concrete joints and weep holes are cleared of grass and weeds
M	Minor obstructions present without hindering the channel flow capacity or has blocked ≥ 10% of any culvert openings; Obstructions need to be cleared; Some grass and weeds in concrete channel joints and weep holes
H	Obstructions have hindered the channel flow capacity or blocked ≥ 10% of any culvert opening; Obstructions need to be cleared to restore flow capacity

Holes/Cracks

Severity Level	Description
L	No apparent breaks, holes, cracks that would cause significant water leakage or threaten structural integrity; Culvert shape is conserved (circular); Joints are closed and soil tight; Cameras or visual inspection methods have been used within the past 5 years to confirm condition, and the report for every conduit is readily available
M	Small amount of pinholes or cracks have the potential to leak water; Repair is necessary but structural integrity is not yet threatened; Culvert shape may be slightly altered in some locations; Some joints are not closed and soil loss is commencing, which warrants repair; Cameras or visual inspection methods have been used within the past 5 years to confirm condition, and the report for every conduit is readily available
H	Significant deterioration/leakage, where leakage is eroding the dam toe; Structural integrity is threatened; Cameras or visual inspection methods have not been used within the past 5 years to confirm condition, or the report for every conduit is not readily available

Unusual Movement

Width of Displacement (in)	Length of Displacement (ft)	
	≤2	>2
≤2	L	M
>2	M	H

Severity Level	Description
L	No major areas indicating tilting, sliding, or settlement that threatens the structural integrity
M	Areas of tilting, sliding, or settlement do not quite threaten the structural integrity, yet warrant repair; Horizontal and vertical movement must be less than 2 in., unless it can be proved that movement is no longer happening
H	Tilting, sliding, or settlement threatens structural integrity; Horizontal or vertical movement exceeds 2 in.

Revetments

Severity level	Description
L	No signs of damage and easy to see; No woody vegetation present
M	Some deterioration that does not necessarily affect the structural integrity of the levee/dam/dike; Unwanted vegetation must be managed
H	Severe displacement, deterioration, or bedding is exposed; Signs of bank undercutting due to scour; Embankments show signs of severe erosion; Channel flows hindered and showing signs of turbulence or shoaling; Excessive vegetation covering revetment (no longer visible)

Gate

Severity level	Description
L	Operable; gate leaf, seat, etc., in fair condition (i.e., no corrosion); may need maintenance
M	Operable but needs repair; Some corrosion; Some debris stuck under gate
H	Uncontrolled release of water; significant debris stuck under gate; Parts need to be repaired or replaced

Pumps

Severity level	Description
L	No signs of deterioration; Properly lubricated; Tested regularly; No vibration or odd sounds that may indicate issues such as cavitation; No issues recorded in bearing temperature sensor records
M	Minor deterioration (but still operational) as evidenced by slight vibrations, packing gland leakage, and inoperable bearing temperature sensors/no records of them; Needs to be monitored or repaired
H	Severe deterioration as evidenced by bearing sensor issues, excessive vibration, corrosion, erosion, or missing impeller blades

Sump/Wet Well

Severity level	Description
L	No debris, sediment, or other possible obstructions; Debris accumulation is removed during operation
M	Debris, sediment, or other obstructions observed and needs to be removed, but does not affect functionality; Debris accumulation is removed during operation
H	Large debris or sediment observed which affects functionality or may harm pumps during operation; Debris accumulation is not removed during operation

Floodwall

Vegetation

Diameter (in.)	
0 to ≤2	> 2
M	H

Encroachments

Severity Level	Description
L	No trash, debris, unauthorized structures, excavations, etc.; Encroachments do not affect performance of floodwall
M	Trash, debris, unauthorized structures, excavations, etc. observed, but do not interfere with the functionality, maintenance, or emergency operations of structure; Encroachment effects have not been evaluated
H	Trash, debris, unauthorized structures, excavations, etc. observed and deemed to interfere with the functionality, structural integrity, maintenance, or emergency operations of the structure

Unusual Movement

Width of Displacement (in)	Length of Displacement (ft)	
	≤2	>2
≤2	L	M
>2	M	H

Severity Level	Description
L	No major areas indicating tilting, sliding, or settlement that threatens the structural integrity
M	Areas of tilting, sliding, or settlement do not quite threaten the structural integrity, yet warrant repair; Horizontal and vertical movement must be less than 2 in., unless it can be proved that movement is no longer happening
H	Tilting, sliding, or settlement threatens structural integrity; Waterstop no longer functional; Horizontal or vertical movement exceeds 2 in., unless it can be proved that movement is no longer happening; For I-wall types: tilting of the wall toward the protected side that has created an open horizontal crack on the upstream base of the monolith

Seepage

Severity Level	Description
L	No seepage, saturated areas, or boils have been observed
M	Little seepage/small saturated areas near the downstream toe, but not on the downstream face of the levee, observed; Seepage is not carrying sediment
H	Seepage is carrying sediment or causing rapid erosion; significant saturated areas; boil formed

-See Concrete/Masonry Surface

Unit Conversion Factors

Multiply	By	To Obtain
acre-feet	1,233.5	cubic meters
cubic feet	0.02831685	cubic meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
miles (U.S. statute)	1,609.347	meters
square feet	0.09290304	square meters
square miles	2.589998 E+06	square meters
yards	0.9144	meters

Acronyms and Abbreviations

AMU	acceptable, minimally acceptable, or unacceptable
API	application programming interface
BLM	Bureau of Land Management
CAT	Category
CF	Consequence of Failure
CFR	Code of Federal Regulations
DoD	Department of Defense
EAP	Emergency action plan
ERDC-CERL	U.S. Army Engineer Research and Development Center, Construction Engineering Laboratory
ESMS	Enterprise Sustainment Management System
ESRI	Environmental Systems Research Institute
FAC	Facility Analysis Code
FCI	Facility Condition Index
FEMA	Federal Emergency Management Agency
GFEBS	General Fund Enterprise Business System
GIS	Geographic Information System
ID	identifier
LIS	Levee Inspection System
M&R	maintenance and repair
NCLS	National Committee on Levee Safety
NDSIP	Navy Dam Safety Inspection Program
NID	National Inventory of Dams
NLD	National Levee Database

OSD	Office of the Secretary of Defense
PF	Probability of Failure
PI	Periodic Inspection
POC	point of contact
PRA	Periodic Risk Assessment
RI	Routine Inspection
ROI	Return on Investment
RPUID	Real Property Unique Identifier
SLL	Statistical Lives Lost
SMS	Sustainment Management System
SVL	Statistical Value of Human Life
UID	Unique Identifier
USACE	U.S. Army Corps of Engineers
USD(ST&L))	Under Secretary of Defense for Acquisition, Technology and Logistics
WCS	water control structures

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“SMS Dam Inspection Module - WHS” OASD EI&E FIM

14. ABSTRACT

Department of Defense (DoD) military services own and maintain a portfolio of dams, dikes, and levees including over 800 assets with a total replacement value of over $2 Billion. The Inspector General has previously found that the DoD requires an inspection policy for dams, to prevent failures. The Office of the Secretary of Defense (OSD) directed the U.S. Army Engineer Research and Development Center, Construction Engineering Laboratory (ERDC-CERL), to create an inspection method and integrate that method with the Enterprise Sustainment Management System, with aims to provide OSD a consistent description of all DoD real property and facilitate calculation of the Facility Condition Index (FCI) for each asset.

This report builds upon ERDC-CERL TR-18-9 to propose a method for both inventory and inspection rating for DoD dams, levees, and dikes. A new real property classification system for DoD water control structures is proposed. To better fulfil the OSD requirement for consistent condition and FCI reporting, it is proposed that DoD reevaluate the replacement values and sustainment cost factors for its water retaining structures. A draft guide for linear segmentation for levees is proposed. Future work will allow CERL to develop an Initial Operating Capability for a module within the Enterprise Sustainment Management System to support the OSD requirement.

15. SUBJECT TERMS
Dam safety, Dams—Inspection, Hydraulic structures—Inspection, Levees—Inspection, Dam safety

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