Regulation of Tailings Dams

Supplement to the Model State Dam Safety Program

Prepared by the Tailings Dam Regulatory Committee
Association of State Dam Safety Officials

March 2025

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Preface

The *Tailings Dam Supplement to the Model State Dam Safety Program* was developed by the Tailings Dam Regulatory Committee of the Association of State Dam Safety Officials in response to a gap analysis of the National Dam Safety Program (NDSP) in the United States (US). The gap analysis evaluated the applicability of, and deficiencies in, the publications of the NDSP to address tailings dams. The gap analysis found the most high-level references broadly applicable to “tailings dams, etc.” including the *Federal Guidelines for Dam Safety* (FEMA 93) which mentions tailings dams (first published in 1979 and reprinted in 2004), the *Model State Dam Safety Program* (FEMA 316) which includes a generic definition of a dam intended to apply to tailings dams, etc. and other inferences (first published in 1987 and updated in 2007) and the Strategic Plan for the NDSP FY2012 – FY2016 (FEMA P-916) which establishes a course of action for improving national dam safety policy and practices. Of the twenty-two references reviewed, half mentioned tailings dams, etc., while only two documents other than FEMA 93 and FEMA 316 include information that specifically address tailings dams, etc. However, all but one contains information generally considered applicable to tailings dams, etc. to some extent, with qualifications as described in more detail in the gap analysis. The apparent gaps were attributed to the disproportion between the total number of dams in the nation compared to tailings dams, etc. causing the relative popularity of water dams to appear to skew the emphasis (ASDSO, 2018). The *Tailings Dam Supplement to the Model State Dam Safety Program* was developed in response to specifically reinforce FEMA 316.

The gaps in the other publications, primarily technical guidelines, were addressed by the United States Society on Dams under the direction of the Federal Emergency Management Agency. The resultant *U.S. Guidelines on Tailings Dam Safety* is a comprehensive technical document on tailings dams and complements the Tailings Dam Supplement by serving as the primary reference for technical subjects discussed herein.

Acknowledgements

The *Tailings Dam Supplement to the Model State Dam Safety Program* was developed by the Tailings Dam Regulatory Committee of the Association of State Dam Safety Officials. The primary contributors to the content were Tim Cazier, Colorado Department of Natural Resources; Charles Cobb, Alaska Department of Natural Resources; Peter Werner, US Forest Service; Mike Henderson, Colorado School of Mines; Jim Casey, Klohn Crippen Berger; Dave Chambers, Center for Science in Public Participation; and Dean Korri, Cleveland Cliffs. Descriptions of select Federal agencies were provided by Sarah Shoemaker, US Forest Service; Stan Michalek, Mine Safety and Health Administration; Patty McGrath, US Environmental Protection Agency; Todd Loar, US Army Corps of Engineers; and Tim Barnes and Ed Everaert, US Bureau of Land Management.

Early draft versions of the *Tailings Dam Supplement* were reviewed and commented on by James Demby, Federal Emergency Management Agency; Sarah Shoemaker and Peter Werner, US Forest Service; Stan Michalek, US Mine Safety and Health Administration; Patty McGrath, US Environmental Protection Agency; Tim Eaton, Alberta Energy Regulators ; Dave Chambers, Center for Science in

Public Participation; Andy Small, Klohn Crippen Berger; and Tawny Bridgeford and members of the National Mining Association.

The final draft of the *Tailings Dam Supplement* was reviewed by Hal Van Aller, Maryland Department of the Environment, past president and committee liaison for the ASDSO board of directors ; Chris Thorson and Keith Conrad, Nevada Department of Conservation and Water Resources; Jason Boyle, Minnesota Department of Natural Resources; Luke Trumble and Dan DeVaun, Michigan Department of Environment, Great Lakes and Energy; Tim Cazier, Colorado Department of Natural Resources; Stan Michalek, Mine Safety and Health Administration; Patty McGrath, US Environmental Protection Agency; Sarah Shoemaker and Peter Werner, US Forest Service; Dave Chambers, Center for Science in Public Participation; and Tawny Bridgeford and members of the National Mining Association.

The Chairman of the committee was Charles Cobb who served as the editor through the final draft. Luke Trumble led the effort to completion including additional reviews by Interagency Committee on Dam Safety and the National Dam Safety Review Board. The editors extend their sincere thanks to all of the contributors, reviewers, supporters and readers for their efforts to make the *Tailings Dam Supplement to the Model State Dam Safety Program* successful in the common endeavor to reduce risks and make tailings dams safe to sustain technology and protect life and the environment for future generations.

Abbreviations and Acronyms

AER	Alberta Energy Regulator
AGBC	Auditor General of British Columbia
ANCOLD	Australian National Committee on Large Dams
APEGBC	Association of Professional Engineers and Geoscientists of the Province of British Columbia
ASDSO	Association of State Dam Safety Officials
ASTM	American Society for Testing and Materials
BLM	US Bureau of Land Management
CCR	coal combustion residuals
CDA	Canadian Dam Association
CFR	Code of Federal Regulations
CORS	Continuously Operating Reference Station(s)
CQA/QC	construction quality assurance/quality control
CSI	Construction Specification Institute
CWA	Clean Water Act
DBM	Design Basis Memorandum
DCF	discounted cash flow
DMMA	dredge material management areas
DOI	US Department of the Interior
EAP	Emergency action plan
EIS	Environmental Impact Statements
EPA	Environmental Protection Agency
EPCM	Engineering, Procurement and Construction Management

EPD	Educational Policy and Development, part of MSHA
FEMA	Federal Emergency Management Agency
FLPMA	Federal Land Policy and Management Act, enacted in 1976
FMEA	failure modes effects analysis
GBA	Geoprofessional Business Association
GIS	geographic information system
GISTM	Global Industry Standard on Tailings Management
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GTR	Global Tailings Review
HAZOP	hazard and operability studies
HQUSACE	Head Quarters (USACE)
ICMM	International Council on Mining and Metals
ICOLD	International Commission on Large Dams
IFT	Independent Forensics Team
ISO	International Organization for Standardization
MAA	multiple accounts analysis
MAC	Mining Association of Canada
MINER	Mine Improvement and New Emergency Response Act of 2006
MPRSA	Marine Protection, Research, and Sanctuaries Act of 1972
MSHA	Mine Safety and Health Administration
MSHE	Mine Safety and Health Enforcement, part of MSHA
NDSP	National Dam Safety Program
NEPA	National Environmental Policy Act

NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
OMS	operation, maintenance and surveillance
PAR	population at risk
PBRISD	Performance Based Risk Informed Safe Design, Construction, Operation and Closure
PFMA	potential failure mode assessment
PRI	Principles for Responsible Investments
PSHA	Probabilistic Seismic Hazard Analysis
QPO	quantifiable performance objectives
RACI	responsible, accountable, consulted, informed
RCRA	Resource Conservation and Recovery Act
RHA	Rivers and Harbors Act of 1899
RIDM	risk-informed decision making
RIDSDM	Risk Informed Dam Safety Decision-Making
RMC	Risk Management Center (USACE)
SCADA	Supervisory control and data acquisition
SDWA	Safe Drinking Water Act
SOP	standard operating procedures
TARP	trigger action response plan
TVA	Tennessee Valley Authority
UNEP	United Nations Environment Programme
US	United States
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation

USFS	United States Forest Service
USGS	United States Geological Survey
USSD	United States Society on Dams
UUD	unnecessary or undue degradation (of the public lands)

Chapter I – Tailings Dam Safety Program Objectives

1. Tailings Dams and the *Model State Dam Safety Program* (FEMA 316)

Tailings dams are a unique class of dams used to temporarily store or permanently dispose of sediment or waste materials generated from hard and soft rock mines, placer mines, coal mines, energy production, dredging operations and other industrial processes. Tailings dams referred to in the *Tailings Dam Supplement* are dams as defined in the *Model State Dam Safety Program* (FEMA 316), wherein tailings are generally considered any mineral solids deposited into the impoundment of the dam at high moisture contents such as "liquid borne" methods. In many cases, the tailings may be used as construction materials in the dam, or the performance of the dam may depend on the strength or other characteristics of the tailings deposit. Tailings dams can store waste products that could create environmental impacts if not contained properly. Consequently, in addition to the protection of life and property, dam safety programs need to ensure environmental protection features designed into a tailings dam function as intended.

The *Tailings Dam Supplement to the Model State Dam Safety Program (Tailings Dam Supplement)* is intended to provide additional information for the *Model State Dam Safety Program* (FEMA 316) to address the unique aspects of tailings dams through a regulator's perspective, regardless of the industry constructing and operating the tailings dam. The *Model State Dam Safety Program* (FEMA 316) and these guidelines are applicable to any water dam associated with the industrial facility, regardless of the water quality or nature of the liquid. In considering regulatory requirements for tailings dams, all of the recommendations of the *Model State Dam Safety Program* (FEMA 316) remain in effect as appropriate, including regulatory, policy and programmatic guidance common to water dams and tailings dams, and additional details and discussions with respect to tailings dams are provided herein.

> *The Tailings Dam Supplement is intended to provide additional information for the Model State Dam Safety Program (FEMA 316) to address the unique aspects of tailings dams through a regulator's perspective, regardless of the industry constructing and operating the tailings dam.*

1.1. Objectives

The information in the *Tailings Dam Supplement* provides guidance to regulators in a comprehensive overview of the regulatory interests toward safe, responsible, and successful design, construction, operation and closure of tailings dam systems to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption from the failure of a complex tailings dam developed under modern engineering practices. These principles should be adapted as appropriate for less complex systems based on the respective risks. The concepts described herein are applicable to new or existing tailings dams regulated under a government authority. The *Tailings Dam Supplement* is not intended to provide detailed, technical guidance for the planning, investigation, evaluation, design, operation, or closure of tailings dams. See the publications of the National Dam Safety Program, including the *U.S. Guidelines for Tailings Dams* and other credible references and consult with professional experts for technical guidance on tailings dam systems.

The *Tailings Dam Supplement* outlines various aspects of tailings dams and related systems of interest over the phases in the life of a tailings dam to identify and reduce risk to ensure the safety of the tailings dam during design, construction, operation, closure and the long-term "post-closure" phases. Tailings dams in the closure and post-closure phases require unique considerations outside of common water dam standards of care, where long-term is generally considered herein as an indefinite period of time.

The agency responsible for the tailings dam safety regulatory program is generally referred to herein as the state; however, these guidelines are applicable to any agency with sufficient authority, whether local, state, federal or other government entities.

The information provided in the *Tailings Dam Supplement* is intended to represent uniform dam safety regulatory guidelines to the extent practical. The agency responsible for the tailings dam safety regulatory program is generally referred to herein as the state; however, these guidelines are applicable to any agency with sufficient authority, whether local, state, federal or other government entities.

Very often tailings dams are associated with sophisticated components and operations that can affect risk and the safety of the dam. In such cases, the regulator must be able to determine all ancillary systems are safe such as tailings deposition systems, diversions, seepage collection systems, water management systems, monitoring systems and other components, referred to collectively herein as the "tailings dam system" or more broadly "tailings facility," and to determine that the persons responsible for various aspects are appropriately qualified.

The information required by regulators should be tailored for the specific project as appropriate. The dam safety program responsible for regulating tailings dams should have the authority as described in Chapter II – Authorities of the *Tailings Dam Supplement* and in the *Model State Dam Safety Program* (FEMA 316) to require, review, observe, or waive information as necessary to determine compliance with respective statutes and regulations, and to determine that a sufficient level of detail is developed in planning the design, construction, operation, closure and reclamation of tailings dams to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption.

As described in Section 2.2 of Chapter III and all of Chapter V, submittals should be developed based on a consideration of multiple stakeholders and defensible decisions that include factors relevant for a specific project and location, generally accepted best available technology and best practices. For example, some projects may require a geomembrane liner system for environmental protection that may reduce slope stability by reducing consolidation of fine materials, increasing pore water pressure, and reducing factors of safety; increasing risk over more stable designs with different seepage control features. Selection of the most appropriate design, construction, operational and closure practices will contribute to reducing the respective risk to as low as reasonably practicable (FEMA P-1025, 2015) for any component critical to the safety of the tailings dam system.

As noted, see the publications of the National Dam Safety Program, including *the U.S. Guidelines on Tailings Dam Safety*, and other credible references and consult with professional experts for technical guidance on tailings dam systems including risk assessments, best available technology and practices, and emerging technologies. Emerging technologies must be anticipated and adopted into regulatory programs as advances in tailings dam engineering, monitoring, data processing, evaluation and reporting continue to bring improved tailings dam performance and reduced risk. The *Tailings Dam Supplement* is intended to be fully flexible to help accomplish that objective and the common goal of “zero harm to people and the environment” (GTR, 2020a) from a failure of the tailings dam system, apart from any environmental effects incidental to the project development and dam safety management.

1.2. Components

The *Tailings Dam Supplement* is presented in the following chapters:

I. Tailings Dam Safety Program Objectives

II. Authorities

III. Public, Stakeholder and Owner Info

IV. Existing Tailings Dams

V. Design, Construction, Operation, Closure and Post-closure

VI. Emergency Planning and Incident Response

VII. Program Execution and Administration

VIII. References

References appropriate to specific subject matter or necessary for additional detail are cited in the format (attribution, date) except for publications under the National Dam Safety Program which are cited with the publication number when available, e.g. (FEMA 316). See the *Model State Dam Safety Program* (FEMA 316) for definitions of terminology not specifically defined herein.

The information in the *Tailings Dam Supplement* enhances the *Model State Dam Safety Program* (FEMA 316) from the perspective of the life of the tailings dams in phases, from planning and design through construction, operation, closure and various post-closure scenarios described in Section 4.4

of Chapter V. Each phase in the life of tailings dams must be considered because decisions in the early stages of planning and project development can have significant effects on the late stages of the operation, closure and post-closure requirements of the facility. The regulatory agency should make decisions for issuance of the appropriate authorizations when permitting processes required during each phase are complete. See the *Model State Dam Safety Program* (FEMA 316) for typical activities that require regulatory authorization.

Tailings dams may be the result of dredging, mining, energy production or other industries, referred to collectively herein as industry.

The *Tailings Dam Supplement* is formatted to include summaries in the beginning of a section under the chapter and where appropriate to highlight suggested uniform dam safety regulatory guidelines, typical considerations for regulators, and general recommendations that are broadly applicable, in the following format:

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems
▪ Description of minimum or typical regulatory requirement. Not intended to be specific regulatory language.
Considerations for Regulators
▪ What are questions tailings dam safety regulators must address?
Recommendations
▪ Summary description of general recommendation

See Appendix A for a compilation of uniform dam safety regulatory guidelines for tailings dam systems from the *Tailings Dam Supplement*. General descriptions, details, unique requirements and recommendations that may be project specific are included in respective discussions in each chapter. Tailings dams may be the result of dredging, mining, energy production or other industries, referred to collectively herein as industry.

Chapter II – Authorities

1. Statutes and Regulations

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems
▪ Tailings dam safety regulatory programs must have well-defined statutory and regulatory authority for tailings dam systems ▪ Tailings dam safety regulations should be coordinated with other regulations and regulatory agencies to preclude duplicative regulatory requirements and conflicts
Considerations for Regulators
▪ What are limitations imposed on dam safety programs by statutes and regulations?
Recommendations
▪ Sequential application processes outlined in regulations to engage regulators and applicants, to develop agreement on key standards early in the project development, and to set submittal requirements and milestones toward a complete application for informing regulatory decisions

The authority to regulate tailings dams should be clearly indicated within the authorizing statutes and regulations of the respective regulatory agency. See the *Model State Dam Safety Program* (FEMA 316) and relevant state legislative and administrative processes for detailed guidance on establishing the appropriate level of authority. When possible, regulations and administrative policies should anticipate where multiple regulatory jurisdictions may overlap to facilitate coordination between regulatory agents and project representatives to ensure project features, engineering evaluations, construction and operation plans, monitoring and inspections, closure plans, financial assurances and other regulatory requirements are consistent and satisfactory to the various agencies in order to limit duplicative efforts and avoid conflicts. See Section 3.2 of Chapter II for more information about other regulatory agencies.

A sequential application process outlined in regulations is recommended in order to:

- Identify common interests of stakeholders,
- Provide early agreement on important design standards, technical investigations and evaluations,
- Identify construction and operational requirements that are included in permits,
- Agree on design, construction, and permitting schedules,
- Establish frequency and timing of tailings facility inspections by the regulatory agency and the engineer/designer of record,

- Facilitate decisions on authorizations for construction and modifications and renewals of operating permits.

A sequential application process paces the regulatory review with the project development which provides scheduling efficiencies for the applicant and the regulator and many other benefits.

When drafting statutes and regulations, agencies must consider other regulatory agencies that may have overlapping authority to avoid promulgating conflicts in law. For example, financial assurance may be required from more than one authority for different purposes. Coordinated regulatory requirements help improve efficiency in permitting processes by allowing consolidated, unified submittals to meet multiple regulatory requirements to the extent practical.

2. Compliance and Enforcement

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems

- Clearly indicate or reference tailings dam safety enforcement authority in dam safety statutes and regulations governing the regulatory agency

Considerations for Regulators

- Voluntary compliance in a cooperative setting is the most efficient and effective method of achieving objectives of tailings dam safety regulatory programs
- How is tailings dam safety regulatory authority maintained?
- What are consequences of enforcement actions?

Recommendations

- Encourage and promote effective communication and other incentives to develop and support cooperative relationships with tailings dam/owner operators
- Provide regulators with authority to issue citations and collect fines under civil authority during tailings dam operation
- Clearly include cross-references in regulations to respective authorities for managing complex obligations and responsibilities that can follow tailings dam closures
- Enforcement actions must be carefully considered and well written to ensure resultant consequences protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption

A cooperative relationship between tailings dam owner/operators and regulatory agencies is the most efficient means to achieve regulatory compliance, although compliance with regulations is incumbent upon tailings dam owner/operators. Regulators can provide incentives by helping dam owner/operators understand risks, effectively communicating regulatory requirements with guidelines and training, or providing reward systems such for tailings storage systems that are inherently stable by design or mitigation (such as dewatered tailings or in-pit placement). Nevertheless, situations may arise where enforcement actions by regulators are necessary.

Enforcement authority for the agency regulating tailings dams should be clearly included in statutes and regulations, such as those for dam safety, mining and/or environmental protection. Civil authority is recommended to provide regulating agency personnel authorization to enter the facility at reasonable times with appropriate notice, or on short notice or unannounced under emergency circumstances, as necessary to assess or confirm the condition and safety status of the tailings dam system and to conduct inspections to ensure the respective regulations and other requirements are met. Civil authority should also include processes to request additional information, issue citations, notices of violations of regulations, agency orders, permit terms and conditions, deficiencies in design, construction, or operation of the tailings dam system, or other infractions.

Penalties should be clearly indicated in regulations including reasonable time periods to allow dam owner/operators to comply prior to initiating legal proceedings. A progressive penalty strategy is one approach to account for repeat violators of significant standards. For example, the US Mine Safety and Health Administration (MSHA) has provisions for a “pattern of violations” where repeat violators get extra penalties and more enforcement visits to encourage compliance with regulatory requirements (MSHA, 2019). Alternatively, a risk-based approach to “compliance verification” includes increased inspections based on the history of compliance, construction and operation activities, and the financial condition of the dam owner/operator (AGBC, 2016). Authority to impose and collect fines should be included to provide additional incentives to dam owner/operators to maintain regulatory compliance. Some regulatory schemes also impose criminal penalties on certain types of regulatory violations. Such penalties implicate issues that go beyond those associated with civil enforcement, including intent requirements, clearly defining the relevant offense, and the level of misconduct sufficient to justify criminal penalties. Regulators should consider these issues in consultation with state legal officials (e.g., state attorney generals’ offices) in developing this component of an enforcement program. Such penalties should generally focus on instances of willful misconduct or conduct that significantly increases risk or causes harm; otherwise, criminal penalties are not generally appropriate.

Regulations should clearly define the parties subject to charges issued by the agency such as those persons or entities described in Section 4.2 in Chapter III. Dam owners are ultimately responsible for the safe design, construction, operation, closure and post-closure scenarios of the tailings dam. To ensure tailings dams function and operate safely, the regulatory agency must be able to enforce its tailings dam safety statutes and regulations quickly, uniformly and fairly. Enforcement authority should allow the regulator to stop operations at a site if a cited condition represents an imminent danger of loss of human life, economic loss, property damage, environmental impacts or lifeline disruption. Such enforcement authority may be addressed specifically within the dam safety legislation and regulations, within general state enforcement procedures, or within a combination of these various authorities, and may lie within the tailings dam safety program or be managed by a separate enforcement program. Tailings dams can be located on land managed by federal, state and local agencies not directly responsible for the safety of the tailings dam. Coordination with federal, state and local agencies during enforcement actions is paramount.

To ensure tailings dams function and operate safely, the regulatory agency must be able to enforce its tailings dam safety statutes and regulations quickly, uniformly and fairly.

Regulatory programs should develop clearly defined administrative procedures for enforcement actions. If a problem, violation, or inadequacy is found, a determination must be made whether an emergency exists. If the problem, violation, or inadequacy also constitutes an emergency, the emergency situation must be resolved before enforcement procedures begin. A non-emergency problem, violation, or inadequacy may result in a request from the agency in writing for compliance by the owner. A violation, citation or enforcement order may be issued whether or not compliance is achieved, with agency discretion considered. Regulatory orders may be subject to appeal by the tailings dam owner consistent with state administrative procedures. If the owner refuses to comply with agency directives, legal action may be required to achieve compliance. In emergency situations, where a compliance issue poses an imminent and substantial risk to human health or the environment, regulatory enforcement powers may provide regulators with authority to take control of operations, but that authority should be sparingly used and focused on extreme situations; the transition of control can itself greatly increase risks. To the extent that the operator defaults on its closure obligations, financial assurance can be used to fund the implementation of an approved closure plan. This will involve significant financial management responsibilities across state agencies such as managing funds, budgets and spending authorizations; and technical and regulatory responsibilities for dam safety programs such as directing the design, construction and operation of seepage collection or dewatering systems, closure covers, spillways, water treatment systems, and long-term care and maintenance of closed tailings dams and appurtenant features.

The regulatory agency must have clear authority to take emergency actions in situations that are life-threatening and/or pose imminent and significant or high risk to human health or the environment. That authority must also ensure those actions remain in force until the emergency is resolved. Emergency actions can include measures to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption including suspension or cessation of operations; decanting (and treating, if necessary) water impounded in the tailings facility; buttressing the dam; or directing the implementation of the closure and reclamation plan approved for the tailings facility. Statutory authority should give the state the right to recover any costs for emergency actions from the owner of the dam by legal action in a court of appropriate jurisdiction where the dam is located or where the owner resides. Statutory authority should also include the ability for the state to manage short and long-term financial assurances and respective funds and obligations from claims.

The following technical issues should be considered when pursuing an enforcement action:

- **Water Balance**

  Water stored in tailings dam impoundments is frequently part of an industrial re-use/recycling water management system. If enforcement and corrective action orders are not carefully written with an understanding of the industrial water use, too much water could accumulate in the tailings facility which may exceed operational constraints such as freeboard and/or tailings beach length requirements.

- **Water Quality**

  Water from seepage collection systems or stored in the tailings dam impoundment may be impacted from the industrial processes and may not meet water quality standards for discharge into the environment. Enforcement actions need to consider water quality and if treatment may be required prior to discharge.

- **Continued Monitoring and Inspection**

  Because a tailings dam system may be under construction during operation, whether continuously or in stages, routine monitoring and regular inspections are required to ensure construction is proceeding as planned and for various conditions which may indicate a problem that may affect the safety of the dam. Depending on the circumstances of enforcement, personnel familiar with these monitoring and inspection procedures may no longer be available, which emphasizes the value of operations, maintenance and surveillance (OMS) manuals when those that are not familiar with the operations must assume control. If operations cease temporarily or permanently for any reason, routine monitoring and inspection requirements may change. Continued monitoring and inspection practices by qualified personnel may be imperative, depending on the long-term post-closure scenario as described in Section 4.4 of Chapter V.

- **Implementation of Closure Plan**

  In the case that the enforcement order terminates filling of the tailings dam or terminates the permit, the state should issue the orders necessary for implementation of the approved closure plan, with the operator's performance secured against default by relevant financial assurances for safe decommissioning of the facility. Regulatory authority should also provide that state emergency funds will be available if needed to ensure the safety of the tailings dam as appropriate to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption.

3. Cooperating Regulatory Agencies

In most cases, tailings dams are associated with industrial facilities that may include multiple regulatory agencies with related regulatory authority. In some cases, regulatory authority for the tailings dam may overlap with other state or federal agencies. The following sections describe typical state agencies that may cooperate with tailings dam safety programs and summaries of various federal agency roles in regulating tailings dams.

Coordination of regulatory requirements across multiple agencies is recommended to avoid conflicts and streamline permit application processes.

3.1. Other state and local agencies

Other state and local agencies may have an interest or authority to regulate tailings dams. Local authorities may have zoning laws or ordinances governing the development of industrial facilities within its jurisdiction. State environmental regulatory agencies responsible for water and air quality typically have an interest or regulatory authority over some aspects of tailings dam systems. State solid waste programs may also have regulatory authority over a tailings disposal facility because of the unique nature of tailings dams as described in Section 1 of Chapter III. In some states, tailings dams are regulated under mine regulatory programs (ASDSO, 2016). State land and water management agencies and fish and wildlife agencies may have an interest in certain aspects of tailings dam systems. Coordination of regulatory requirements across multiple agencies is recommended to avoid conflicts and streamline permit application processes. Clear, concise, and achievable timelines and expectations should be communicated with the applicant to maintain the integrity and transparency of the proposed regulatory process.

3.2. Select federal agencies

Regulatory authority for federal agencies related to tailings dams varies depending on the nature of the industry, land ownership, agency mission and other factors. The following sections describe summaries of select federal agencies' roles related to tailings management. This is not a complete list of all agencies that may be involved in a permitting process or all agencies that regulate tailings dams. For example, the US Nuclear Regulatory Commission (NRC) regulates uranium tailings dams, and neither are specifically described or considered in the *Tailings Dam Supplement*.

3.2.1. US ENVIRONMENTAL PROTECTION AGENCY

The mission of the US Environmental Protection Agency (EPA) is to protect human health and the environment. EPA develops and enforces regulations under a variety of environmental laws, including the Clean Water Act (CWA), Clean Air Act, Resource Conservation and Recovery Act (RCRA), Safe Drinking Water Act (SDWA), and Comprehensive Environmental Response, Compensation and Liability Act (or Superfund). Many of EPA's environmental permitting programs (RCRA, SDWA, CWA-NPDES) are delegated to states or local agencies. Where permitting is not delegated in several states, territories, Tribal lands and certain federal lands, EPA is the permitting authority. Depending on the complexity and specific activities at a mine, energy facility or other industrial project, permits may be required for activities such as generation/disposal of wastes and discharge of pollutants into waters of the US or groundwater aquifers. The following laws and regulations may apply to tailings facilities depending upon the specific activities associated with the facility.

- Mining wastes (i.e., wastes from extraction, beneficiation, and processing of mineral ores and phosphate rock, including tailings) and cement kiln dust are generally exempted from EPA's hazardous waste regulations under the RCRA Subtitle C program by the Bevill Amendment in the Solid Waste Act of 1980. Following the Kingston TVA coal ash spill, EPA developed regulations for disposal of coal combustion residuals as non-hazardous wastes under RCRA Subtitle D to address the risk of leaking contaminants and catastrophic failure of impoundments. The regulations include provisions related to location restrictions, design criteria, closure, and beneficial use. EPA has not developed RCRA Subtitle D regulations for mine tailings impoundments, phospho-gypsum stacks or similar industrial facilities although the authority to do so is retained; instead, EPA currently defers to other federal and state authorities for direct regulatory oversight of such facilities.

- Under the Section 402 of the CWA, National Pollutant Discharge Elimination System (NPDES) permits are required for the discharge of pollutants from point sources to waters of the US. The NPDES regulations include Effluent Limitation Guidelines that apply to specific industrial sectors and wastewater sources. Discharges from tailings facilities to waters of the US may require an NPDES permit. NPDES permits do not regulate construction, operations, or safety of the tailings facility itself, but may be pertinent to the water balance associated with the facility since permits set limits on the amount and characteristics of water that can be discharged based on Effluent Limitation Guidelines and state water quality standards.

- CWA Section 404 regulates the discharge of dredged or fill material into waters of the US, including jurisdictional wetlands. Regulated activities include mining operations and other industrial developments, which need a 404 permit before discharging dredged or fill material to construct a tailings facility or discharge tailings or dredged material into waters of the US. The US Army Corps of Engineers administers the 404 program and issues permits. EPA has authority to review and comment on permit application public notices, can elevate specific cases, and can prohibit, deny, or restrict the use of any defined area as a disposal site.

- Under the SDWA, Underground Injection Control permits are required for underground disposal of wastes and wastewaters. UIC permits are issued by EPA or delegated states.

- Under Section 309 of the Clean Air Act, EPA is charged with reviewing National Environmental Policy Act (NEPA) Environmental Impact Statements developed by Federal agencies and commenting on the adequacy and acceptability of the environmental impacts of the proposed action. EPA reviews Federal EISs that include tailings facilities and tailings dams and often participates in the NEPA process as a cooperating agency.

- EPA's Superfund program is responsible for cleaning up contaminated land and responding to environmental emergencies and natural disasters. EPA addresses tailings impoundments at abandoned mines during cleanup of these facilities.

3.2.2. US ARMY CORPS OF ENGINEERS

Established in 1802, the US Army Corps of Engineers (USACE) is an engineering branch of the United States Army with a mission to deliver vital military and civil engineering solutions in collaboration with partners to secure the Nation's challenges, energize the economy, and reduce disaster risk. This includes planning, design, construction, operation, monitoring, and management of flood risk reduction infrastructure that consists of over 700 dams and 15,000 miles of levees and maintaining coastal and inland navigation systems. Additionally, the USACE administers and enforces several regulations designed to protect the Nations waterways. These are discussed in the following subsections relative to the dam and levee safety and regulatory programs.

3.2.2.1.USACE Dam and Levee Safety Program

USACE implements a dam safety program that utilizes a risk-informed decision making (RIDM) process to manage the dam, levee, and lock safety with life safety as the highest priority, followed by economic, navigation, cultural, and environmental impacts. USACE Engineering Regulation: "Safety of Dams - Policy and Procedures", ER 1110-2-1156 prescribes the guiding principles, policy, organization, responsibilities, and procedures for implementing a RIDM program in compliance with the "Federal Guidelines for Dam Safety" (FEMA 93, 2004a) and "Federal Guidelines for Dam Safety Risk Management" (FEMA P-1025, 2015). The program uses a risk-informed decision-making process to manage all dams and appurtenant structures in the USACE inventory. The process considers aspects such as design, construction, management, and operation, as well as advancements in state-of-the-art for dam and levee safety including hydrologic and consequence modeling. RIDM provides a framework for prioritization of limited resources to manage the portfolio safely and effectively under a range of loading conditions, informed by dam and levee safety principles and authorizations.

The Risk Management Center (RMC) is responsible for leading the development of risk-related tools and risk methodology for the USACE Dam and Levee Safety programs and supports risk approaches in other related areas as directed by USACE Headquarters (HQUSACE). The mission of the RMC is to support Civil Works by management and assessment of the safety and risks for dams and levee systems across USACE; to support dam and levee safety activities throughout USACE; and to develop policies, methods, tools, and systems to enhance those activities in accordance with the Dam Safety Engineer Regulation 1110-2-1156. Many of the USACE RIDM processes, methodologies, and tools (e.g., training, toolboxes, software, publications, and references) can be accessed at https://www.rmc.usace.army.mil/.

In addition to flood control dams, levees, and navigation lock structures, USACE has over 400 confined dredge material disposal facilities related to harbor and waterway maintenance operations. These facilities are designed according to USACE engineering manual "Dredging and Dredged Material Management" (EM 1110-2-5025). Due to the nature of how these facilities are constructed and operated, they may appropriately be classified as a dam. Currently, ER 1110-2-1156 does not specifically identify dredge material management areas (DMMA) as part of the Dam Safety program. USACE is currently performing a review and reassessment of how DMMA's may be incorporated into the dam safety program. This assessment will evaluate the need for dam safety and RIDM processes depending on the consistency and condition of contained materials; height and volume of the structure; operation and construction methods; and potential consequences and impacts of a failure. The level of dam safety assessment may be adjusted to meet the needs of the dredge material management area that do not pose a risk to the public. USACE has initiated a screening of each DMMA for possible classification as a dam and its hazard potential and the appropriate level of risk assessment applied for those DMMA's that qualify as dams. Additional guidance and dam safety management procedures for evaluating and managing DMMA's will be developed.

3.2.2.2.Department of the Army Regulatory Program

- Sections 9 and 10 of the Rivers and Harbors Act of 1899 (RHA):
  - Under RHA Section 9, a permit is required for the construction of any dam or dike across any navigable water of the US
  - Under RHA Section 10, a permit is required for work or structures in, over or under navigable waters of the US
- Section 103 of the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA):
  - Under Section 103 MPRSA, a permit is required for the transportation of dredged material for the purpose of disposal in the ocean
- Section 404 of the Clean Water Act (CWA):
  - Under CWA Section 404, a permit is required for the discharge of dredged or fill material into waters of the US including jurisdictional wetlands

The Regulatory Program is committed to protecting the Nation's aquatic resources and navigation capacity, while allowing reasonable development through fair and balanced decisions. The USACE Regulatory Program is neither a proponent nor opponent of any permit proposal. The USACE regulatory staff evaluates permit applications pursuant to CWA Section 404 from non-USACE applicants for proposed projects, which may include mining and industrial activities, tailings dams and DMMAs, where there could be a discharge of dredged or fill material into waters of the US.

The decision to issue a permit is based on an evaluation of the probable impacts, including cumulative impacts, of the proposed activity and its intended use relative to the public interest, as well as procedural and substantive compliance with other Federal law. For example, the USACE must ensure compliance with the Clean Water Act, National Environmental Policy Act, the Endangered Species Act, and the National Historic Preservation Act prior to reaching a permit decision *(See 33 CFR 320).*

As part of the public interest review completed by USACE, relevant factors are considered including the cumulative effects thereof. For example: conservation, economics, aesthetics, general environmental concerns, wetlands, historic properties, fish and wildlife values, flood hazards, floodplain values, land use, navigation, shore erosion and accretion, recreation, water supply and conservation, water quality, energy needs, safety, food and fiber production, mineral needs, consideration of property ownership, and, in general, the needs and welfare of the people (33 CFR 320.4(a)).

In the context of tailings dams and DMMAs, the design, construction, monitoring, operations, and safety of these facilities are considered as part of the public interest and required to comply with applicable Federal and State laws. When the USACE Regulatory Program evaluates activities that would involve the construction of a tailing dams or DMMA structure the applicant may be required to demonstrate that the structure complies with established state dam safety criteria or that the structure has been designed by qualified persons and, in appropriate cases, independently reviewed by similarly qualified persons. No specific design criteria are to be prescribed nor is an independent detailed engineering review to be made by USACE (33 CFR 325.1(d)(6)).

3.2.3. US DEPT. OF LABOR – MINE SAFETY AND HEALTH ADMINISTRATION

The US Department of Labor's Mine Safety and Health Administration (MSHA) works to prevent death, illness, and injury from mining and promote safe and healthful workplaces for US miners. MSHA carries out the provisions of the Federal Mine Safety and Health Act of 1977 (Mine Act) as amended by the Mine Improvement and New Emergency Response (MINER) Act of 2006.

The agency develops and enforces safety and health rules for all US mines regardless of size, number of employees, commodity mined, or method of extraction. MSHA also provides technical, educational, and other types of assistance to mine operators. The agency works cooperatively with industry, labor, and other federal and state agencies to improve safety and health conditions for all miners in the US.

The Mine Act specifically includes impoundments, retention dams, and tailings ponds in the definition of a “coal or other mine.” Consequently, MSHA regulates these structures along with all other aspects of a mine, regardless of land ownership or location. In support of the Mine Act, MSHA enforces Title 30 of the Code of Federal Regulations, titled “Mineral Resources.” MSHA groups mines into two commodity categories - coal and anything other than coal, which is referred to as “metal and nonmetal.”

Parts 56 and 57 of Title 30 pertain to safety and health standards at surface and underground metal and nonmetal mines, respectively. Sections 56.20010 and 57.20010 are specific to retaining dams. Where failure of a water or silt retaining dam will create a hazard, it shall be of substantial construction and inspected at regular intervals. Substantial construction means construction of such strength, material, and workmanship that the object will withstand all reasonable shock, wear, and usage to which it will be subjected. The purpose of MSHA’s inspections is to ensure that the dam is maintained in this substantially constructed condition and does not exhibit potentially hazardous conditions.

Part 77 of Title 30 pertains to safety standards at surface coal mines and surface work areas of underground coal mines. Section 77.216 is specific to water, sediment, or slurry impoundments and impounding structures. Dams meeting the size or hazard potential criteria stated in the standard must have a design plan that is certified by a registered professional engineer to be in accordance with current, prudent engineering practices. In addition, the standard provides inspection, monitoring, abandonment, and reporting criteria. MSHA's inspections help ensure the site is being constructed and operated according to the approved design plan and the site does not exhibit potentially hazardous conditions.

MSHA's Dam Safety Program consists of a Dam Safety Officer and several program areas, namely Mine Safety and Health Enforcement (MSHE), Educational Policy and Development (EPD), and Technical Support. MSHE inspectors are located across the country to conduct mine inspections and assist mine operators, and include specialists trained in dam safety. EPD specialists provide training to inspectors and industry personnel. Technical Support provides expertise mining, geotechnical engineering, geology, hydrology, and hydraulics, and in many cases, provides training for specialist and operators. Technical Support staff often possess professional licensures and advanced degrees.

MSHA performs inspections two times a year at surface mines and four times a year at underground mines. However, dams with a high hazard potential classification are inspected quarterly and potentially more often depending on conditions and activities at the site. MSHA's Dam Inspection and Plan Review Handbook states that these inspections should be performed by Impoundment Specialists or inspectors with advanced training. Inspectors cite deficiencies and potential hazards, requiring the mine operator to correct the condition. In addition to MSHA inspections, mine operators must perform dam inspections weekly at coal mines and on a regular frequency at metal and nonmetal mines.

Engineering design plans for dams associated with coal mines must be submitted to MSHA for review and approval. Many of these plans are reviewed by engineers in MSHA's Directorate of Technical Support. Following these reviews, the engineer either recommends approval of the plan or requests additional information that the designer should provide. These requests may also inform the designer of errors and omissions in the plan or areas that may require improvement. The engineers also assist MSHA inspectors when dams that are complete or under construction have issues that are beyond the inspectors' expertise and conduct on-site investigations when requested.

In 2009, MSHA published the second edition of its "Engineering and Design Manual: Coal Refuse Disposal Facilities." This reference addresses dam siting, design, and operation among other issues. In 2021, MSHA revised and published its "Dam Inspection and Plan Review Handbook" (PH21-006). Both of these publications and additional references can be found on MSHA's website at www.msha.gov.

3.2.4. US DEPT. OF INTERIOR – OFFICE OF SURFACE MINING, RECLAMATION AND ENFORCEMENT

The Office of Surface Mining, Reclamation and Enforcement (OSMRE) was established in 1977 with the passage of the Surface Mining Coal and Reclamation Act (SMCRA). Under the Department of the Interior, OSMRE is exclusively focused on a nationwide program to "to ensure that citizens and the environment are protected during coal mining and that the land is restored to beneficial use when mining is finished.” This includes regulating active coal mines, reclaiming abandon coal mines and adjacent lands, protecting the public interest and the environment, and promoting education and research (OSMRE, 2021). The OSMRE mission statement is:

> Our mission is to carry out the requirements of the Surface Mining Control and Reclamation Act (SMCRA) in cooperation with States and Tribes. Our primary objectives are to ensure that coal mines are operated in a manner that protects citizens and the environment during mining and assures that the land is restored to beneficial use following mining, and to mitigate the effects of past mining by aggressively pursuing reclamation of abandoned coal mines.

The regulations under SMCRA are well developed and include authority over coal mine waste dams, sediment dams and wash plant discharge dams. Some of these dams share characteristics with tailings dams systems. SMCRA allows states and tribes primacy with SMCRA based regulatory programs and OSMRE supports these state and tribal programs and steps in when approved programs are missing.

3.2.5. US DEPT. OF INTERIOR – BUREAU OF LAND MANAGEMENT

The Bureau of Land Management (BLM) is a Bureau within the Department of the Interior (DOI), managing 245 million acres of public lands and 700 million acres of mineral estate. The BLM was originally formed in 1946 from a combination of the General Land Office and the US Grazing Service, and administers public lands in accordance with the Federal Land Policy and Management Act (FLPMA), enacted in 1976, and other land management laws, including the Mining Law of 1872 (Mining Law), as amended. In accordance with FLPMA, BLM reviews project proposals for design, construction, operations and maintenance, including tailings dams/impoundments, to ensure that the project will not result in unnecessary or undue degradation (UUD) of the public lands. The BLM approval process includes the analysis of potential environmental impacts of the project in compliance with the National Environmental Policy Act. Where dams/impoundments are proposed for tailings disposal, the approval process allows the agency to consider state requirements and other applicable guidelines such as the National Dam Safety Program guidelines, other non-federal guidelines and guidelines proposed by the operator. In many applications, such as mining, the operator must provide a financial guarantee covering the costs of reclamation of any surface disturbance resulting from the operations. The BLM requires that any impoundments or similar structures meet standard engineering practices to achieve and maintain stability and facilitate reclamation, complying with all applicable state and other federal laws and permitting requirements. Upon completion of service life, the operator must reclaim disturbed areas, including impoundments, to approved uses and conditions.

3.2.6. US DEPT. OF AGRICULTURE – FOREST SERVICE

The US Department of Agriculture Forest Service (Forest Service) is a land management agency. The Organic Act of 1897 authorizes the Forest Service to promulgate regulations to prevent the destruction of forest resources. As such, the Forest Service strives to balance the environmental impacts and protections, the demands of multiple-use management required of federally managed lands, the economic and industrial drivers of mineral and energy development, and the engineering and technical aspects of dam design and dam safety. When tailings dams are proposed on or adjacent to National Forest System lands, the Forest Service reviews its construction as part of the overall project development. The Forest Service review process focuses on the environmental impacts of the project through completion of an environmental analysis pursuant to the National Environmental Policy Act. Where impoundments are proposed for tailings disposal, the review process allows the agency to consider state requirements and other applicable guidelines such as the National Dam Safety Program guidelines, other non-federal guidelines and guidelines proposed by the operator. The Forest Service also requires financial assurance related to tailings dams, as discussed in Section 4.4 of Chapter III, Section 4.1.2 of Chapter V and Appendix C. This is an example of where state and federal regulatory agencies may have nearly identical regulatory requirements in principle, and state and federal coordination is necessary to satisfy the regulatory obligations of the proponent. To execute its program, the Forest Service engages and cooperates with co-permitting agencies to review, permit, and inspect the construction and operation of tailings dams including Memorandums of Understanding for specific items such as financial assurance.

Chapter III – Public, Stakeholder and Owner Information

1. Tailings Dam Defined

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems
▪ Provide definition of tailings dam in statutes or regulations
Considerations for Regulators
▪ What is a tailings dam?
Recommendations
▪ Anticipate a wide variety of tailings dams and appurtenant works and complex considerations for design, construction, operation and closure with some projects involving multiple stakeholders

Tailings dams referred to in the *Tailings Dam Supplement* are dams as defined in the *Model State Dam Safety Program* (FEMA 316), wherein tailings are generally considered any mineral solids deposited into the impoundment of the dam at high moisture contents such as "liquid borne" methods. This may include any materials that are initially deposited in an unconsolidated state such as waste streams discharged from a mine mill, coal preparation plant or baghouse where tailings are completely processed, or overburden, dredge spoils or placer tailings with limited or no processing other than sorting by water. Tailings may range from benign, gravelly, silty, sand, to fine grained sandy, silty slimes, and could include mineralogical constituents that cause adverse reactions in the environment such as acid rock drainage/metal leaching contamination. These materials are deposited behind a constructed embankment referred to as a tailings dam that otherwise meets the definition of a dam, regardless of the construction materials within the embankment.

The initial, unconsolidated nature of liquid borne tailings deposits could be interpreted to exclude tailings sufficiently dewatered and compacted to exhibit dilative behavior under shear stress at a measurable density based on classic Proctor curves, with or without buttressing, referred to as "drystack" technology. However, a drystack could be a dam or appurtenant feature to a dam if the structure impounds water or diverts water to a nearby water management dam. Tailings thickened by dewatering to paste consistency, industrial sludges such as bauxite red mud, and phospho-gypsum stacks represent special cases that are not specifically addressed herein, although containment and water management requirements may be similar. Tailings disposed of in mine pits or underground workings where, a sudden or gradual release of solid materials are not likely, are not addressed.

Appurtenances to tailings dams may include sophisticated components, ancillary systems and operations that can affect risk and the safety of the dam such as tailings transport and deposition systems, diversions, seepage collection systems, water management and treatment systems, monitoring systems and other components, referred to collectively herein as the “tailings dam system”. The tailings dam system is typically an element within the overall development plan such as a large mine project, or an ancillary feature to another project such as dredging.

Where tailings are utilized as structural components of the tailings dam, the behavior of the tailings under load and other conditions must be well understood.

1.1. Unique aspects and special design considerations of tailings dams

Tailings dams are unique from water dams because of special aspects that must be considered in the design and operation of the dam. In some cases, tailings may have suitable properties to be included in structural components of the dam during construction or perform other functions such as reducing seepage. At mines, tailings may be subjected to additional processing after the mill process to reduce water content or separate relatively coarse and fine fractions to control deposition behavior and physical characteristics. These factors may contribute to a continuous process of construction during operations when tailings are produced. Or construction may occur in discrete stages during operations where borrow materials are sourced and used in embankment raises. The commonly recognized methods of tailings dam construction referred to as downstream, centerline, and upstream designs are illustrated in Figure III-1. A fourth design also shown referred to as “modified centerline” allows the centerline of the embankment to translate upstream until the centerline reaches the tailings deposit. Typical applications of tailings dams are described in Section 1.2 of Chapter III.

Where tailings are utilized as structural components of the tailings dam, the behavior of the tailings under load and other conditions must be well understood. Some tailings dams may require efficient seepage collection and water treatment systems or utilize geomembranes and other geosynthetics for seepage control and other purposes. The hydrologic performance of tailings dams varies significantly from water dams; for example, overflow spillways are commonly not utilized for tailings dams that are continuously or regularly raised during operation. Consequently, water management plans with complex water balances and monitoring programs must be required to ensure the operating limits on the tailings dam are not exceeded, and must be updated regularly with precipitation records, mill production, impoundment bathymetry and current forecasts.

Dam owner/operators must implement monitoring programs for tailings dams that may include geotechnical and environmental instrumentation to collect data for evaluation of the performance of the tailings dam system such as monitoring wells, piezometers, thermistors (thermometer nodes), inclinometers, survey monuments, meteorological stations and other monitoring devices as appropriate for the specific site. Emerging technologies may be utilized in tailings dam monitoring programs such as satellite monitoring or artificial intelligence. The complexity of the monitoring program will be driven by the design and operation of the tailings dam and the respective risk of adverse performance and failure. Continuous risk management programs may be required for tailings dams that include consideration of the complete tailings dam system and the consequences of failure determined by the hazard potential classification as discussed in the *Model State Dam Safety Program* (FEMA 316), *Hazard Potential Classification System for Dams* (FEMA 333) or other failure consequence classification schemes consistent with local regulations. In some cases, monitoring for critical performance parameters such as seepage and structural integrity may be required indefinitely after closure. In such cases, site-specific financial assurances may be required for the post-closure scenario.

The hydrologic performance of tailings dams varies significantly from water dams; for example, overflow spillways are commonly not utilized for tailings dams that are continuously or regularly raised during operation.

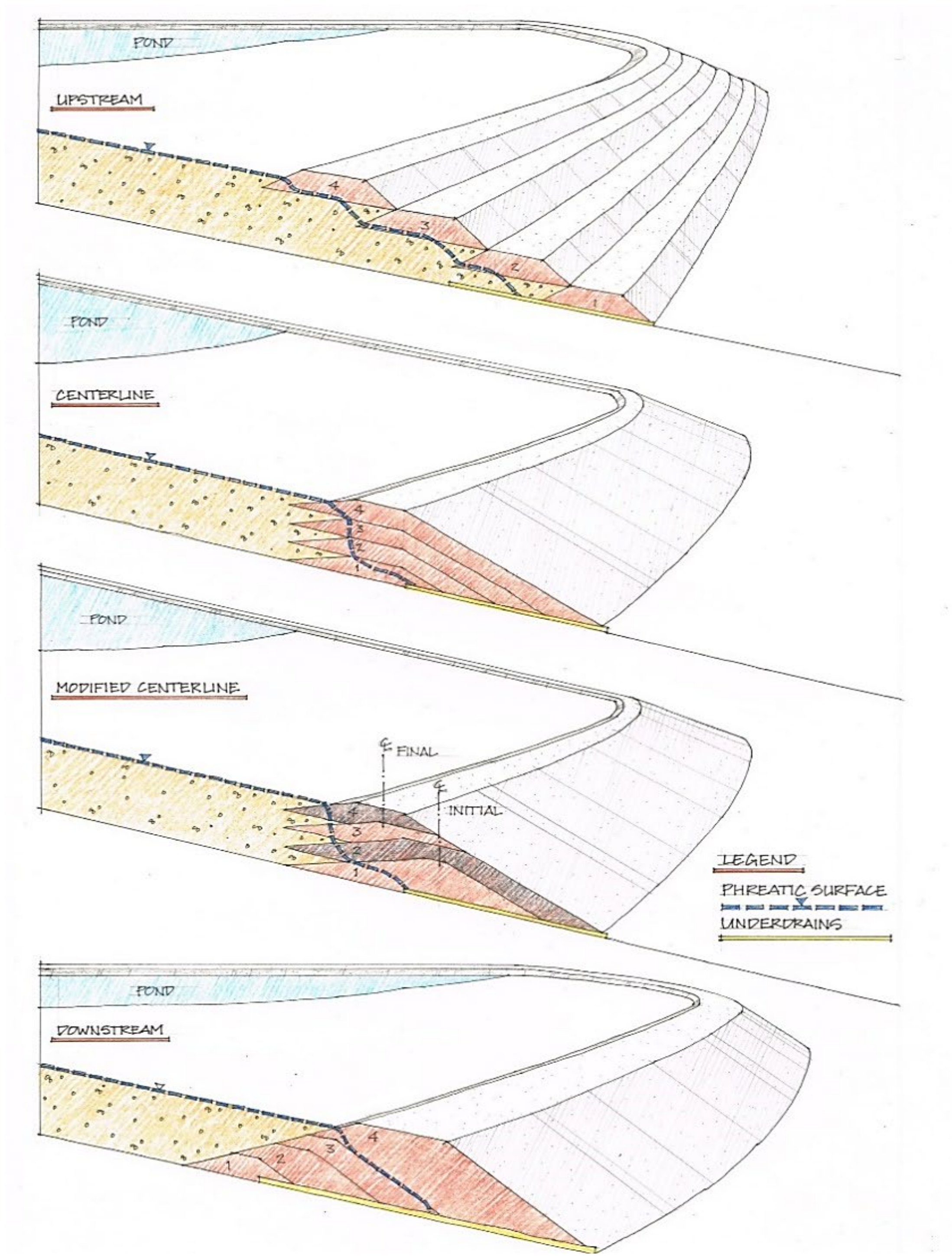

Figure III-1. Types of tailings dam construction methods[1] (Courtesy BGC Engineering)

[1] This figure is for illustration only and does not reflect actual design or performance information. Tailings and embankment fill are shown in contrasting hatching, however in some cases, embankment fill may consist of tailings.

When impoundments behind tailings dams are full, the tailings storage facility is closed and reclaimed, referred to as closure. Closure can also be required if operations cease early for any reason, typically referred to as pre-mature or unplanned closure. The future behavior of the tailings dam and the tailings must be estimated and described for the post-closure phase early in the planning process and refined throughout the design and operation phases. Closure and reclamation may include removing ponds formed by water expelled from tailings as consolidation occurs, capping the tailings deposit with engineered covers that may include geosynthetic materials and growth media for vegetation, construction of surface drainage ditches and spillways, or other work to meet federal, state or local reclamation standards. Where tailings deposits create environmental hazards such as acid rock drainage or metal leaching, special considerations may be required to promote "chemical stability" such as permanent water covers (Wilson, et.al., 2015).

In some cases, tailings dams may be closed and reclaimed into landforms where dam safety regulations may be removed or relaxed. In other cases, tailings dams must function as dams for an indefinite post-closure phase. In any case, the closure of the tailings dam must be considered in the initial planning and design to ensure that any foundation requirements such as underdrains are included in the initial construction of the tailings dam. Operating plans must be implemented to achieve the anticipated outcome at closure. See Section 4 of Chapter V for more information about tailings dams in closure and post-closure scenarios.

1.2. Typical applications of tailings dams

Tailings dams occur in multiple industries that generate slurry waste products including mining, smelting and refining, energy production and other industries. Dredging operations may utilize tailings dams for sediment confinement. (USACE, 1987). Historically, the energy production industry hydraulically discharged flyash, also known as coal combustion residuals (CCR), into storage facilities that utilize tailings dams; however, after the failure incident in Kingston, Tennessee in 2008, CCR disposal is now regulated under Subtitle D of RCRA. Placer mining operations may also utilize tailings dams for sediment management, even though there are no mill facilities. Typical applications of tailings dams are shown in Figures III-2 through III-11. This is not a complete review of all applications of tailings dams.

Figure III-2. Tailings dam at hard rock mine constructed by the upstream method (Google Earth, 2017)

Figure III-3. Tailings dam at hard rock mine constructed by the centerline method (Google Earth, 2016)

Figure III-4. Tailings dam at hard rock mine constructed by downstream method (photo by Al Ott)

Figure III-5. Zoned-fill tailings dam constructed by downstream method at hard rock mine under transition to the modified centerline method for raises (photo by Chandler Engel)

Figure III-6. Sand tailings dam for waste clay settling pond at soft rock mine (Google Earth, 2016)

Figure III-7. Tailings dam at confined dredge material management area (Google Earth, 2019)

Figure III-8. Coal combustion residuals disposal at power generation facility (Bing)

Figure III-9. Phospho-gypsum stack (Bing)

Figure III-10. Reclaimed tailings beach on tailings dam at hard rock mine in post-closure phase (photo by Dave Enos)

Figure III-11. Reclaimed tailings dam at remote placer mine in post-closure phase (photo by Charles Cobb)

2. Regulatory Authorizations, Public Process and Risk Management

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems
▪ Clearly defined requirements in regulation necessary for the regulatory agency to support an informed decision to issue or deny authorizations and contest appeals ▪ Clearly defined administrative regulations to support agency policy for public process and official public notice in tailings dam regulatory actions and decisions ▪ Clearly indicate whether interim authorizations necessary to develop the appropriate detail over the subsequent project phases including closure may be subject to public process or public notice
Considerations for Regulators
▪ What is a defensible and informed regulatory decision? ▪ How are the interests of multiple stakeholders accounted for in decisions? ▪ Permitting schedules must consider state program policy and procedures for public notice or engagement including regularly occurring authorizations as expected for tailings dam systems such as construction and operations progress, safety reviews, or as conditions change ▪ How can risk management inform and defend decisions?
Recommendations
▪ The primary outcome of all decisions must be to protect public interest and to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption ▪ Consider multiple stakeholders in all decisions ▪ Public process, notice and posting should be consistent with state policy and supported by respective administrative regulations ▪ Maintain detailed records of permit applications and correspondence to support decisions including decisions subject to review by public process or records requests ▪ Use risk management techniques to the degree and extent necessary to support project development and dam safety objectives at all life phases of the tailings dam including portfolio management ▪ Use a team of qualified experts including the dam owner/operator and engineer/designers of record to conduct risk assessments using the most appropriate tools depending on the intended objectives, the complexity of the project and the hazard potential classification of the tailings dam system ▪ All decisions should be based on a complete permit application demonstrating a reasonable standard of care and sound, reasoned judgement, with appropriate consideration of risk at all stages of the project development

Regulatory agencies must make significant decisions to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. All decisions should be based on sound, reasoned judgement supported by a complete permit application and relevant correspondence. For some projects, multiple stakeholders can be affected by project development, regulatory decisions and other factors that significantly influence decisions. Risk reduction drives dam safety concepts and risk management should factor into regulatory decisions in several ways including project-specific risk identification and mitigation, and portfolio risk assessments. The following sections elaborate on these points.

2.1. Regulatory authorizations

The primary purpose of regulatory authorizations for tailings dams is to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. Regulatory authorizations must be based on compliance with the respective regulations. Records of permit applications and reviews should be maintained, including regular project submittals and correspondence, to demonstrate a complete permit application and a considerate, defensible review of the permit application and project details. Detailed records supporting regulatory decisions are imperative and may be subject to public disclosure and review, either by policy or public records requests, as discussed in Section 2.2 of Chapter III. Where regulatory decisions may be appealable, appropriate notices with specific statutory and regulatory citations should be included with decision letters, permits, or other authorizations. All decisions should be based on a complete permit application, and revisions if applicable, demonstrating the minimum standard of care set by regulation for the safety of the proposed work. Appropriate consideration of risk as described in Section 2.3 of Chapter III should occur during the permit application process for all phases of the life of the tailings facility.

2.2. Public process, official public notices and posting

2.2.1. PUBLIC PROCESS

Tailings dams can be complex systems and where large tailings dams are planned for facilities such as modern mining operations or other industrial developments, many different stakeholders have an interest in unique and often interrelated aspects of the project. For purposes of this discussion, public process infers an invitation from the regulator for public comments on a proposed action or decision of the agency. No inference is made herein regarding how the regulator considers or manages those comments to provide flexibility for the wide range of options that are subject to department policy beyond the scope of the *Tailings Dam Supplement* to address. In any case, public process should be consistent with agency policy and supported by respective administrative regulations.

Public processes associated with tailings dams may occur at federal or state levels, often incidental to the larger industrial project that may include other features or purposes such as mines, mineral processing, energy production, harbors and waterways maintenance and other activities.

For purposes of this discussion, public process infers an invitation from the regulator for public comments on a proposed action or decision of the agency. No inference is made herein regarding how the regulator considers or manages those comments to provide flexibility for the wide range of options that are subject to department policy beyond the scope of the Tailings Dam Supplement to address.

Where federal authorizations are required, federal agencies are subject to public process provided under NEPA, as described in Section 3.2 of Chapter II. This may include the development of environmental assessments (EA) and environmental impact statements (EIS). These documents may identify a tailings dam as part of a project and evaluate the environmental impacts, but the design, construction and operation documents may not be developed in sufficient detail to satisfy a dam safety program review as described in the *Tailings Dam Supplement* and to support authorization as described in Section 2.1 of Chapter III. This may be true for land use and other authorizations at state and local levels. Consequently, federal, state and local reviews and respective authorizations may occur on different schedules.

In the mining industry, companies typically use internal "stage gate" milestones to manage development of projects that may include tailings dams. An example stage gate approach is shown on Figure V-1 in Chapter V. The regulatory milestones shown on the project development continuum may, on a case-by-case basis, be appropriate for public process or public notice as discussed in following Section 2.2.2 of Chapter III. For example, initial construction authorizations for new tailings dams including detailed design for starter dam construction, as well as consideration for full build out of the tailings dam system in the "design for closure and reclamation" described in Section 1.1 of Chapter V may be appropriate points for public comment. However, an authorization such as a construction approval for an interim level of the tailings dam system already approved for full build out, or a routine operating approval or regulatory orders after a comprehensive dam safety review as described in Section 2.5.3 of Chapter IV, may merit a public notice or posting. Duplicative public comment periods for a specific project should be avoided at multiple levels of permitting, apart from major changes, if possible.

Agencies should endeavor to coordinate, streamline and organize opportunities for public comment and public notices for regulatory authorizations of tailings dam systems, or otherwise ensure dam safety regulators are aware of public comments on respective projects.

In a broader project development sense, land and water use authorizations that could include disposals of interest, water use, waste and water discharge, institutional controls, zoning or other restrictions may be considered for public process. If the applicant is aware that these authorizations may involve further future development of a tailings dam system, the disclosure of this information is appropriate. Agencies should endeavor to coordinate, streamline and organize opportunities for public comments and public notices for regulatory authorizations of tailings dam systems, and to otherwise ensure dam safety regulators are aware of public comments on respective projects.

A full discussion of federal public process for tailings dams is outside the scope of the *Tailings Dam Supplement*, as is a full review of public processes in all the state and local jurisdictions.

2.2.2. OFFICIAL PUBLIC NOTICES AND POSTING

Official public notices from regulatory agencies may be published on websites, in press releases, classified ads, or other media to provide transparency in government business. Official public notices are often required by state administrative procedures for appealable decisions whether comments are considered as discussed in Section 2.2.1 or not. In contrast, public posting of certain information may occur on some agency websites as a matter of form without an official notice but may not be as widely distributed as a public notice. Because of high profile tailings dam failures, the public interest increased for reports on dam safety inspections and reviews as described in Section 2 of Chapter IV. Such reports may be subject to public information requests or pro-actively posted based on agency policy while balancing considerations of site operational and physical security, and appropriate protection of confidential business information provided under applicable state law. Any regulations that increase public notices or postings should consider the value of information being provided relative to the resources required by the regulator to post such information. The following considerations are offered for public notice and posting for tailings dam regulatory programs:

- Premature closures and default situations where extraordinary circumstances merit unusual responses such as claims on financial assurance or receivership may merit public notice or press releases
- Planned closure, post closure operations, transfers of custodial care or financial responsibility, or de-regulation of tailings dam systems may require authorizations subject to public notice
- Dam safety regulatory authorizations for initial construction and raises, interim authorizations and renewals, and authorizations for closure modifications and post-closure operations may merit public posting
- Routine safety or performance reports, comprehensive tailings dam safety reviews, or independent technical review panel reports if required by regulatory authority may merit public posting in some cases

> *Official public notices are often required by state administrative procedures for appealable decisions whether comments are considered or not…Because of high profile tailings dam failures, the public interest increased for reports on dam safety inspections and reviews.*

Federal policy in some cases limits public access to certain information related to dams such as vulnerability assessments, condition assessments, and consequences of dam or component failures. The USACE considers dams listed in the NID as critical infrastructure defined by the Uniting and Strengthening America by Providing Appropriate Tools Required to Intercept and Obstruct Terrorism (USA PATRIOT) Act of 2001 (P.L. 107-56) (CRS, 2019). However, the Final Rule for Disposal of Coal Combustion Residuals from Electric Utilities promulgated by the EPA on December 9, 2014, requires posting of hazard assessments, stability evaluations, inspections, emergency action plans, and other information on a publicly available internet site because value is placed on transparency and public disclosure related to the stability of CCR storage facilities (40 CFR 257.107) (EPA, 2014).

Agencies charged with protecting the public interest should exercise discretion when deciding what information must be restricted from public disclosure to properly protect the public, while providing an appropriate level of transparency.

2.3. Risk management

Considerations for Regulators
Useful questions to ask about risk management for tailings dam systems include:

- Do risk management measures take into account: physical and chemical hazards of the tailings facility; downstream development and population growth; changing environmental conditions including climate and water quality; geohazards and cascading events (e.g., earthquakes, landslides, avalanches, structures failing upstream of the facility, potential for breakthrough of impoundment into adjacent or underlying mine workings, etc.)?
- Has risk avoidance been incorporated into the design to the extent practicable?
- Do risk management measures take into account aspects that may be external to the dam owner/operator and the tailings facility including regulatory and permitting risks (e.g., permit denial or revocation, permit violations, not obtaining permits in a timely manner, or permits that are not aligned with the design intent of the tailings facility)?
- Has a risk management plan or unusual occurrences plan been prepared and documented that describes controls to recognize and prevent a failure from occurring, or mitigate the incremental consequence after a failure has occurred?
- Have critical controls been identified from the risk controls?
- Has the risk management plan been implemented in the project's business plan and is corporate management responsive to implementation and recommendations of risk management plans?
- Is the risk management documentation, including the risk assessment record, reviewed and updated as necessary in the event of any changes not anticipated at the beginning of design (e.g., mine life extensions, suspensions to care and maintenance, re-starts, and process and technology changes)?
- Are risk assessments completed and/or updated at a frequency that supports the objectives of the tailings management activities for that facility?

- Is the risk assessment scope, context and evaluation criteria well defined prior to undertaking a risk assessment including tolerable or acceptable levels of risk?

Reducing risk is the driving force behind dam safety concepts. Risk management is the "overarching" framework under which various tools are used to make important decisions about risk from dams. Risk Informed Dam Safety Decision-Making (RIDSDM) is a method of dam safety evaluation that uses the likelihood of loading, dam integrity or fragility, and consequences of failure to estimate risk and implies:

> …decisions are made considering risk estimates and many other contributing factors that might include confidence in the risk estimates, risk uncertainty, deterministic analyses, and the overall dam safety case in addition to other local or regional considerations. (FEMA P-1025, 2015)

Consideration of risk is used on top of standards-based analyses to decide if additional dam safety investments are justified or warranted based on the consequences of an adverse event. Many benefits from this approach include a greatly improved understanding of the safety of the dam and identification of dam safety vulnerabilities that have not been identified or appropriately mitigated using standards-based evaluation techniques. The RIDSDM approach is the process of making safety decisions by evaluating if existing risks are tolerable and present risk controls are adequate, and if not, whether alternative or additional risk reduction measures are required. For entities that own or regulate dams, various decisions are made regarding an individual structure or an inventory of structures, including decisions about:

- The safety of a structure
- Necessary actions to reduce risks
- Prioritization of actions for an individual tailings dam or inventory of structures

Risk management is the systematic application of management policies, procedures and practices to the tasks of identifying, analyzing, assessing, mitigating, monitoring, making decisions and communicating risk.

The discussion and application of risk management used in the *Tailings Dam Supplement* is based on the framework and terminology described in *Federal Guidelines for Dam Safety Risk Managemen*t (FEMA P-1025, 2015) and may be applied to unique decisions, individual projects or for portfolio risk management. FEMA P-1025 describes risk:

> The term *risk,* when used in the context of dam safety, is comprised of three parts:
>
> 1. the likelihood of an occurrence of a load (e.g., flood, earthquake, etc.);
> 2. the likelihood of adverse structural performance, (e.g., dam failure, damaging spillway discharge, etc.); and

3. the magnitude of the incremental consequences resulting from that adverse event (e.g., life loss, economic damages, environmental damages, etc.)

Risk management builds on risk analysis and risk assessment phases as presented in the framework for risk management shown in Figure III-12.

Risk management is the systematic application of management policies, procedures and practices to the tasks of identifying, analyzing, assessing, mitigating, monitoring, making decisions and communicating risk. Risk management can be a complex process that requires careful attention to details to establish credibility in the assessment of risk and potential mitigation measures. When properly executed and applied, risk management for tailings dams can be measurably and demonstratively proven to reduce risk (Oboni, et.al., 2013). However, risk is a multi-faceted concept that is extremely difficult to convey, and practical application of risk management and effective communication of risk are often as elusive as the uncertainty that risk management endeavors to address. Risk management must occur in both the regulatory program and the dam owner's tailings and water management policies and protocols and should be interpreted independently.

Risk management is fundamental to a dam safety program and integral to informed decisions and safe design and must occur across the phases of a regulated facility's life. Risk management must adapt to changing conditions which could require changes in design and operation of tailings dams. Corporate risk management may cause changes to the tailings and water management policies and protocols for a dam owner/operator and regulatory requirements must be adaptable. In addition to risk identification and mitigation on each individual project, portfolio risk assessment on tailings dam inventories for both the regulator and the dam owner/operator can identify and target high risk projects to effectively utilize resources for risk mitigation.

Tools under the risk management framework include the estimation, evaluation, analysis and assessment of risk, and respective measures to control risk. Risk analysis estimates and evaluates risk to individuals, populations, property or the environment from hazards such as tailings dams. Estimating risk involves the scientific characterization of what is known and what is uncertain about the present and future performance of the tailings dam system under certain loading conditions as well as the consequences of various failure modes. Risk evaluation is the process of examining and judging the significance of the risk where values (societal, regulatory, legal, and dam owner/operator) and value judgements enter the decision process, explicitly or implicitly.

Risk assessment assimilates the risk analysis and risk evaluation phases. Risk assessment considers the risk analysis and the associated social, environmental, economic, and other factors to identify and evaluate a range of alternatives for managing the risks. The process is used to recommend decisions on whether present risk measures are adequate and existing risks are tolerable, and if not, whether alternative risk reduction measures are justified and should be implemented to reduce the risk to "as low as reasonably practical" (ALARP). Risk analysis and risk evaluation should be completed as frequently as required within the risk management framework and to the degree necessary to define the risk controls needed to meet the dam safety objectives established for any given facility including the identification of "critical controls" as described in Section 3.1.2 of Chapter V.

Risk assessments can be conducted in various forms within the risk management framework. FEMA P—1025 defines ALARP and describes tools used for risk assessment including potential failure mode assessment (PFMA), screening level risk assessments, qualitative and quantitative risk assessments, and risk communication methods such as probability vs. consequence charts (f—N and F—N plots and risk matrices). Other tools range from qualitative methods such as hazard and operability studies (HAZOP), semi-quantified methods such as failure modes and effects analysis (FMEA) (Robertson and Shaw, 2006), bowtie, decision-tree, or event tree through to quantitative risk assessments (Oboni et.al., 2019), or complex statistical analyses utilizing Monte-Carlo simulations.

A team of qualified experts including the dam owner/operator and engineer/designers of record is recommended to conduct risk assessments using the most appropriate tools depending on the intended objectives. Subjective and objective decisions during the risk estimation and evaluation that informs risk assessment depends heavily on professional expertise and judgement of the evaluators. Risk analysis may be subject to significant bias if not carefully conducted (Thomas, et.al., 2014). Consequently, regardless of the tool(s) used, the risk assessment should be facilitated and conducted by an experienced professional, supported by a multi-disciplinary group including dam owner/operator's technical staff described in Section 4.2 of Chapter III and subject matter experts, depending on the complexity and hazard potential of the project. For some projects, regulators and independent parties with special expertise may be invited to participate in a risk assessment conducted by the dam owner/operator. In any case, a commonly recognized approach to the risk assessment is recommended, such as the following detailed guidance:

- *Federal Guidelines for Dam Safety Risk Management* (FEMA P-1025, 2015)
- *Best Practice in Dam and Levee Safety Risk Analysis* (USBR, 2019)
- *ISO31000:2018 Risk Management–Guidelines* (ISO, 2018)
- *U.S. Guidelines on Tailings Dam Safety* (FEMA, 2025)

Private companies that conduct completely internal risk assessments using these or other methods may or may not share outcomes with regulators. Unless disclosures of such risk assessments include a respective mitigation plan which the tailings dam owner/operator wishes to pursue, the regulator should not accept risk assessments as assurances of safety without other corroborating evidence.

Risk communication is a critical component of an effective RIDSDM process that must be integrated into all aspects of the regulatory process. Risk communication is essential within the relationship between the dam owner/operator and the regulatory agencies and between other individuals or organizations that are stakeholders in the tailings facility or would be impacted by its failure. Regulatory authorizations should clearly require compliance with any risk controls such as performance requirements (Section 1.5.2 of Chapter V), design criteria (Section 1.5.4 of Chapter V) and OMS requirements (3.1 of Chapter V) including those identified as critical to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. A full discussion of risk management is beyond the scope of the *Tailings Dam Supplement*. For more information, visit the USACE Risk Management Center online.

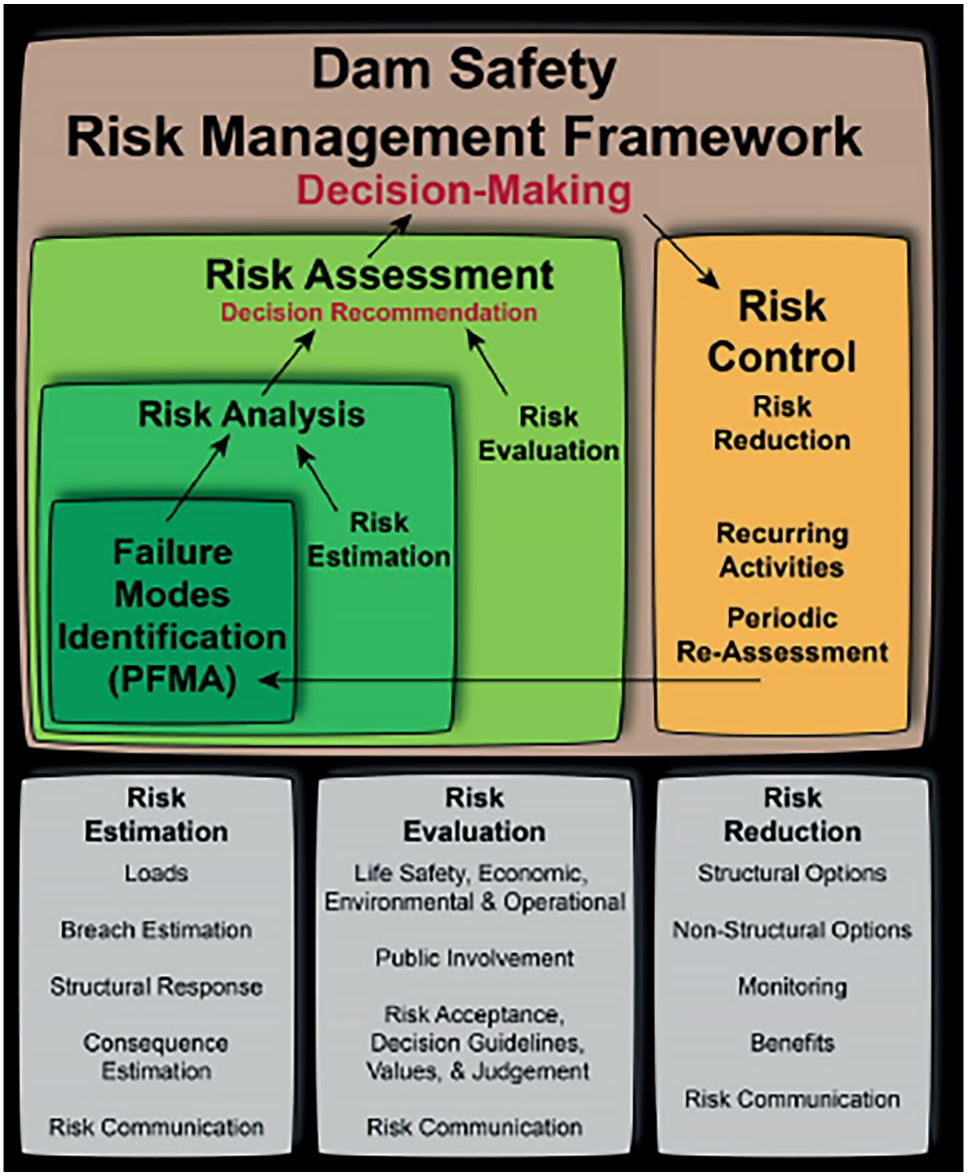

Figure III-12. Relationship between dam safety risk analysis, risk assessment and risk management (FEMA P-1025, 2015)

3. Coordination with Other Standards

The *Tailings Dam Supplement* was developed and intended to be consistent to the extent applicable in consideration of emerging standards and initiatives as described in detail in the *History of the Tailings Dam Supplement* included in Appendix B. In "Geotechnical Risk, Regulation and Public Policy" (2018), Dr. Norbert R. Morgenstern described the complex evolution of tailings dam history and regulation and concluded:

> The responsibility for improving the safety culture associated with the performance of tailings storage facilities through all cycles of their life resides primarily with the operators. While regulators also have a role, it is necessarily subordinate to the role of operators. Experience reveals that the advance of this safety culture to the goal of zero failures requires intrusion into not only the activities of the operator, but also into the activities of the engineer(s). However, this intrusion must not be so prescriptive that it needlessly limits the creative input from both the operator and the engineer.

The Tailings Dam Supplement is narrowly focused to address regulatory guidance for tailings dam systems regardless of the industry, and specifically intended to limit or exclude guidance on corporate policies, broad stakeholder engagement and detailed technical engineering.

Every regulator should strive to maintain the boundaries between regulation and design and operation of the tailings storage facility while ensuring the safety of the dam. To ensure the safety of the tailings dam, Dr. Morgenstern suggests that the regulatory requirements are based on a "tailings management system" concept that incorporates principles described as "Performance Based Risk Informed Safe Design, Construction, Operation and Closure (PBRISD) [sic]." These concepts are incorporated in the Tailings Dam Supplement as described in detail in Appendix B.

The *Tailings Dam Supplement* progresses beyond Dr. Morgenstern's recommendation for regulatory requirements to be based on a "tailings management system" that includes PBRISD, to recommend commitments to "tailings and water management policies and protocols" as a primary responsibility of the dam owner, as described in Section 4.1 of Chapter III.

The genesis of the *Tailings Dam Supplement* began in 2015 after tailings dam failures at the Mount Polley Mine in British Columbia, Canada and the Samarco Mine in Minas Gerais, Brazil. During the development of the *Tailings Dam Supplement*, the scope of work was narrowed to address regulatory guidance for tailings dam systems regardless of industry, and specifically intended to limit or exclude guidance on corporate policies, broad stakeholder engagement and detailed technical engineering.

The drafting of the *Tailings Dam Supplement* occurred concurrently with, but independent from, the *Global Industry Standard on Tailings Management* (GISTM) published by the Global Tailings Review on August 5, 2020. However, the *Tailings Dam Supplement* is narrowly focused on tailings dams regardless of the industry and is directed toward regulators, whereas the GISTM is broadly focused on tailings management exclusively for the mining industry and is directed to the operator (GTR, 2020).

The *Tailings Dam Supplement* is generally consistent with concepts of the GISTM where tailings dam safety related requirements are listed, but does not address technical guidance, other issues faced by the mining industry or corporate practices beyond the extent it effects the safety of the tailings dam system. For example, the *Tailings Dam Supplement* defers using the term "tailings management system" used in the GISTM, even though the term was used by Dr. Morgenstern in describing a regulatory system based on PBRISD. Instead, as noted, the *Tailings Dam Supplement* refers to tailings and water management policies and protocols as the responsibility of the dam owner as discussed in Section 4.1 of Chapter III, tailings dam systems as described in Section 1 of Chapter III, and tailings processing and transport systems as described in Section 1.2.1 of Chapter V. The *Tailings Dam Supplement* intentionally avoids technical guidance such as design criteria and there are no definitions for the responsible persons listed in Section 4.2 of Chapter III. A more detailed review of the GISTM is included in Appendix B.

Important subjects described in the GISTM that diverge from common standards in the US include the consequence classifications and specific design criteria for hydrologic and seismic parameters.

Notable international references related to tailings dams include publications of the International Commission on Large Dams (ICOLD), the Australian National Committee on Large Dams (ANCOLD), the Canadian Dam Association (CDA) and the Mining Association of Canada (MAC). These publications are referenced in the *Tailings Dam Supplement* which is tailored to specifically address regulators, whereas the international publications typically address broader or different audiences, or include significant technical details specifically excluded from the *Tailings Dam Supplement*, as previously noted.

In order to help provide consistency for the benefit of industry and engineering consultants, as well as to promote dam safety and to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption, the *Tailings Dam Supplement* was developed in consideration of well-known references and more recent publications since 2014. The *Tailings Dam Supplement* borrows a concept from the CDA by serving as a dependent supplement to the *Model State Dam Safety Program* (FEMA 316), but as previously noted, is targeted to regulators. The *Tailings Dam Supplement* is also intended to be generally consistent with the requirements of the British Columbia and Alberta regulations. However, the *Tailings Dam Supplement* and the *Model State Dam Safety Program* (FEMA 316) do not have the authority of regulations under publications of the National Dam Safety Program. The authority must be established, and the appropriate regulations developed, for the respective US regulatory agency as described in Chapter II.

4. Qualified Applicant

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems
▪ Clearly indicate requirements to identify a qualified applicant and other parties responsible for the tailings dam system in the regulatory permitting process ▪ Require demonstration of financial responsibility to ensure tailings dam closure and post-closure performance to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption ▪ Financial assurance in appropriate form consistent with state law to secure the performance of closure and reclamation and post-closure requirements against a default by the dam owner/operator, with the amount of financial assurance subject to approval by the regulators on a site-specific basis ▪ Construction, operation and closure authorizations contingent upon demonstration of compliance with financial assurance requirements
Considerations for Regulators
▪ Who owns, designs, constructs, operates and closes tailings dams? ▪ Why is financial assurance important and what is involved?
Recommendations
▪ Applicants and all responsible parties must be appropriately licensed businesses, persons, or other entities consistent with requirements of the respective business and occupational licensing agencies in the area of the project ▪ Parties responsible for tailings dam project development, construction and operation should disclose internal tailings management policies and commitments including designing for closure ▪ Applicants should demonstrate financial ability to provide for the safety of the proposed work at all phases of the tailings dam life including construction, operation, closure, reclamation, and long-term care and maintenance in the post-closure phase, if required.

State or federal regulatory agencies must be able to legally identify the responsible parties for an permit application because certain legal and administrative actions are involved in the regulatory process. For example, enforcement actions could be imposed on a responsible party. All responsible parties must have appropriate corporate, business, and professional licenses required by state law. The responsible party must be qualified to take on the respective liabilities associated with a tailings dam and depending on the complexity of the system, which may, in appropriate circumstances, be demonstrated through appropriate documentation including insurance, when and where available and practical to obtain, and relative, sensible, corporate assurances consistent with state laws, where applicable. The applicant should be initially qualified by paying an appropriately developed permit application fee sufficient to fund reasonable technical and administrative reviews by regulators including site visits at periods during construction and operation. The applicant should demonstrate further qualifications by providing appropriately developed financial assurance for modifications for closure and reclamation (prorated to allow for concurrent reclamation) and post-closure operation if necessary. Other qualifications must be demonstrated through corporate policies and commitments as described below including the technical information established through the project planning and permitting processes required by statutes and regulations, such as water and tailings management plans described herein.

4.1. Corporate and dam owner commitment and management policies

An applicant may be further qualified by submitting written commitments to corporate tailings management policies or international standards of care developed by trade associations or independent, internationally recognized entities. Recommendations for such commitments that can affect the safety of the dam, subject to the control of the dam owner and operator include:

- Designing for closure and reclamation to account for foundation level design elements for construction of starter dams and raises, and conceptual closed configurations to allow for relatively accurate cost estimates for, closure, reclamation and post-closure operations, if necessary

- Tailings and water management policies and protocols as necessary to ensure the safety of the tailings dam formally considered by the dam owner or operator, from design through construction, operation, closure and reclamation, beyond any minimum regulatory requirements and with business procurement practices that ensure quality of engineering over discount services

- Information management systems to ensure that documentation for scheduling, planning, design, operations, maintenance, surveillance, inspections, evaluations, emergency response, and other information are readily accessible and current

- Quality management and assurance systems that ensure the work of employees, consultants, contractors, and other parties under the responsibility of the qualified applicant is of sufficient detail and quality to ensure the safety of the tailings dams as described in Section 3.3 of Chapter V

4.2. Responsible persons

The following responsible and qualified persons should be clearly identified:

- Tailings dam owner/operator

- For companies operating in the US, the registered agent for the business entity

- Designated, corporate officer responsible for the facility such as the accountable executive officer described in the GISTM (GTR, 2020a)

- Project operations manager or supervisor

- Engineering or technical services manager for tailings facility
- Engineer and/or designer(s) of record for tailings dam system
- Resident construction engineer and other construction quality assurance personnel
- Inspection engineer for leading dam safety reviews required by regulations

The *Tailings Dam Supplement* generally refers to the dam owner/operator as the same entity and the engineer/designer of record as the same entity but recognizes that multiple parties may exist on most projects with respectively different responsibilities including different companies and their staff. Because of the wide variety of projects, business models, contractual relationships, professional licensing laws and other factors, no additional distinctions are provided in the *Tailings Dam Supplement*.

4.3. Quality assurance, engineering oversight and independent technical review

Quality assurance is imperative from design through construction and operation and closure. Quality assurance must be based on a systematic application and documentation of review and confirmation that reinforces the intent or details of the design including engineering evaluations, the suitability of construction or the conformance of the operation. Projects with complex designs and site conditions or designs distinctly altering or expanding the original site design, and projects with high risks, should include engineering oversight and independent technical review panels that may be internally set up by the dam owner/operator proactively, or compelled by and subject to reporting to the state.

4.4. Financial assurance

Considerations for Regulators

- Identify appropriate instruments for financial assurance such as surety bonds, letters of credit, trusts, etc. depending on factors that include the scope of closure, reclamation and post-closure requirements, the tailings dam owner/operator’s financial strength and assets mix, and other factors
- Financial assurance for post-closure scenarios requiring long term care and maintenance of a tailings dam on public land may require special agreements such as a trust
- The dam owner/operator should demonstrate financial assurance prior to commencing operations and when required, begin funding a trust account on a schedule agreed to prior to commencing operations

- The regulator should ensure dam owner/operator is actively managing all financial assurances to ensure the financial benchmarks established at the outset are being achieved
- Revisit the assumptions used in the initial cost estimates; adjust as necessary, and periodically require financial assurance "true ups" from the dam owner/operator as necessary prior to closure
- Do not defer the financial assurance demonstration, and where using a trust, do not defer full funding of the trust account as a lump sum, until closure
- Officially issue public notice or post financial assurance information consistent with department policy and regulations

An applicant must be further qualified by demonstrating the ability to provide appropriate financial resources for the closure and reclamation of the tailings dam whether the closure is planned or not. The demonstration may include financial instruments available for claim by the regulatory agency in the event of a default by the dam owner/operator. A special situation exists when the tailings dam requires active oversight and maintenance in the closed configuration in order to ensure the safety of the dam. In this case, the amount and form of financial assurance for closure and reclamation may be substantially different from the amount and form of financial assurance for the long-term care and maintenance of the tailings dam for the duration of the post-closure phase. Appropriate and enforceable regulations as discussed in Chapter II must be in place to require and administer such financial assurances.

In many cases, a tailings storage facility may be part of a closure and reclamation plan for a larger project such as a large mine or industrial project and financial assurance may be required by other authorities for other purposes. The financial assurance for such plans should accurately identify and reflect the requirements for the tailings dam system distinct from other parts of the project. Detailed discussions of various specific instruments that may be used to provide financial assurance such as bonds or letters of credit are outside the scope of the *Tailings Dam Supplement*. Trusts are briefly discussed in Appendix C. Tailings dam safety regulators are encouraged to coordinate with other regulatory agencies as described in Section 3 of Chapter II that may have financial assurance requirements for the industrial facility to avoid duplicative demonstrations. See Section 4.1.2 of Chapter V and Appendix C for more detailed discussions of financial assurance for tailings dams.

Tailings dam safety regulators are encouraged to coordinate with other regulatory agencies as described in Section 3 of Chapter II that may have financial assurance requirements for the industrial facility to avoid duplicative demonstrations.

Chapter IV – Existing Tailings Dams

1. Inventory

Inventories of tailings dams should include information unique to the facility consistent with the guidance for the National Inventory of Dams published by the US Army Corps of Engineers including tailings as a purpose for the dam (USACE, 2020a). Inventory data should also indicate the design of the tailings dam based on the method of construction, commonly referred to as downstream, centerline, modified centerline, or upstream construction types as shown on Figure III-1. The impoundment quantities listed should include the design capacity for tailings in dry tonnage, total tailings and water storage capacity including the design storm, and normal and maximum volumes of open surface water (not entrained in tailings pore space) for the stage of the tailings dam under operation at the time of the inventory update. Available freeboard capacity along with hydrologic estimates are useful to measure performance capabilities which is also a measure of risk, reflecting the value of inventory data. The inventory data should indicate whether the tailings dam includes a spillway and the respective design flow capacity. These are examples of quantifiable performance objectives (QPO) discussed in Section 1 of Chapter V. QPOs can be identified with each tailings dam in a portfolio and associated with the inventory and monitoring data through information management systems as described in Section 3 of Chapter VII. Inventory data should be updated to reflect the most accurate information available and used with caution pending verification.

2. Inspections

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems
▪ Inspection requirements and responsible parties including routine and extraordinary inspections, performance monitoring, inspection reporting frequencies, dam safety reviews and standardized inspection and evaluation formats ▪ Authority to require independent inspections and reviews based on hazard potential classification or when indicated by risk assessments ▪ Publication of inspection reports consistent with state policy
Considerations for Regulators
▪ Who inspects tailings dams and how often? ▪ What does tailings dam inspection involve? ▪ What are minimum qualifications for inspectors?
Recommendations
▪ A variety of inspection methods must be considered to evaluate the safety of a tailings dam system

- The "owner-responsible" inspection model described in FEMA 316 is recommended for tailing dam system inspections described herein
- Tailings dam owner/operators should provide for regular inspections of tailings dams systems by qualified inspectors and engineers
- Tailings dams must be inspected by qualified persons sufficiently frequently and to the extent necessary assign a hazard potential classification to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption
- Inspections for complex tailings dam systems should include routine and special visual inspections; instrumentation and performance monitoring; evaluations of collected information; review of design basis and criteria, engineering evaluations and operating plans; observations for changes in the hazard potential classification; and other information
- Regular inspections by regulators, as well as inspections on short notice when necessary
- Inspection requirements should be coordinated with other regulatory programs that may share jurisdiction over the tailings dam system to avoid duplication of effort
- Regulatory agencies should be sensitive to public records requests for inspection reports; redactions may be required to protect confidential information or for security reasons

Tailings dams should be inspected to a scale and scope consistent with guidance provided in the *Model State Dam Safety Program* (FEMA 316) and supplemented here for tailings dams. The full model describes the "owner-responsible" inspection model which is recommended for tailing dams. Monitoring is considered part of inspection and should be conducted consistent with the OMS manual discussed in Section 3 of Chapter V. Inspections are required by dam owner/operators, engineers, regulators, and independent reviewers depending on the complexity of the design, construction, operation, closure, and post-closure requirements of the tailings dam, and the respective risk of adverse performance and failure. Comprehensive dam safety reviews and independent reviews are considered part of the inspection program for existing dams as described in Section 2.5.3 and 2.5.4 of Chapter IV. Tailings dams must be inspected by qualified persons sufficiently frequently using a variety of methods and to the extent necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. Inspection requirements should be coordinated with other regulatory programs that may share jurisdiction over the tailings dam system to avoid duplication of effort.

2.1. Hazard potential classification

Inspections of all tailings dam systems should be conducted to the degree necessary to assign a hazard potential classification in accordance with the *Model State Dam Safety Program* (FEMA 316) and *Hazard Potential Classification System for Dams* (FEMA 333). Additional guidance specific to tailings dams is provided in the *U.S. Guidelines on Tailings Dam Safety.* Hazard potential classification must be reviewed regularly and updated as necessary because the size of a tailings dam increases, operations can change, and downstream conditions evolve over time such as new development in flood zones. The hazard potential classification is one of the primary criteria to determine the standard of care in all regulatory decisions as discussed in Section 2.1 of Chapter III and design, construction, operation and closure criteria described in Chapter V. The GISTM also incorporates the concept of credible failure modes, so it is important to analyze whether a potential failure mode is credible (GTR, 2020). When indicated by analysis of failure modes, credible failure modes that could result in a tailings dam breach and inundation may be modeled as discussed in Section 3.2 of Chapter IV and should be used to inform hazard potential classification assignments when a low hazard potential classification cannot be confidently assigned. The *Tailings Dam Supplement* defers to the above referenced documents for the consequences associated with the hazard potential classifications without elaboration other than to note that the US federal guidelines are generally more conservative than recent international standards, as discussed in Section 3 of Chapter III and Appendix B. The condition of the tailings dam or the probability of failure are not directly considered in hazard potential classifications. No additional guidance on hazard potential classification is provided herein.

2.2. Performance monitoring

Performance monitoring is the concept of defining the expected behavior of a tailings dam for a variety of characteristics, then observing and measuring certain features to determine if the behavior is within the limits of criteria or assumptions used in the development of the design. For example, the factor of safety for the geotechnical slope stability of a tailings dam is dependent on assumptions about the phreatic surface within the embankment and porewater pressure. The phreatic surface can be controlled by internal drains and seepage collection systems and the resultant porewater pressure can be measured by piezometers within the embankment. Therefore, the pore water pressure is an indicator of the performance of both the underdrain and the stability of the embankment. However, performance monitoring is much broader in scope than instrumentation monitoring. Performance monitoring is the essence of the “observational method” which includes not only predictions of expected behavior, but also contingencies for behavior outside of expectations (Peck, 1969). Note that limitations in the ability of the observational method to predict brittle failures common in hydraulically deposited fill demands more from performance monitoring in some cases. A potential failure modes analysis (PFMA) should be conducted to identify failure mechanisms that determine surveillance parameters which can be monitored for normal and adverse behavior as shown in Figure IV-1 (MSHA, 2009). The complexity of the performance monitoring will depend on the size of the project and the consequences of the tailings dam failure and designed to incorporate or adapt to new and emerging technologies to improve the efficiency and effectiveness of the monitoring (Cobb, et.al. 2021). A well-defined performance monitoring program with QPOs can be considered a critical control to mitigate risk as described in Section 2.3 of Chapter III to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption.

A well-defined performance monitoring program with quantifiable performance objectives can be considered a critical control to mitigate risk.

2.3. Inspection schedule

The inspection schedule for tailings dams will be project specific and depend on the type of inspection and the nature of the tailings dam including its purpose; the hazard potential classification; QPOs and other parameters as described in Chapter V; engineering evaluations of accumulated data; observations listed by engineers to be consistent with the "observational method"; steps to predict sudden brittle failures; industrial operation requirements; operational or closed status of the tailings dam; risk management and risk controls; and other considerations to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. For some facilities, continuous monitoring may be required via instrument data loggers, or continuously staffed, operations control rooms with real-time video and data displays and automatic alarms. The dam owner/operator should clearly describe the project specific inspection schedule consistent with regulatory requirements during the initial permitting process and subsequent renewals, and continuously review and update the inspection schedule as conditions merit.

Typically, inspection requirements for a tailings dam system for a complex modern mine may include:

- Supervisory control and data acquisition (SCADA) systems including relevant facility monitoring systems on display in control rooms
- Video displays of critical processes and key operational perspectives in real-time
- Daily inspection, monitoring and recording routines by qualified staff
- Weekly inspection, monitoring and recording routines by qualified staff
- Monthly inspection, monitoring and recording routines by qualified staff
- Annual detailed performance reviews by qualified engineers
- Comprehensive tailings dam safety reviews typically performed on a five-year interval by qualified engineers, as described in Section 2.5.3 of Chapter IV, assuming annual performance reviews
- Independent reviews by specialized engineering experts on intervals commensurate with the risk and the complexity of the specialized subject under review, as described in Section 2.5.4 of Chapter IV
- Event driven inspections caused by heavy precipitation, earthquakes, or unusual conditions discovered in routine or periodic inspections
- Contingency plans for interruptions from pandemic, civil unrest, economic crashes or other causes
- Regular inspections by regulators, as well as inspections on short notice when necessary

The scope and detail of each item is typically progressively more complex. For example, a daily shift technician for a mine tailings dam system may check the decant pond water level, seepage collection system pump operation, pipeline flow rates, and other features. The weekly and monthly inspections would include more observations such as embankment crest and slope alignment, erosion, diversion ditches, tailings beach development, and instrument readings. All routine inspections should be based on a standard checklist typically used as a form for recording the inspection and be reviewed by supervisors or managers. Data must also be collected from inspection forms and recording devices, reduced as appropriate, and be reviewed by qualified engineers.

2.4. Evaluation

Evaluation of inspection information should occur at several levels. Initially, a determination must be made that the observations were valid when collected, for example, some instruments must be properly calibrated before collecting data. The primary evaluation will typically occur by shift supervisors or operators to determine if the observations or data are within normal operating parameters. QPOs with trigger levels as described in Section 1.5.2 of Chapter V make the primary evaluation of certain data convenient. Subsequent evaluations will assimilate inspection information and monitoring data to track trends that may indicate changes in performance that could signal an adverse situation is developing. Current monitoring and data acquisition technologies are resulting in enormous quantities of data that require emerging technologies to evaluate efficiently and effectively, a concept referred to as “Big Data” (Bachus, 2020). However, technology-based systems must be based on real physical parameters defined by qualified engineers, with appropriate quality assurance reviews to ensure the reliability of the system and the evaluation. Regular, comprehensive, tailings dam safety reviews as described in Section 2.5.3 of Chapter IV are required during operations to ensure the safety of the dam and unusual findings or complex technical challenges discovered during the inspections should be carefully evaluated by qualified engineers and reviewed by independent, specialized, engineering experts, as necessary depending on risk.

The following recommendations from the Oroville Dam Spillway Incident Independent *Forensic Team Report* on one of the largest water dams in the U.S. are pertinent for tailings dam systems:

- In order to ensure the safe management of [tailings dam systems], dam owners must develop and maintain mature dam safety management programs which are based on a strong “top-down” dam safety culture. There should be one executive specifically charged with overall responsibility for dam safety, and this executive should be fully aware of dam safety concerns and prioritizations through direct and regular reporting from a designated dam safety professional, to ensure that “the balance is right” in terms of the organization’s priorities
- More frequent physical inspections are not always sufficient to identify risks and manage safety
- Periodic comprehensive reviews of original design and construction and subsequent performance are imperative. These reviews should be based on complete records and need to be more in-depth than periodic general review

- Appurtenant structures associated with [tailings dam systems], must be given attention by qualified individuals. This attention should be commensurate with the risks that the facilities pose to the public, the environment, and dam owners, including risks associated with events which may not result in uncontrolled release of reservoirs, but are still highly consequential.
- Shortcomings of the current Potential Failure Mode Analysis (PFMA) processes in dealing with complex systems must be recognized and addressed. A critical review of these processes in dam safety practice is warranted, comparing their strengths and weaknesses with risk assessment processes used in other industries worldwide and by other federal agencies. Evolution of "best practice" must continue by supplementing current practice with new approaches, as appropriate.
- Compliance with regulatory requirements is not sufficient to manage risk and meet dam owners' legal and ethical responsibilities (IFT, 2018)

2.5. Reporting

Regular reporting to regulatory agencies is necessary for tailings dams under construction and operation. Routine construction and operating inspections should be reported and reviewed as required by regulations; within the context of the dam owner's tailings and water management policies and protocols as described in Section 4.1 of Chapter III; and as described in Sections 2 and 3 in Chapter V. This information should be consolidated, reviewed, and summarized for regulatory reporting in accordance with the following recommendations. In addition to a list of observations, charts and tables of data collected, reports should include a detailed narrative explaining the data and the conclusions reached based on analyses of the data. Tailings dam owner/operators may request confidentiality on some reports or report content, and regulatory agencies should be sensitive to public records requests for respective documents. Redactions may be required to protect confidential information or for security reasons such as vandalism prevention or counter-terrorism. See Section 2.2.2 of Chapter III for more information on public records requests.

2.5.1. ANNUAL MONITORING DATA REPORT

Reports for instrumentation data in tailings dams that require active monitoring should be submitted to the regulatory agency annually. Such reports should be in a form and format that data is clearly presented in a useful manner for review and interpretation of performance. The data may or may not be presented completely in raw format, depending on the measurement, but is typically reduced to meaningful parameters for reporting purposes. Charts and graphs summarizing current and historical data should be included. Any unusual behavior observed in data should be highlighted.

2.5.2. ANNUAL PERFORMANCE REPORT

An annual performance report by a qualified engineer should be submitted to ensure that all monitoring data, field observations, and other supporting information are within the specified operating limits and consistent with quantitative and qualitative performance objectives and parameters. The annual performance report should include:

- findings of a visual inspection of the tailings dam system
- photographs of key features of the tailings dam system including unusual or interesting observations from the visual inspection
- review and evaluation of routine inspection, maintenance, and construction reports
- review and evaluation of monitoring data from annual instrumentation reports and tailings production, material characterization, and shear strength tests
- review of the current water balance including bathymetry surveys, water level forecasts, and raise construction schedules
- conclusions drawn from the review on the condition of the tailings dam, and the performance and safety of the system
- recommendations for follow-up investigations, monitoring or mitigation (Cobb, et.al., 2021)

The report should also provide a list of deficiencies observed at the site along with an explanation why the condition occurred, and the steps taken to prevent recurrence. The report should contain a list of all incidents during the report period, the impacts on the safety of the facility, and steps taken to prevent recurrence. A summary and conclusions on the safety and performance of the tailings dam system with respect to the approved operating limits must be included.

2.5.3. COMPREHENSIVE TAILINGS DAM SAFETY REVIEW REPORTS

Tailings dams should be subjected to a comprehensive dam safety review depending on the hazard potential classification, the design and construction method, the complexity of the tailings dam system, the body of knowledge about the tailings dam and other factors. However, considering the ongoing operational construction of most tailings dams, dam safety reviews are only part of the range of inspections necessary to evaluate the safety of a tailings dam system along with a “holistic” view of the facility, and other independent review mechanisms may meet or exceed the level of assurance that is typically provided by use of comprehensive dam safety reviews (ICMM, 2021). Assuming an annual performance review as described in Section 2.5.2, a five-year interval is reasonably appropriate for a tailings dam designed and constructed under modern engineering practices and in satisfactory condition. Frequency and intensity of comprehensive tailings dam safety reviews should increase to the extent necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. A general dam safety review process which may be used for tailings dams that includes comprehensive reviews is presented in Figure IV-2. More information about comprehensive dam safety reviews is included in the *Model State Dam Safety Program* (FEMA 316) but is generally targeted to water dams. A detailed discussion of comprehensive dam safety reviews is not repeated in the *Tailings Dam Supplement,* however, requirements for comprehensive tailings dam safety reviews should be clearly articulated in regulations.

2.5.4. INDEPENDENT TECHNICAL REVIEW REPORTS

While many tailings dam owner/operators voluntarily retain independent expert review panels to manage risks, independent technical reviews may be required by regulators for tailings dams based on the hazard potential classification or risk assessments. When required by regulation or permit conditions, unredacted reports from independent technical reviews should be made available to all regulatory agencies in a reasonable time frame. Company responses to any issues raised by the independent technical review should also be submitted with the report. Companies sometimes request confidentiality for independent technical reviews which should be considered within the provisions of state public records statutes and regulations. See *Legislated Dam Safety Reviews in BC* (APEGBC, 2016a) and the *Oroville Dam Spillway Incident Independent Forensics Team Report* (IFT, 2018) and other references for more information about independent, multi-disciplinary technical reviews.

2.5.5. REGULATOR'S REPORTS

Regulators should develop reports from all site inspections. The report should include the date of the site visit, weather conditions, identification of regulatory staff and site contacts, descriptions of noteworthy observations including deficiencies, photographs, citations issued, recommendations, action items and other pertinent information.

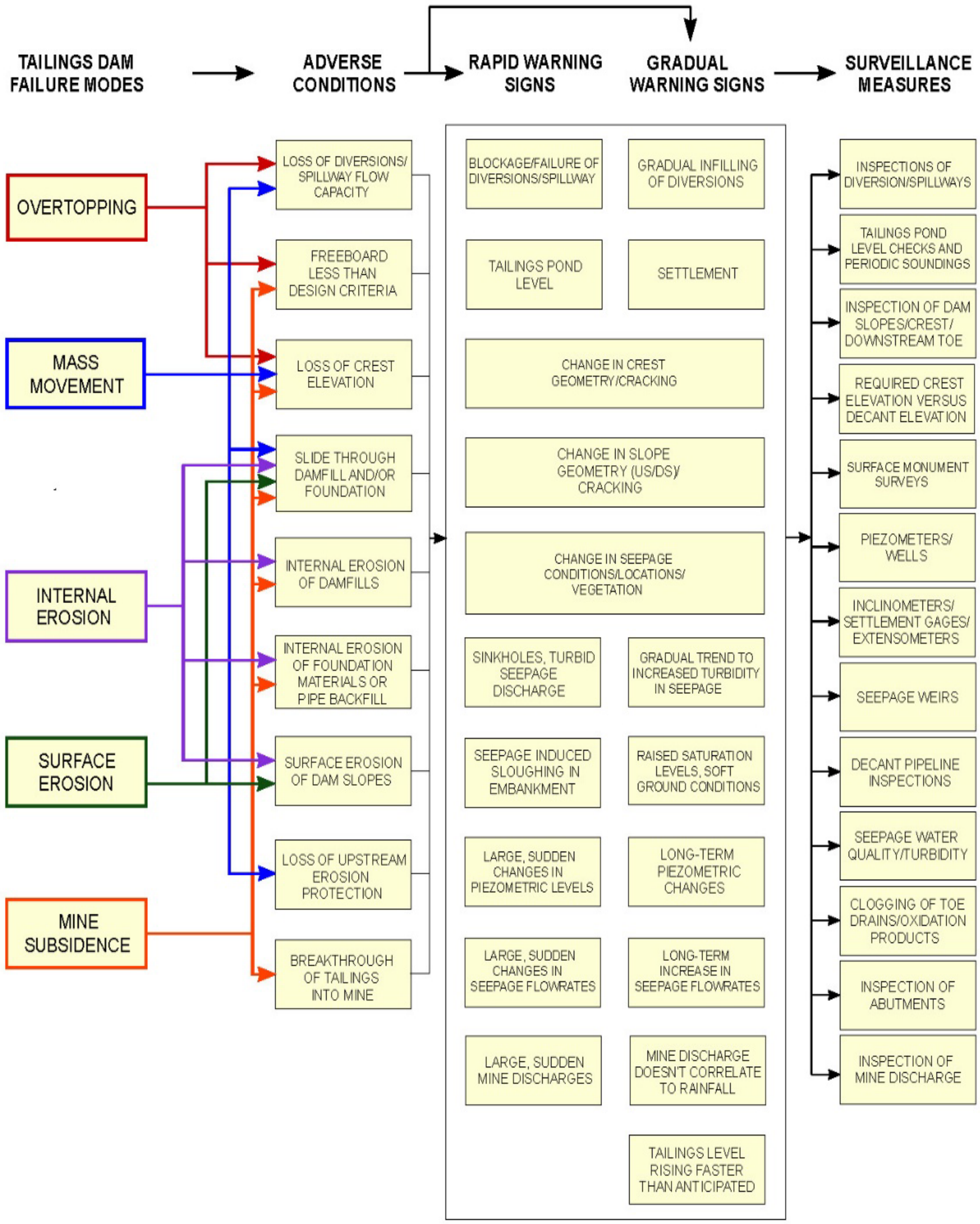

Figure IV-1. Failure modes, warning signs and surveillance measures (MSHA, 2009 – Adapted from Martin and Davies, 2000)

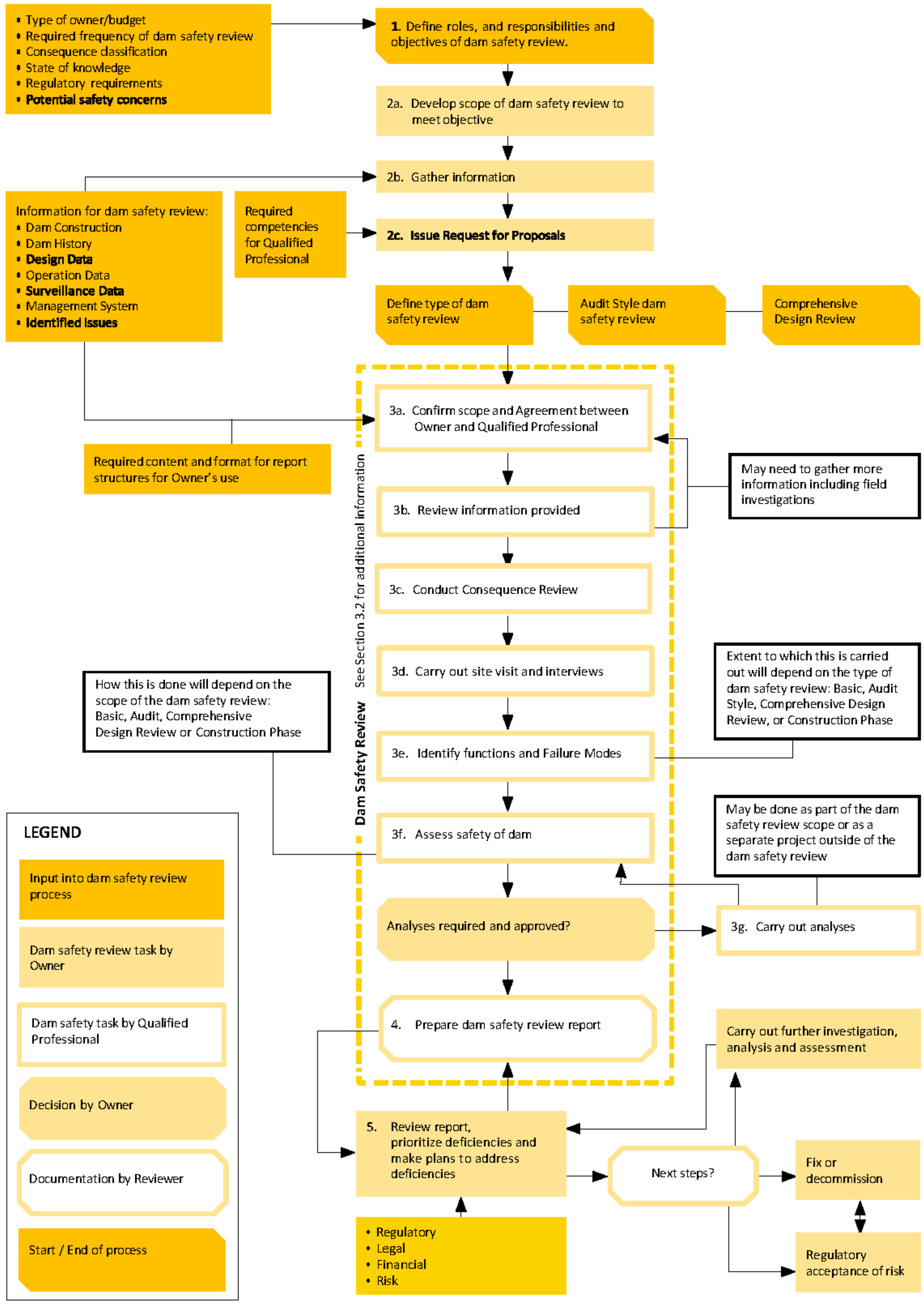

Figure IV-2. Tailings Dam Safety Review Process (APEGBC, 2016a)

3. Risk Management for Existing Tailings Dams

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems
▪ All existing tailings dams must be assigned a hazard potential classification and a condition assessment rating subject to periodic review and update ▪ Allow considerations of risk in design, construction, operation, closure and post-closure phases of existing tailings dam systems in dam safety decisions
Considerations for Regulators
▪ The hazard potential classification and the condition assessment rating provide the basic elements for the simplest risk assessment ▪ An accurate understanding of the hazard potential classification and the condition assessment rating provides confidence in the basic assessment of risk ▪ The assessment and management of risk becomes more complex with the complexity of the individual tailings dam system and tailings dam portfolios
Recommendations
▪ Risk management principles should be applied to all existing tailings dam systems and inventory portfolios and developed to the degree necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption in all dam safety decisions

Risk management as described in Section 2.3 of Chapter III for existing tailings dams should occur for individual projects and for inventory portfolios. Two key aspects of risk management that must be considered for each facility are risk estimation and risk evaluation.

Risk estimation includes considerations of:

- loads imposed on the tailings dam system such as seismic and hydrologic events
- structural behavior of the components during loading
- consequences of failure

The structural response of a tailings dam system to loads is a major concern of inspections as described in Section 2 of Chapter IV and design evaluations as described in Section 1.5.5 of Chapter V. This information is required to assess the condition of the tailings dam system.

Condition assessment ratings using guidance described by the USACE should be assigned for all tailings dams. Consequences of failure are summarized in the hazard potential classification assigned to the tailings dam system as described in the *Model State Dam Safety Program* (FEMA 316) and *Hazard Potential Classification System for Dams* (FEMA 333). An accurate hazard potential classification requires a detailed evaluation of the inundation zone defined by a flood wave from a tailings dam failure.

Risk evaluation includes considerations of consequences of failure on the objective to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. The risk assessment considers the risk estimates and the risk evaluation. At the simplest level, the risk assessment is reflected by the hazard potential classification and the condition assessment of the tailings dam. See Section 2.3 of Chapter III for more information on risk management. The following sections briefly discuss condition assessments and dam breach and inundation zone modeling for tailings dams.

3.1. Condition assessment

A tailings dam in bad condition is more likely to fail than a tailings dam in good condition. The problem is that such subjective terms do not provide a meaningful understanding of the performance capability of the dam. Inspection engineers may be inclined to describe parts and pieces and whole dams as being in “good” or “excellent” condition. To combat this ambiguity, the USACE developed a condition assessment rating system for the National Inventory of Dams (USACE, 2021). This rating system is appropriate for tailings dams and the inspection engineer should include a condition assessment in the scope of work for the dam safety reviews and evaluations as described in Section 2.5.3 of Chapter IV.

3.2. Tailings dam breach and inundation modeling

If engineering judgement is not sufficient to confidently assign a low hazard potential classification to the tailings dam system as defined in the *Model State Dam Safety Program* (FEMA 316) and *Hazard Potential Classification System for Dams* (FEMA 333), a more comprehensive engineering review may be required to understand the potential consequences of a tailings dam failure. If credible failure modes suggest potential for movement or loss of tailings containment, then an inundation study should be completed. Accurately estimating the inundation zone of a tailings dam failure is a complicated exercise. Tailings dams occur in a variety of forms as illustrated on Figure III-1 and described in Section 1.2 of Chapter III. Tailings may range from benign, gravelly, silty, sand dredge spoils, to fine grained sandy, silty slimes, that could include mineralogical or organic constituents that cause adverse reactions in the environment such as acid rock drainage/metal leaching contamination. Regardless of the geochemical considerations, the variations in sediment sizes will have a significant effect on floodwave estimates. Conventional water dam breach models and floodwave estimators are not specifically designed for tailings dams. Mechanical properties of tailings and water slurries are substantially different from water and exhibit non-Newtonian flow behavior that requires special consideration in computer modeling. Static, seismic, and flow liquefaction behavior of tailings further complicate dam break and flood wave modeling. Most water dam break analyses are focused on determining the peak discharge flow rate and routing that flow downstream as it attenuates in the flood plain. Tailings dam failure analyses also consider the run-out from the tailings deposit because all of the tailings are not typically discharged from a tailings dam failure. The tailings will begin to deposit as the flood wave velocity decreases and the viscosity and strength of the tailings slurry increases, while the sediment-laden water will separate and continue to flow. Studies have shown that historical tailings dam failures release 20% of contents on average (Azam and Li, 2010) and regression equations can be used to estimate release volumes from specific facilities (Rico, et.al., 2007). More current incidents such as the multi-factor failure of the Mount Polley tailings dam in British Columbia in 2014, the complex failure of the Fundão Dam above Minas Gerias, Brazil in 2015, and the brittle failure of the upstream fill tailings dam above Brumadinho, Brazil in 2019 added case studies with large volumes released. Proprietary, numerical computer software and services for tailings dam breach and inundation zone modeling continue to be developed (Ramirez, 2019). A reliable, open-source tailings dam break model is unknown at the time of this publication.

> *Mechanical properties of tailings and water slurries are substantially different from water and exhibit non-Newtonian flow behavior that requires special consideration in computer modeling.*

Dam failure analysis requires highly skilled engineers and tailings dam failure analysis is even more complicated and esoteric. Any technical demonstrations of tailings dam breach and inundation zone modeling should represent realistic failure scenarios and follow all engineering principles and standards to the extent applicable and to the level of detail necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. See *Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures* (FEMA 946, 2013) for more information. A detailed technical discussion on tailings dam breach and inundation zone modeling is beyond the scope of the *Tailings Dam Supplement*. See Section 4.3 of the *U.S. Guidelines for Tailings Dam Safety* for technical information on this subject.

4. Modifications of Existing Tailings Dams

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems
▪ Provisions for modifying existing tailings dams because of industrial operational requirements or measures necessary to control risk
Considerations for Regulators
▪ The frequency of modifications of tailings dams is one of the unique attributes that distinguish tailings dams from water dams
Recommendations
▪ Designs for modifications of existing tailings dams should be subjected to the standard of care described in Chapter V as appropriate

Modifications of existing tailings dams should be subject to the same regulatory requirements as described in the Chapter V unless the modification was included as part of the original, approved design such as staged construction and planned raises that were developed to sufficient detail in the original design.

Modifications for complex tailings dam systems typically include:

- raises to the embankment for additional tailings and water storage capacity

- changes in instrumentation such as piezometers and inclinometers to monitor performance parameters that may be identified from recurring inspections and evaluations
- maintenance requirements such as drainage system improvements
- changes based on review of the design basis and engineering evaluations
- industrial process and operating plan change that effect tailing deposition characteristics
- implementation of closure and reclamation plans
- risk mitigation measures such as slope buttresses
- modifications to reduce risk because of changes in the hazard potential classification
- other requirements as necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption

All of the design, construction, operation and closure considerations described in Chapter V, and respective permitting and regulatory requirements, should be considered to the extent applicable for modifications of tailings dam systems.

Chapter V – Design, Construction, Operation and Closure

1. Design

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems

- Authority to require, review, observe, or waive information developed in the design process as necessary to determine compliance with respective statutes and regulations and to determine that sufficient level of detail is developed in planning the design, construction, operation, closure and reclamation of the tailings dam system to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption.
- Requirement for detailed design report describing the tailings dam project development and plan; site investigations and characterizations; hydrology, seismology, and other technical studies; design basis memorandum; engineering evaluations demonstrating the expected performance of the tailings dam system under approved loading conditions during operations and closure; and detailed construction drawings and specifications
- Authority to require independent reviews by specialized engineering experts on intervals commensurate with the risk and the complexity of the specialized subject under review

Considerations for Regulators

- Is the design complete and sufficiently developed to demonstrate a reasonable standard of care for the safety of the proposed design based on the hazard potential classification of the tailings dam?
- Does the design include an appropriately detailed closure concept or plan?
- Were assumptions and uncertainties identified early in the design process, and were subsequent investigations and evaluations sufficiently developed to validate assumptions and eliminate uncertainties?
- Were risk assessments conducted sufficiently during the design development to include risk reduction measures in the design concept and through the detailed design?
- Is the risk of the final design in operation and closure within a tolerable range to approve construction based on the hazard potential classification of the tailings dam?
- Is the level of detail in the design sufficiently developed to protect against loss of life, economic loss, property damage, environmental impacts and lifeline disruption?
- Has the conceptual plan and/or detailed design been reviewed by an independent, expert review with respective recommendations incorporated into the plan?

Recommendations

- Preliminary meeting with project proponent prior to feasibility study to preview design concepts to be evaluated, regulatory requirements for permitting, and agree on design standards, performance requirements for the tailings dam, and permitting schedules

- Review and approve the proposed hazard potential classification, site investigations, scope of the design effort and design standards before the feasibility level stage of design is initiated
- Review the preliminary findings of the feasibility study and relay any concerns or shortcomings in the information for resolution before advancing the preferred alternative to final design
- Review and define guidance for best available technology, best available practices, and emerging technologies for all technical components including evaluation criteria such as design, operation and closure performance requirements
- Confirm that the design report is sufficiently developed, supported, and complete to issue a permit for construction
- Ensure independent, expert review of the complete plan when necessary based on hazard potential classification, complexity, size, regulatory requirements, or other factors

Proper and adequate engineering design of a tailings facility is critical if the facility is expected to function as expected, with understandable and acceptable risks. A tailings disposal facility is a complex system, requiring multiple components of the facility to work together in an integrated manner. Numerous options in the beginning of the project must be winnowed down to a final choice that defines the tailings dam system to be constructed for the operation. While the detailed design report is the primary document to demonstrate the safety of the tailings dam, a tailings dam safety regulator benefits in regulatory decisions with a full understanding of the project development.

Engineering design for a project can be described in a process called “stage gates” where the level of understanding and design concepts are incrementally improved, and optional or alternative approaches are refined to a point of decision followed by detailed design and construction (Hickson, et.al., 2015). Figure V-1 summarizes the generalized workflow used in the mining industry in stages, from initial project contemplation throughout the life phases of the project, extending to closure. This description is broadly applicable to complex industrial projects or can be narrowly focused on components such as the tailings dam, regardless of the industry.

Performance based, risk informed, safe design, construction, operation and closure” (PBRISD) is recommended as a guiding principle when advancing the design of a tailings dam from concept through construction, operation and closure to ensure the safety of the tailings dam in the post-closure scenario.

The individual or discrete design stages vary from project to project and other design processes than shown in Figure V-1 exist and can be used. The following descriptions are general processes that must be custom tailored to meet the scale and scope of the individual project. These descriptions are intended to be consistent with the state of the practice of modern engineering of tailings disposal in the mining industry but are not exclusive to mining, nor inclusive of all considerations that may be required to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. Consequently, “performance based, risk informed, safe design, construction, operation and closure” (PBRISD) is recommended as a guiding principle when advancing the design of a tailings dam from concept through construction, operation and closure to ensure the safety of the tailings dam in the post-closure scenario (Morgenstern, 2018). See Section 3 of Chapter III and Appendix B for more discussion on PBRISD. See Chapter 7 of the *U.S. Guidelines for Tailings Dam Safety* for more information on design processes.

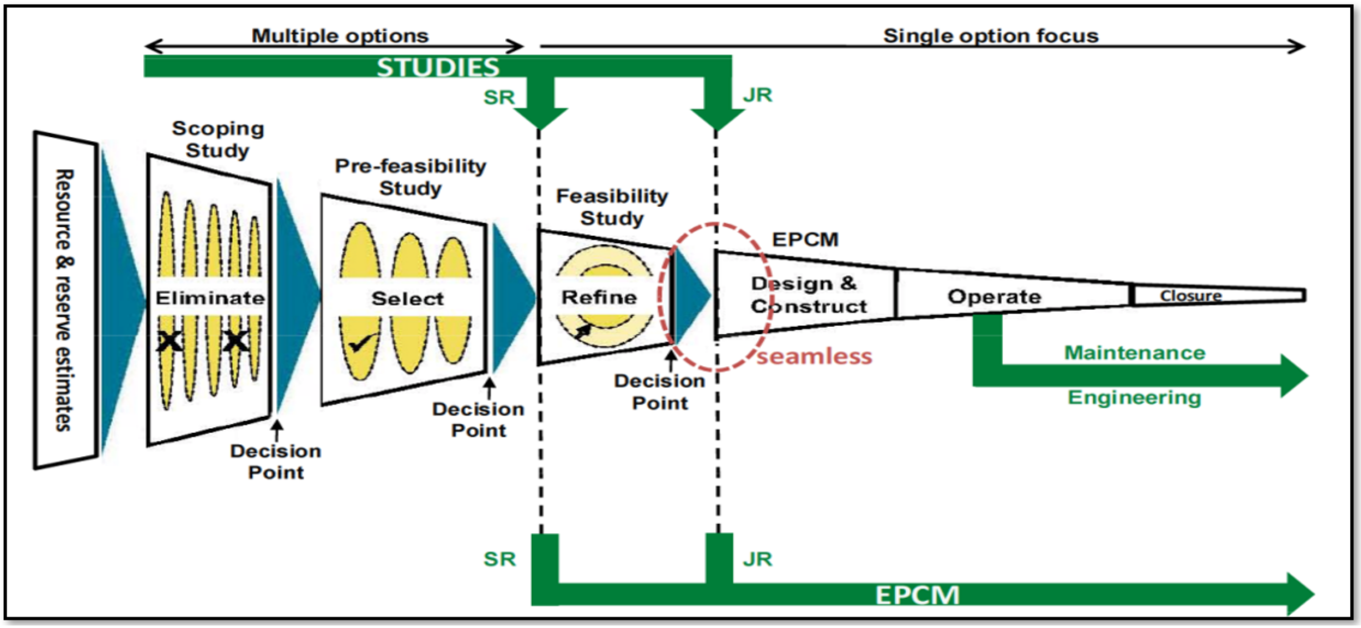

Figure V-1. Engineering design process in mining industry (Adapted from Hickson, et.al., 2015)

The dam or mine safety program responsible for regulating tailings dams should have the authority as described in Chapter II to require, review, observe, or waive information developed in the design process, as necessary to determine compliance with respective statutes and regulations; and, to determine that sufficient level of detail is developed in planning the design, construction, operation, closure and reclamation of the tailings dam system to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. Regulatory reviews are recommended at the beginning of the feasibility study described in Section 1.4.2 of Chapter V, after the feasibility study is complete, and after the detailed design report described in Section 1.5 of Chapter V is complete. Regulatory reviews also occur after construction, before and during operations, for significant modifications such as tailings dam raises, and for closure and post-closure phases. Typical regulatory milestones are shown on Figure V-1.

1.1. Designing for closure and reclamation

Because closure and reclamation are the ultimate goals of the final tailings dam design, closure and reclamation must be considered in the scoping study when evaluating the initial options (ICOLD, 2013). Closure and reclamation continue to be the final goals through the refinement of the alternatives and into the detailed design and construction of the selected option. If foundation level features affect the closure design, these features must be included at the beginning of construction. The “design for closure and reclamation” approach throughout each stage of the design process ensures that the alternatives, final design and initial construction are consistent with how the facility will be effectively closed and reclaimed, which effects the post-closure scenario as described in Section 4.4 of Chapter V. Designing for closure and reclamation also ensures that financial assurance requirements as described in Section 4.4 of Chapter III and Section 4.1.2 of Chapter V consider the costs of closure, reclamation and post-closure phases in the life of the tailings facility. Note that the respective costs for post closure scenario 1 described in Section 4.4 of Chapter V, where closed tailings dams require active care and OMS under full dam safety regulatory oversight, will be substantially higher than a tailings dam in post-closure scenario 3, where passive maintenance for stable and safe landforms allow relief from dam safety regulatory oversight.

1.2. Minimizing operation and long-term risk

Risk management should occur as described in Section 2.3 of Chapter III at various points in the design process to evaluate the tailings dam system for potential failure modes, the probability of such failures actually occurring during operations and closure, the consequences that could result from the failure, and the controls that can be implemented to reduce the risk to as low as reasonably practical. Whenever possible, opportunities for incorporating resiliency in the project design should be included such as redundant systems. In general, the target for the annualized risk of failure for any component that is critical for the safety of the tailings dam system including the embankment should range from 1 x 10-3 to 10-6 or better depending on component and consequences of failure to maintain credible measures of safety for any new facility (FEMA P-1025, 2105). However, variability in specific projects and other risk assessment methods must be considered. Conversely, factors of safety alone are not credible measures of risk and caution must be observed in the evaluation of risk when considering factors of safety (Oboni, et.al., 2020). Furthermore, factors of safety are almost always presented for embankment slope stability, and rarely presented in design evaluations of other critical components that can affect the risk of failure such as underdrains. See the publications of the National Dam Safety Program, including the *U.S. Guidelines for Tailings Dam Safety*, and other credible references and consult with professional experts for technical guidance on risk analysis, component design, factors of safety and evaluation of tailings dam systems.

> *The “design for closure” approach throughout each stage of the design process ensures that the alternatives, final design and initial construction are consistent with how the facility will be effectively closed, which effects the post-closure scenario.*

Many different factors affect the performance of a tailings dam including site conditions, design features of the tailing dam system, and the nature of the tailings. For example, the geochemical profiles of orebodies and the respective tailings can have a significant impact on the design of the tailings facility and the resultant post-closure monitoring and water treatment requirements. In addition, economic factors in business planning can influence site selection, design features, and other aspects of the tailings facility. In the process of designing for closure, the designer should consider the post-closure scenarios described in Section 4.4 of Chapter V, and endeavor to avoid, to the extent possible, any designs that require long-term active care and OMS as described in Section 4.4.1 of Chapter V.

Addressing all of the factors that can affect risks are outside the scope of the *Tailings Dam Supplement*. However, important decisions made when managing economic and environmental risks may transfer risks to the physical components of the tailings dam system, for example, water storage. Consequently, in order to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption, dam safety concepts must be included in the alternatives analyses to ensure economic influences and environmental protection features designed into a tailings dam function as intended without compromising the safety of the tailings dam system. A catastrophic failure clearly defeats the purposes of tailings facilities. Select features that can affect the long-term risk of the tailings dam are described in the following sections.

1.2.1. TAILINGS PROCESSING AND TRANSPORT SYSTEMS

The type of tailings waste stream, transport methods, and deposition methods can affect the risk of the tailings facility. The methods used to process tailings will depend on the activity that created them, such as the nature of the ore in mining, and considerations of technical viability, economics, regulatory/social acceptability and risk. These considerations will influence whether the tailings will be wet slurry form, thickened, paste, or filtered (drystack), or if other options were considered such as reprocessing or co-disposal with waste rock or other materials. Some tailings may not be processed or subject to limited processing such as dredge spoils and placer tailings.

Wet slurry tailings, also referred to as conventional tailings, are transported from a pipe as “whole tailings” (all particle sizes blended together) at where 20% to 30% of the waste stream are solid materials and the balance water. This will result in decant ponds forming on the tailings deposit that affect risk during operations and in closure, if the decant pond is not minimized or removed. Conventional tailings may be subjected to post-mill processing through cyclones or other devices to segregate coarse and fine-grained particles for different deposition strategies. For example, dams can be constructed continuously from the coarse sand fraction to contain the remaining fraction referred to as “slimes.” Dewatering of tailings may occur after the mill beneficiation process by specialized techniques and result in “thickened” or “paste” tailings with solid contents typically ranging from 40% to 60% of the discharge which may be pumped to a tailings facility. Tailings may be substantially dewatered by a squeezing through a filter press, resulting in a relatively dry tailings with moisture contents less than 20%. These tailings may be trucked or conveyed to the disposal area, commonly referred to as a “drystack”, spread with bulldozers, and compacted to achieve “dilative” conditions, significantly reducing or eliminating the potential for liquefaction. Drystack tailings may eliminate the need for a tailings dam completely, but may transfer risk during operations to a more conventional water dam that should be regulated under programs following the *Model State Dam Safety Program* (FEMA 316) as appropriate.

Conventional tailings are typically transported from the generating source (such as a mill) by gravity or pumps, through pipelines and discharged into the tailings facility. Tailings may be discharged underwater “sub-aqueously” or from an elevated spigot (sub-aerially). Centerline and upstream fill tailings dams depend on sub-aerial tailings deposition along the upstream face of the dam to segregate coarse particles from slimes and develop beaches of higher strength tailings for subsequent construction. Tailings beaches can also serve as low-permeability barriers to push open water away from the upstream face of the dam and reduce seepage into the embankment. Tailings transport and deposition strategies are outside the scope of the *Tailings Dam Supplement*; however, the OMS Manual described in Section 3.2 of Chapter V should include detailed instructions for tailings transport and placement methods, especially when the tailings deposits are used as structural components of the tailings dam as described in the following section.

1.2.2. TAILINGS DAM CONSTRUCTION METHOD

The type of the tailings dam construction method is influenced by hazard potential classification, risks, climate, available construction materials, seepage control measures, loading conditions and other factors. Different types of tailings dam construction have different performance requirements, and depending on a number of factors, can affect operational and long-term risk. Figure III-1 shows the three primary tailings dam designs described by the nature of the embankment fill construction methods commonly referred to as downstream, centerline and upstream tailings dams. A fourth design known as the “modified” centerline tailings dam is also shown. Modified centerline tailings dams may include waste rock comingled with the tailings beach to reinforce soft foundations on the upstream slopes. Each of these tailings dams carry different risk profiles depending on technical factors outside the scope of the *Tailings Dam Supplement* to discuss. However, a general comparison of risk is conveyed from the following brief descriptions of the tailings dam design listed in order of increasing risk of catastrophic failure, relative to each other (assuming many other factors are equal such as structurally competent, select, engineered fill in the embankment, hydraulically deposited, conventional tailings without comingling and similar consequences of failure.)

- Downstream—Lowest risk because the full cross section of the embankment is constructed of select, engineered fill that does not depend on the strength of hydraulically deposited tailings for structural competence
- Centerline—More risk because the structural competence of the embankment upstream of the centerline of the dam depends on the strength of hydraulically deposited tailings
- Modified centerline—More risk because more of the select, engineered embankment fill drifts upstream onto the tailings deposit creating foundation conditions for the part of the upper portion of the tailings dam dependent on the strength of hydraulically deposited tailings
- Upstream—Highest risk because the stability of the tailings dam is highly dependent on the strength of hydraulically deposited tailings

Note that the dependence on the strength of the hydraulically deposited tailings is the primary contributor to the increasing risk in these descriptions. Generally speaking, increase in the amount of select, engineered fill in the embankment section increases the stability of the section and reduces risk. A select, engineered fill or consolidated tailings will typically exhibit “dilative” behavior under shear stress where soil particles move apart allowing pore pressures to dissipate and causing effective stress to increase; however, the soil particles continue to carry the load without significant loss of strength. Poorly consolidated, hydraulically deposited tailings are prone to “contractive” behavior under shear stress where tailings particles collapse; when this happens, depending on the degree of saturation, the load can be transferred from the soil particles to the interstitial fluid, causing a rapid increase in pore pressure and the respective, significant, reduction in strength caused by reduced effective stress. This is the phenomenon called liquefaction.

Poorly consolidated, hydraulically deposited tailings are prone to “contractive” behavior under shear stress where tailings particles collapse; when this happens, depending on the degree of saturation, the load can be transferred from the soil particles to the interstitial fluid, causing a rapid increase in pore pressure and the respective, significant, reduction in strength caused by reduced effective stress. This is the phenomenon called liquefaction.

These descriptions are simplified, based on generalized assumptions, and are intended to help regulators understand conceptual technical aspects of tailings dam construction that affect risk; however, these comparisons may not withstand detailed engineering evaluations demonstrating liquefaction resistance of tailings deposits, structural factors of safety and deformation limits that meet minimum standards for all of these alternatives. Risk assessments as described in Section 2.3 of Chapter III should be conducted on the final design alternative advanced for construction to demonstrate that risks are sufficiently reduced to tolerable levels for each specific project.

1.2.3. DRY VERSUS WET CLOSURE

The water content of the tailings deposit and volume of open water behind the tailings dam in a closed configuration can have a significant effect on risk. Removing surface water from the tailings deposit generally contributes to a reduction in risk; however, the surface drainage features must be considered. If the spillway design depends on the reservoir capacity of the tailings impoundment to attenuate the design flood required for closure, tailings dams must serve as retention dams and the risk from intermittent impounded water must be considered. Tailings dam designers must also consider both geotechnical stability and geochemical stability of the tailings facility (Wilson, et.al., 2015). Chemical processes such as acid rock drainage can be sensitive to oxygen and an anaerobic environment can be accomplished by submerging the tailings underwater. This leads to some closure designs that include a shallow pond of open water over the tailings deposit that must be impounded by the upper portion of the tailings dam. In these cases, the tailings must remain saturated and seepage from the tailings deposit must be captured and treated. These inter-related concepts connect the cover with the underdrains discussed in the following section.

1.2.4. FOUNDATIONS AND UNDERDRAINS

The effect of appropriate drainage on geotechnical slope stability is elementary but critical in consideration of tailings dams. All tailings dam embankments should have underdrains or other features designed to ensure adequate internal and foundation drainage for long-term control of the phreatic surface to improve stability (Marr, 2019). Many tailings deposits include fine-grained materials (silt and clay particle sizes) that inhibit drainage and consolidation due to low hydraulic conductivity. Without seepage and consolidation or significant confining pressure, tailings deposits can exhibit contractive and brittle behavior, leading to liquefaction and the resultant loss of strength from both seismic and static triggers. Risk trade-offs occur when geomembrane liners are included for environmental considerations because the geomembrane prevents or limits seepage out of the tailings deposit. Unless protected by carefully designed and constructed filters, fine graded tailings can also clog foundation level drains or drains constructed on top of liners (FEMA, 2011). Because these features must be constructed prior to embankment construction or tailings deposition, they must be carefully considered in risk assessments conducted early in the alternative analyses and subsequent detailed design. Risk assessments should include consideration of underdrain failure if the stability of the embankment is dependent on underdrain performance.

1.3. Uncertainty and problem assessment

One of the first steps in PBRISD is conducting an “uncertainty assessment” during the pre-feasibility study based on a review of the various engineering models that will be used to evaluate the project alternatives (Morgenstern, 2018). The assumptions used to build those models must be identified and validated as the engineering design advances. This process begins with considerations identified in the conceptual design that directly affect risk including the type of tailings dam and tailings processing system, site selection, and key design features from the foundation to the final configuration that must be investigated and evaluated in the detailed design to determine the performance requirements of the tailings dam system.

In addition, PBRISD includes a potential problems analysis in the pre-feasibility study described by Dr. Morgenstern as the “first formal risk analysis for all options under consideration.” By identifying problems at an early stage of project development that could develop later, project decisions are informed by risk that must be addressed in subsequent design efforts. See Section 2.3 of Chapter III for information about potential failure modes assessments (PFMA) and Section 7.3 of the *U.S. Guidelines for Tailings Dam Safety* for technical discussion on tailings dam failure modes.

1.4. Alternative analysis, site selection and decision making

Regulators need to make decisions and understand how project proponents make decisions that can have significant effects on the community, public safety, the environment, project development and various project components. Alternative analysis and site selection are a critical phase for the safe design of new tailings dams. The physical locations will have a significant influence on the alternatives that can be safely adapted to the setting, and choosing the best alternative involves significant design elements that are subject to regulatory review. This is an important phase in PBRISD as described in Section 3 of Chapter III and Appendix B. Decision making continues to occur throughout detailed design, as well as operation, modification and closure.

In the mining industry, scoping and pre-feasibility studies are used to develop a preliminary suite of project alternatives that include the tailings facility and preliminary design requirements such as tailings storage capacity. This stage is followed by the feasibility study which further evaluates a short list of alternatives for the selection of the preferred alternative that is advanced to detailed design. Points of regulatory interest and engagement are included in the brief descriptions of these studies provided in the following sections, although other methods of analysis, selection and regulatory interaction may be used depending on the unique aspects of each project. Further, the following descriptions are broadly general; some companies may do more rigor and alternatives studies during one phase or the other and use various methods to make decisions.

1.4.1. SCOPING AND PRE-FEASIBILITY STUDIES

The scoping and pre-feasibility studies are typically the first time that a formal process is used to evaluate a potential project and determine how corporate goals or project demands can be supported. This is the stage where potential sites for tailings facilities will be identified depending on a wide range of considerations.

Scoping and pre-feasibility studies generally include the following considerations:

- Tradeoff studies for tailings processing options, including life-phase costs and risk assessments. The type of tailings waste streams evaluated may include alternatives such as conventional, wet slurries, thickened, paste, and filtered (drystack) options. Recommendations are typically made for one to three alternatives that can be advanced to the next stage.

- Facility location studies with recommendations for two to three potential sites or locations for the tailings facility that can be advanced to the next stage. These studies may initially be made without regard to land ownership and using readily available geotechnical and hydrologic data. Experience on similar projects is important to guide the conceptual evaluations.

- A conceptual-level engineering design is provided for several combinations of locations and features, evaluating the technical parameters and engineering approaches for each potential site and tailings disposal options. At this level of design, the overall size (height, capacity and areal extent) of each potential tailings facility is shown, along with certain important features such as surface water diversions and groundwater controls.

- A preliminary assessment of the consequences should a tailings dam breach occur is considered for each of the alternatives, including an initial evaluation of the population at risk (PAR) in the immediate downstream areas, property damage, environmental impacts and lifeline disruption.

- Preliminary project costs are estimated for each alternative

The scope and schedule for obtaining necessary permits are usually identified during the pre-feasibility stage including high-level evaluations such as MAAs and public processes as described in Section 2.2 of Chapter III to address considerations of other stakeholders, social acceptance and sustainability. The end of this stage is an appropriate point for an initial "kick off" meeting with regulatory agencies. Project proponents should meet with tailings dam safety regulators and other regulatory agencies with respective permit requirements before advancing to the feasibility study described in the next section. The agenda for this initial meeting should include:

- An overview of the proposed project
- Descriptions of the conceptual design alternatives and evaluations and identify which options will be advanced to the feasibility stage of the design
- Provide an initial summary of the design basis for tailings dams at the facility
- Indicate the initial hazard potential classification for tailings dams and other dams for each alternative
- Provide a tentative timeline for the project development including life of the operational phase and conceptual design of the closed configuration
- Discuss regulatory requirements, agency information needs and design criteria for the project, including agency review timelines
- Describe the scope and timeframe for the feasibility stage of design development

The tailings dam proponent should prepare a letter of intent that provides the following information:

- Description of the proposed project, and anticipated schedule
- Identity and contact information of the applicant to be qualified as described in Section 4 of Chapter III
- Identity and contact information for the engineer/designer of record and other responsible persons listed in Section 4.2 of Chapter III
- Meeting agenda and handouts

The tailings dam safety regulator should signal preliminary agreement or objections with the proposed hazard potential classifications, design criteria and standards, and provide a detailed summary of the regulatory requirements based on the information presented, including any concerns, data needs, or other requirements. This ensures that the final selection from the feasibility study will meet permit requirements when the detailed design is complete. The value of the early agreement on regulatory requirements is illustrated in Figure V-2.

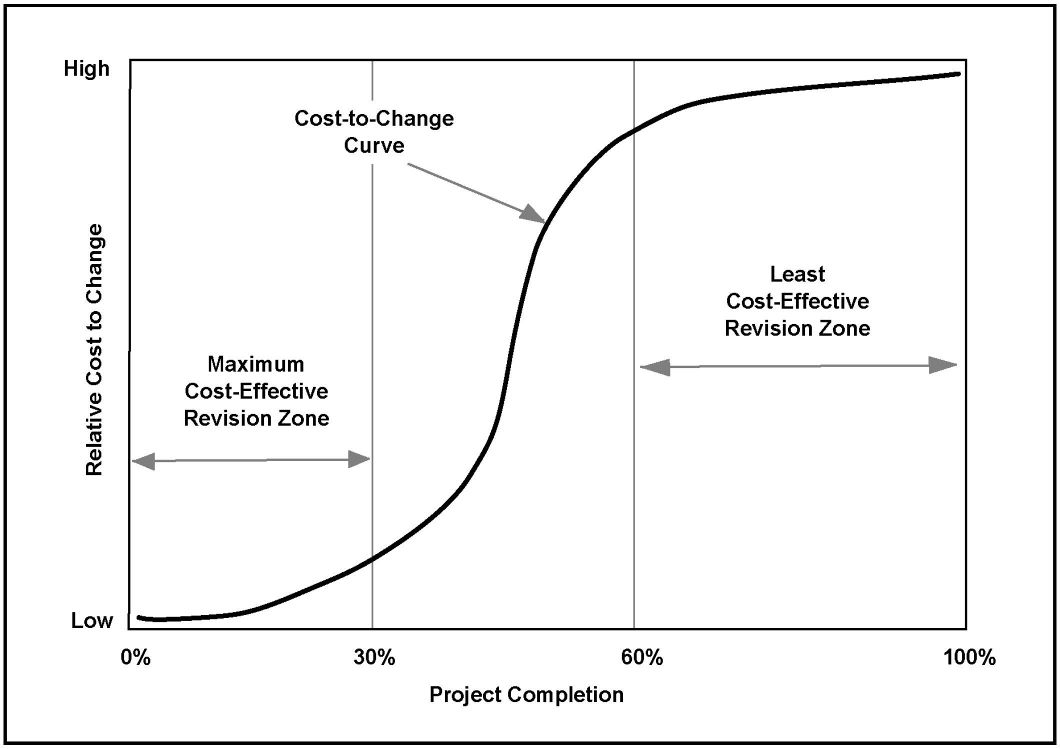

Figure V-2. Value of early agreement on regulatory requirements (adapted from ASDSO, 2003)

1.4.2. FEASIBILITY STUDIES

The objective of the feasibility study is to use a consistent and understandable methodology to further understand and evaluate the various project alternatives, optimizing the overall project such that at the end of the feasibility study, the project options have been reduced to a single "preferred alternative" which can be advanced through permitting, project financing, and into detailed design. Final feasibility level designs are generally advanced to the 90 percent complete level, meaning that there would be approximately 10 percent more of the total hours or level of effort to complete the detailed design of the preferred tailings dam system, further emphasizing the point of Figure V-2.

A significant number of basic environmental and technical studies may be required from various regulatory agencies during this phase of most major industrial project developments. As an example, environmental studies generally provide at least one year of on-site monitoring of the preferred location. Environmental studies are outside the scope of the *Tailings Dam Supplement*. However, during the feasibility stage, technical studies critical to the safety of the tailings dam are generally developed to a level of detail appropriate to support final design including hydrology, geology, hydrogeology, seismology, geotechnical drilling investigations and laboratory testing. Typically, limited additional studies and engineering evaluations are required to advance the selected project from the feasibility level design to the final, detailed design ready for construction.

Typical studies, investigations and reports that are completed during the feasibility level stage are described in Sections 1.5.3 and 1.5.4 of Chapter V. Typical engineering evaluations to support the detailed design of the selected alternative are described in Section 1.5.5 of Chapter V. A final, detailed design report as described in Section 1.5 of Chapter V is required to support the regulatory decision described in Section 2.1 of Chapter III.

1.4.3. DECISION MAKING

Pre-feasibility studies and feasibility studies are used to develop alternatives, then reduce those alternatives to the final selection advanced for detailed design and permitting. Selecting the alternatives for advanced studies should be conducted in a systematic process to illuminate broad interests that factor into significant decisions that may affect various parties with outcomes that may be difficult to reverse. The interests of the various parties may include dam safety, economics, environmental impacts, local culture, indigenous peoples, and corporate interests. Generally speaking, these considerations often occur during public processes such as NEPA reviews as described in Section 2.2 of Chapter III. Behind the scenes, other decision tools are often used in project developments. Formal processes such as risk assessments including as described in Section 2.3 of Chapter III and other methods, multiple accounts analyses and decision tools are extremely important on complex projects to reinforce business decisions about the preferred alternative developed during the prefeasibility and feasibility stages of the engineering process. Regulatory decisions may use such tools as well, depending on the specific project authorizations.

> *Selecting the alternatives for advanced studies should be conducted in a systematic process to illuminate broad interests that factor into significant decisions that may affect various parties with outcomes that may be difficult to reverse.*

A “multiple accounts analysis” (MAA) is an example of organizing various interests in terms of a specific project in an orderly and comparative format (Robertson, 1999). Such interests may be as diverse as dam safety, engineering, economics, environmental impacts, local culture, indigenous peoples and corporate interests. An MAA helps decision makers optimize their decision based on these and other input variables.

Decision tools such as the matrix presented in Figure V-3 are methods of assisting in decisions which allow assignment of metrics such as scores and weighting factors to quantify influences on decisions, i.e., more important aspects can be assigned higher weighting factors to make up for lower scores. This logic is the basic building block utilized to evaluate more complex project alternatives with a “multi-criteria decision tool” described as “what could be a complex decision-making process with potentially conflicting stakeholder opinions [that breaks] the process down into smaller parts, allowing more focus on what is most important to the decision makers” (Bennetts, et.al, 2021). This alternatives analysis process is similar to the MAA but can be summarized as presented in Figure V-4.

Systematic processes such as an MAA, the multi-criteria decision tool, or a simple decision matrix can illuminate broad interests that factor into significant decisions and ensure that under-represented positions are supported, or home in on details. The MAA and other decision tools can also inform hazard potential classifications of the tailings dam, risk management, and design, construction, operation, and closure requirements as discussed in Chapter V.

b) Survivability Rating

Geomembrane Type	Thickness		Tensile Strength		Elongation		TOTAL SCORE		RATING
	Score	Weight	Score	Weight	Score	Weight	Unweighted	Weighted	
HDPE	1.00	2	0.29	2	0.60	1	1.89	3.18	1
VLDPE	0.83	2	0.28	2	1.00	1	2.12	3.24	1
CSPE	0.50	2	0.44	2	0.02	1	0.96	1.89	3
PVC	0.50	2	0.18	2	0.35	1	1.03	1.70	3
URETHANE	0.28	2	0.52	2	0.02	1	0.81	1.60	3
XR-5	0.33	2	1.00	2	0.02	1	1.35	2.69	2
SHELT. 8218	0.15	2	0.60	2	0.02	1	0.77	1.52	3

NOTES: 1) Score for each category was obtained by dividing the maximum property value for the individual geomembrane by the maximum property value for all geomembranes.
2) Weighting factors are based on a subjective evaluation of the relative importance of the various properties. Other justifiable weighting factors could result in different ratings.

Figure V-3. Example of simple decision matrix (Golder, 1996)

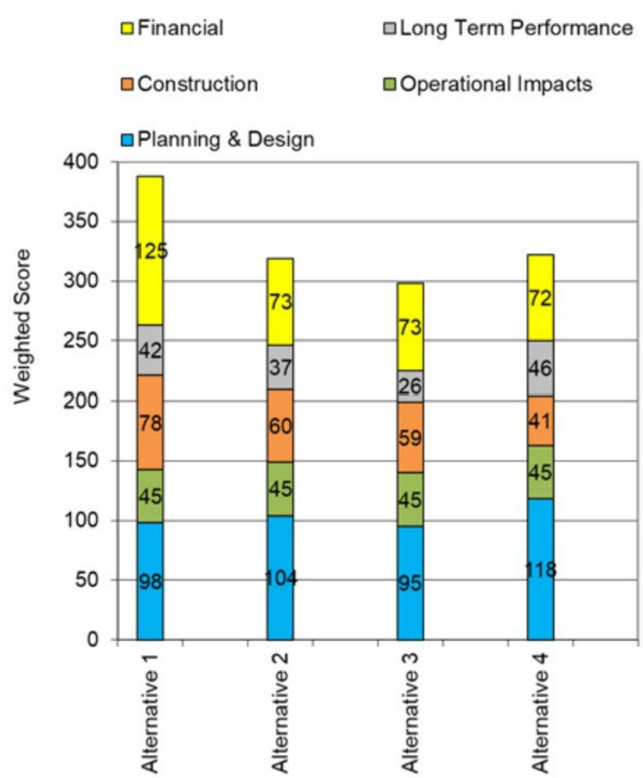

Figure V-4. Histogram of weighted scored alternatives (Bennetts, et.al, 2021)

1.5. Design report

The final report on the detailed design of the preferred alternative selected from the feasibility study is the basis of the regulatory decision for permitting described in Section 2.1 of Chapter III. This report will summarize the work conducted to demonstrate the tailings dam system is safe for construction, operation and closure and should also include the evaluations necessary to demonstrate the safety of the conceptual closed configuration of the tailings dam in the post-closure scenario. The components of a well-developed, detailed design report are described in the following sections. However, depending on the scale and scope of the project, some of the elements may be published in separate documents for convenience, or may not be included based on regulatory requirements or allowances, or at the discretion of the regulatory agency. As noted, this description is intended to be representative for a large, complex tailings dam such as those used in the mining industry and may be scaled down for smaller projects.

> *All final design reports should include basic information including project name, dam owner/operator, engineer/designer of record, date of publication, document control log and table of contents.*

All final design reports should include basic information including project name, dam owner/operator, engineer/designer of record, date of publication, document control log and table of contents. The report should also include the endorsement of the engineer/designer of record such as signature and professional engineering seal, consistent with state professional licensing statutes and regulations and dam safety agency requirements. See the *Model State Dam Safety Program* (FEMA 316) for information on engineering endorsements.

The following sections describe important content that may be expected in a detailed design report for a tailings dam, but is not intended to convey comprehensive technical detail, a rigid outline, a table of contents, or format. Many variations may occur across or within regions, industries, project scopes and regulatory jurisdictions. The specific regulatory agency should be as flexible as possible to the extent detailed prescriptive requirements are not codified in statutes and regulations and the objectives are met to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption.

1.5.1. PROJECT DESCRIPTION

The final detailed design report should include a general description of the overall project including the tailings dam system, tailings processing and transport system, and the nature of the proposed work. The project description should include the general location, details of the operation, and summaries of the physical setting including geology, hydrology, seismology and native materials and borrow sources. Other important information pertinent to the design should be described. Executive summaries are convenient for complex, lengthy reports.

1.5.2. PERFORMANCE REQUIREMENTS

Performance requirements for the tailings dam should be described including the key factors driving or controlling the design as well as operational requirements. Many of the performance requirements will be based on the design criteria included in the design basis memorandum described in Section 1.5.4 and the engineering evaluations described in Section 1.5.5 of Chapter V.

When possible, performance requirements should be defined as "quantifiable performance objectives" (QPOs) (Morgenstern, et.al., 2015) that can be directly measured and observed. QPOs may be included in technical specifications to inform CQA/QC programs described in Section 2 of Chapter V; for example, the specified, maximum hydraulic conductivity of a seal zone may be the performance necessary from a layer of fill constructed based on a soil classification and a compaction specification. QPOs may be used to define normal operating ranges or "trigger" levels to inform OMS programs described in Section 3 of Chapter V; for example, the maximum phreatic surface within the tailings dam embankment where the factor of safety for stability drops below the design criteria. QPOs should also be listed in the Design Basis Memorandum (DBM) described in Section 1.5.4 of Chapter V.

Performance requirements cannot always be quantified. For example, unexpected seepage on the embankment or slope cracking can be a signal of adverse behavior and are key points of interest for the "Observational Method" as first presented by Dr. Ralph Peck in the Ninth Rankine Lecture (1969). Notably, the Observational Method requires describing the normal and abnormal behavior of the object so that deviations can be detected, as well as pre-planned contingencies in the event that adverse behavior is observed. The regulator should be aware that the Observational Method has limitations predicting brittle failures that can occur in hydraulically deposited fills subject to load.

One of the primary performance requirements of a tailings dam is the volumetric capacity requirements which will be driven by the amount of storage required by the overall project, such as grade and quantity of resources in a mine, production rates, operational life span, topography of the site, and the tailings dam design details and construction method. Other factors include areal extent of the tailings facility, embankment heights, average in-situ tailings density, the tailings beach slope, and the required surface water pond volumes if required for make-up water for mill processes. The total surface pond volume requirements may be based on operational volumes, decant water from consolidation, storm storage volumes and freeboard requirements. Storm storage volumes and freeboard are critical to the safety of tailings dams where emergency spillways are not included. Volumetric capacity will constantly change as tailings deposition fills the impoundment, and is necessary for operations, so initial calculations should be based on the most recent topographic survey of the proposed site at a resolution appropriate for detailed design, and regularly updated with bathymetric surveys of the tailings deposit. The relationships between surface water, tailings, and freeboard are described in Figure V-5; note that freeboard must also consider embankment deformation which is not shown.

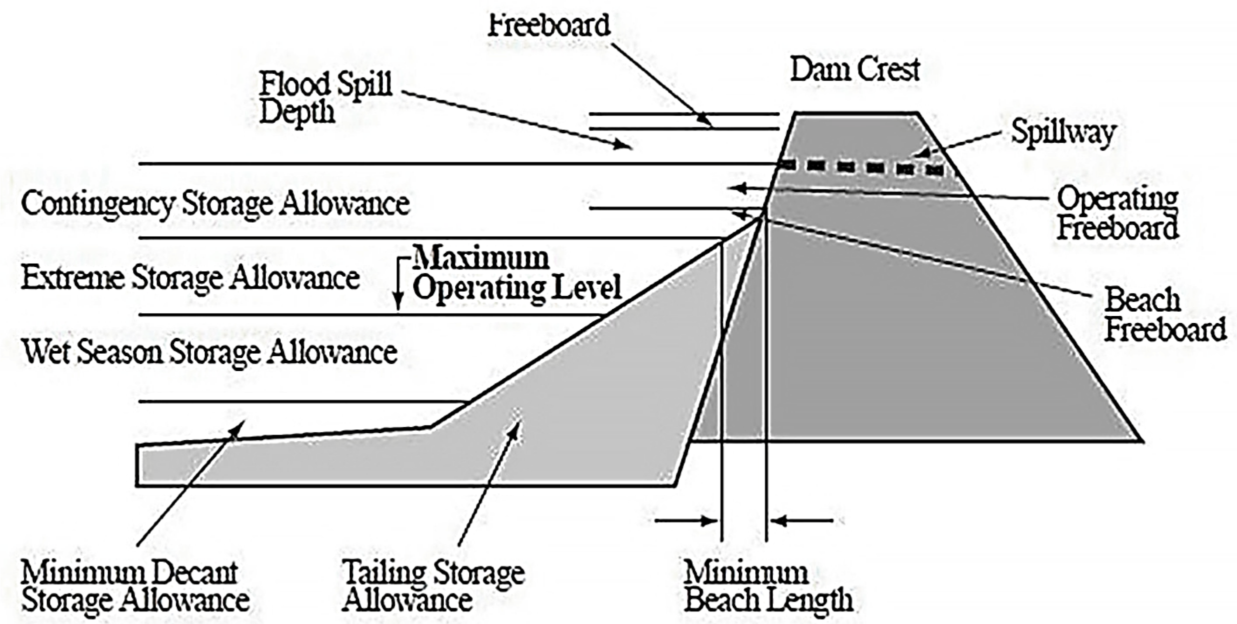

Figure V-5. Operating limits for tailings dam safety (ANCOLD, 2012)

Volumetric performance applies to earthworks as well. Tailings dams constructed by the downstream method require substantially more competent fill than tailings dams constructed by the upstream method, tailings excluded, and quantities of suitable waste rock or borrow sources must be available to construct the tailings dam according to the design. If a borrow source is depleted during operations, an unsafe condition may develop or a significant change in the design may be required. This aspect can be a factor in the type of tailings dam selected for final design and should be described.

Closed configurations should be described in sufficient detail to understand the features that must be constructed during the foundation construction and during operations to accomplish the post-closure objective. While detailed design reports for starter dam construction and interim raises may not include any details for closure covers, surface water controls and spillways, they must include details for constructing any features in the foundation that are necessary for the safe performance of the tailings dam when closed. Performance requirements for closed configurations should be described with the conceptual design and evaluated in a detailed design report prior to closure. See Section 4 of Chapter V for more information about closure that must be considered in the design process and summarized in a comprehensive detailed design report.

1.5.3. ENGINEERING AND GEOSCIENCE REPORTS

Engineering and geoscience reports convey important information about natural phenomenon that can affect the safety of the tailings dam system and must be accounted for in the design. These studies are used to define design criteria in the design basis memorandum described in the next section and define the setting in which the tailings dam system must exhibit acceptable performance. The following brief descriptions must be fully developed in the detailed design to the extent necessary to ensure the safety of the tailings dam and to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. Respective submittals during the permit application process should be developed by qualified engineers, geologists, seismologists, hydrologists and other earth science professionals and reviewed by experienced tailings dam safety regulators as described in Section 1 and 2 of Chapter VI.

- Site investigation and description
    - Geologic studies aimed at evaluating underlying site geology, faulting, local and regional seismicity, other geologic risks and potential borrow sources
    - Geotechnical and geophysical site investigations of the specific site of the preferred alternative of the tailings dam including a program for data collection and evaluation adequate for final design. The scope of the site investigations should be developed around the site-specific geology and anticipated design requirements and should be done to a level of detail necessarily to characterize the foundation conditions fully and adequately including an evaluation of the suitability of the foundation for the intended purpose (USACE, 2001) (APEGBC, 2016b)
    - Detailed laboratory test program on discrete samples collected from the field investigation phase. These laboratory tests utilize commonly available ASTM International standards and are intended to determine the engineering properties for the soils. This laboratory program should be developed to appropriately simulate the expected design conditions
    - Hydrogeologic studies which provide information on the depth and quality of local and regional groundwater, indications of permeability and transmissive properties (to estimate aquifer yield)
- Materials characterization
    - The physical and geochemical properties of predicted tailings based on samples taken from the orebody or source should be described in a number and spatial distribution adequate to fully characterize the tailings that will be produced over the operational life of the project
    - Tests should include grain size distribution, specific gravity, permeability, strength, consolidation parameters, leaching potential of metals and/or organic compounds potentially present, neutralization potential, and other analytical tests to characterize the source for regulatory compliance. In addition, all borrow materials that will be used in construction should be similarly described
    - For modifications of existing tailings dams, the tailings deposit should be characterized using deposition histories and current investigations with cone penetrometers

- Hydrology
  - Hydrology studies to investigate climate history, evaluate precipitation records, and predict site-specific precipitation and design storm events and evaporative losses. These studies utilize local and regional meteorological stations to determine the potential magnitude of precipitation at various return periods. The effects of climate change and advances in meteorological monitoring and modeling should be considered. See *Selecting and Accommodating Inflow Design Floods for Dams* (FEMA 94, 2013) for general guidance and more current, related publications
- Seismology
  - Site specific deterministic and Probabilistic Seismic Hazard Analysis (PSHA) studies should be conducted to inform stability analyses, as appropriate for the hazard potential classification of the tailings dam, along with a comparison to the USGS seismic risk model. Anthropogenic seismic effects such as hard rock mine blasting or regional hydraulic fracturing (fracking) industries should be considered where tailings will be used in construction and may be subject to liquefaction. See *Earthquake Analyses and Design of Dams* (FEMA 65, 2005) for general guidance and more current publications for consideration of rapid advances in seismology

1.5.4. DESIGN BASIS MEMORANDUM

A Design Basis Memorandum (DBM) should be prepared that supports all of the design criteria including the seismic and hydrologic standards, minimum safety factors for geotechnical slope stability, and engineering standards and references, specifically including identification of QPOs, performance requirements and risk controls to demonstrate acceptable performance to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. The DBM may also include other information influencing the design including operational requirements, tailings production rates, geometric limitations, construction materials, units of measure, coordinate systems and other limitations or requirements that affect the design.

The Design Basis Memorandum contains important information that is evaluated in a risk assessment at various points in the design process to accomplish Performance Based, Risk Informed Safe Design.

Finalizing or “locking in” the design basis, which is largely a function of the hazard potential classification of the structure occurs during the feasibility study and is reported in the DBM for the preferred alternative. The hazard potential classification drives selection of minimum design loading conditions (earthquakes and floods) and also influences the selection of appropriate factors of safety or acceptable risk levels. The applicant should clearly indicate the basis of the design standards using state regulations as appropriate or technical guidance from respective publications from recognized authorities such as FEMA, USACE, or ICOLD. Details on these technical standards are outside the scope of the *Tailings Dam Supplement*.

Performance requirements from the DBM that must be accomplished during construction must be advanced to the detailed design drawings and construction technical specifications described in Section 1.5.6 of Chapter V. This includes an instrumentation plan based on the performance requirements and critical controls as described in Section 3.1.2 of Chapter V to be installed during and immediately after construction, prior to placing new construction in service. Performance requirements from the DBM that must be monitored during operations as described in Section 2.1 of Chapter IV must be advanced to the OMS program described in Section 3.1 of Chapter V. The DBM also contains important information that is evaluated in a risk assessment at various points in the design process to accomplish PBRISD (Morgenstern, 2018)

1.5.5. ENGINEERING EVALUATIONS

Detailed engineering evaluations must be conducted for a tailings dam. The level of detail in these evaluations drive the reliability of the outcomes and should be based on the hazard potential classification of the tailings dam and developed to the extent necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. Design submittals generated during the permit application process should be developed by qualified engineers, geologists, seismologists and other professionals and reviewed by experienced tailings dam safety regulators as described in Section 1 and 2 of Chapter VII as well as independent review panels described in Section 4.3. of Chapter III.

At a minimum, the following subjects must be carefully considered and addressed by the engineer/designers of record. These descriptions are not intended to provide a complete list or detailed technical guidance. See the *U.S. Guidelines for Tailings Dam Safety* for technical information on these subjects.

- Hydrology
  - Surface water hydrology and controls are considered to limit precipitation runoff from entering into the tailings impoundment via upgradient diversions and to accommodate storage and/or discharge of design flood events from the impoundment catchment area. To reduce risk, tailings dam designs should incorporate emergency spillways whenever practical, even with adequate flood storage, as described in Section 1.5.2 of Chapter V
- Water management
  - A water balance model is critical for tailings dam systems, especially for those that do not include emergency spillways. The design report should describe the water management requirements of the overall facility processes and decant or operational water contained within the tailings facility. The water balance model is used to predict makeup water in deficit environments or required water storage and treatment in net surplus environments. Any

design controls or other constraints on the water balance must be advanced into the OMS manual described in Section 3.2 of Chapter V

- **Seepage control**
  - Seepage analyses are necessary to determine the expected phreatic surface in the embankment, to determine the operational and long-term seepage losses from the tailings deposit, and to determine the degree of saturation in the embankments. These estimates are used in stability analyses and help guide the design of seepage collection and containment systems, and water treatment systems, if required. The seepage collection systems often include provisions for foundation drainage and seepage control with appropriately designed filters within the tailings dam (FEMA, 2011) and the impoundment basin itself, and can be critical to the safety of the dam as described in Section 1.2.4 of Chapter V. See *Evaluation and Monitoring of Seepage and Internal Erosion* (FEMA P-1032, 2013) for more information
- **Stability**
  - Stability analyses of the tailings dam embankment must be conducted under static and dynamic loading conditions. All tailings dams should be evaluated using limit equilibrium methods for static and pseudo-static conditions. Appropriate undrained and drained strengths and pore pressures should be considered to model operational and long-term closure scenarios. More sophisticated and rigorous analytical methods by specialized, expert engineers using material properties confirmed from advanced testing and evaluations are typically conducted for tailings dams constructed by the centerline, modified centerline and upstream methods; and, for relatively large tailings dams or significant and high hazard potential tailings dams regardless of the construction method. Numerical deformation models are used with predicted zones of liquefaction where liquified or residual strength values may be assumed. Post-earthquake evaluations should be conducted using residual strengths
  - For any tailings dam that depends on the strength of hydraulically deposited tailings for structural integrity, the stability analysis must specifically consider the potential for static liquefaction to occur with a sudden loss of strength of potentially contractive tailings. The ductile or brittle behavior of a contractive material must be understood based on advanced geotechnical investigations, laboratory testing and engineering analyses. The degree of saturation is a factor in these analyses emphasizing the value of seepage models and piezometric monitoring to improve confidence in geotechnical evaluations using sophisticated, critical state soil mechanics. Potentially brittle tailings should not be used as a structural component of any tailings dam; if present, the tailings should be assumed to be subject to static liquefaction without consideration of specific triggering events.

- **Settlement, deformation, brittle behavior and collapse**
  - Static settlement should be predicted for tailings dam embankments in order to account for long-term integrity in the post-closure phase and sufficient camber should be included in the design. Consolidation of tailings deposits overtime can affect closure covers and surface drainage features and should be estimated and accounted for in the design to ensure long-term function of components that are critical to the long-term safety of the tailings dam
  - Seismic deformation estimates must be conducted to ensure adequate freeboard remains for containment after the design earthquake. Acceptable seismic deformation limits may be defined in the DBM where pseudo-static analysis is not appropriate or factors of safety are not expected to meet minimum standards, e.g., less than unity, indicating that some movement is predicted under the seismic load. Complex numerical models developed by experienced modelers should be carefully reviewed by equally experienced modelers or experts on independent review panels as described in Section 4.3 of Chapter III
  - Sudden strength loss or brittle behavior can occur where saturated, contractive tailings are subject to changes in stress conditions. Triggers for this phenomenon are extremely difficult to predict and the subject of current research at the time the *Tailings Dam Supplement* was developed. Consequently, structural elements that can undergo brittle behavior must be avoided in new design and mitigated if suspected in an existing tailings dam.
  - Sudden collapse has occurred in underground mining districts where native ground under tailings deposits collapses into underground workings. A tailings dam and impoundment should not be located over underground workings if at all possible, and if so, the potential for this phenomenon must be evaluated

1.5.6. DESIGN DRAWINGS AND SPECIFICATION

Engineering design drawings are typically developed to a level of detail consistent with a 90% complete design at the end of the feasibility study. Regulatory reviews are recommended at earlier intervals such as 30% and 60% completion for singular projects that do not include multiple alternatives. After final reviews, drawings should be completed to 100% and marked “Issued for Construction” or similarly, appropriately endorsed by the engineer/designer of record and cited in regulatory authorizations for construction.

Technical specifications and CQA/QC plans do not present well at the same levels of completion as design drawings; however, early agreement on specification format and levels of CQA/QC are recommended, and regulatory reviews should occur for draft documents before being finalized and marked “Issued for Construction” or similarly, appropriately endorsed by the engineer/designer of record, and cited in regulatory authorizations for construction.

See Section 2.1 of Chapter V for more information about construction documents.

2. Construction

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems
▪ Approval authority for construction drawings, technical specifications, construction quality assurance and quality control plans, and construction documentation records ▪ Approval authority for changes that can affect the safety of the tailings dam system
Considerations for Regulators
▪ What are a regulator's interests in tailings dam construction? ▪ Is the construction schedule/plan realistic? ▪ Does the schedule include milestones, critical paths, delay buffers, inspection hold points and other information? ▪ Are critical construction items identified in the plans and specifications?
Recommendations
▪ Drawing packages and technical specifications for tailings dam construction should be marked "Issued for construction" or similar and subjected to careful document control ▪ CQA/QC plans should be carefully developed and implemented ▪ Deviation management must evaluate and document changes ▪ Construction records must be developed and maintained.

Regulators have a significant interest when construction of tailings dam systems occur and how the work is controlled and documented. No construction should occur before any required regulatory authorizations are issued. See Section 2.1 of Chapter III for information about regulatory authorizations. All regulatory authorizations should clearly reference the respective construction documents that describe the work necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. This includes ensuring that all materials used in construction and the methods and means of the work meet the intent of the design engineer. CQA/QC programs accomplish this objective and support the engineer's acceptance of the work as described in Section 2.6 of Chapter V.

2.1. Construction documents

Regulatory authorizations should include specific references to key documents that are necessary to accomplish construction such as bid packages or construction drawings and technical specifications. Construction documents should clearly indicate project name and attributions. Standard drawing templates for construction drawings should include title blocks, drawing numbers, revision, check and review logs, legends, conventions, scales, coordinate systems, north arrows, notes and annotations. Content should include project cover page, location maps, topographic maps, plan views, cross sections and profiles, details, geologic profiles, grading plans, staged construction phases, instrumentation, and project specific features such as borrow sources and the details of the tailings dam system design. Technical specifications may be included in notes on drawings but are typically separate documents for major construction projects. Cover sheets, title pages including project name and attributions, document control logs, and table of contents should introduce technical specifications for specific features and aspects of the work. Standardized specification formats such as Construction Specification Institute (CSI) are recommended. All construction drawings and technical specifications should be marked as “Issued for construction” (or similarly) and be signed and dated by the engineer/designer of record. Final construction documents approved by signature of the engineer/designer of record should be clearly referenced in regulatory authorizations.

The details of the drawings and specifications must be developed sufficiently to ensure that the contractor understands the work necessary to construct the project to meet the intent of the engineer/designer of record. This is a critical control point in risk mitigation.

The details of the drawings and specifications must be developed sufficiently to ensure that the contractor understands the work necessary to construct the project to meet the intent of the engineer/designer of record. This is a critical control point in risk mitigation. This requirement is accomplished through CQA/QC. A CQA/QC plan should be included with the construction documents and reflect the work necessary to confirm that the construction meets the intent of the engineer/designer of record. The CQA/QC may range from dam owner/operator self-compliance and contractor QC to independent, third-party quality assurance and testing facilities. The CQA/QC plan should clearly identify project personnel, roles, decision hierarchy, testing and evaluation requirements, recording and reporting frequencies, and other important information. The scope and scale of the CQA/QC program will depend on the project specific details but must be sufficient for all projects to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption.

Other documents that may be required for construction include temporary coffer dams, dewatering or diversion plans, erosion and sediment control plans, pollution and spill prevention plans, emergency action plans and health and safety plans.

2.2. Materials and methods

Embankment fill and drainage control materials for tailings dams may be either select, natural source, borrow material processed as needed, waste rock overburden removed during mining operations, competent plant grinding process reject materials separated by sieve, cyclone or other methods, dewatered or thickened tailings, or whole tailings subject to segregation upon deposition. Coal combustion residuals (CCRs) or fly-ash may not be suitable materials for use in construction under federal regulations. Regardless of the source, materials must meet strict geotechnical design criteria based on conformance with detailed technical specifications and geotechnical design intent by both physical properties and specified location and placement methods. These details can have a direct effect on the safety of the tailings dam system. Borrow sources must also be evaluated for geochemical properties such as the potential for acid rock drainage/metal leaching to manage environmental risks.

2.3. Raises

Tailings dam raises are routine during the operational life of most tailings dam systems. Raises may occur continuously where tailings streams are part of the structural fill which can occur for all tailings dam construction methods shown on Figure III-1. Raises for all construction methods shown in Figure III-1 may also occur in discrete stages resulting in intermittent construction projects that occur during normal operations. In such cases, temporary operation and inspection plans may be required for tailings dam systems during the construction period. Where raises are intermittent, the dam owner/operator should ensure plans are submitted to regulators with sufficient time for review without impacting disposal operations. Otherwise, construction permit applications must include sufficient detail for the full build out if regulatory authorizations are to cover multiple raise tailings dam systems.

2.4. Change and deviation management

Changes may be required during construction to fit designs to existing conditions, adapt to conditions that are different than anticipated, exploit value-added or continuous improvement benefits that do not compromise the safety of the tailings dam system, conform to contractor's selected methods or equivalent products, new information that is discovered after construction begins, or other reasons. Clarifications in designs may be required because of a lack of detail or uncertainty in interpretation of design drawings or specifications. Any design changes or clarifications should be carefully tracked and recorded during construction. Under no circumstances should a design change occur in the field during construction without the express, written approval of the engineer/designer of record. The construction record documents should include all design change and clarification records. Regulatory authorizations should clearly require changes in the approved design that can affect the safety of the tailings dam to be specifically approved by the agency unless the modification was included as part of the original, approved design such as staged construction and planned raises that were developed to sufficient detail in the original design.

Regulatory authorizations should clearly require changes in the approved design that can affect the safety of the tailings dam to be specifically approved by the agency.

2.5. Construction documentation and records

Operational or construction testing criteria with related instrumentation installations must be recorded for each tailings dam system. Records must be diligently stored and a summary report should be prepared, typically annually for seasonal or continuous work, or upon completion of discrete projects or raises. CQA/QC records and reporting assure both the dam owner/operator and the appropriate regulatory agency that the approved design has been correctly and diligently constructed. If the records and reporting are not required for regulatory submittal they should be stored, preserved and kept readily available for review by any engineering or regulatory inspection.

2.5.1. SURVEYING

Surveying is a key facet of the CQA/QC program throughout construction and operation to ensure the design plan is properly established, from the design drawings to reality in the field. Surveying also provides baseline metrics for performance monitoring, instrumentation, construction alignments, field references, settlement of conflicts and methods of payment. As technology evolves, surveying is crucial for implementation of GIS reference systems, GPS grade control references and remote site monitoring systems. Surveying should be conducted based on the most current guidance from the US Geodetic Survey using the Global Navigation Satellite System (GNSS) equipment and the most current datum. For complex projects, site coordinate systems should be located with verified CORS station references and tested regularly using formal procedures. Daily surveys should be conducted in accordance with vetted, written survey quality control protocols. Redundant benchmarks must be well-constructed and located strategically to survive future development without disturbance.

2.5.2. RECORD DRAWINGS AND DOCUMENTS

Construction of an approved design must be carefully recorded including detailed drawings showing both exact implementation along with any approved deviations from the approved design. Construction surveys, inspection reports, contractors logs, field test results, photograph logs, weather records and other information are a significant part of the construction record that must be preserved. The dam owner/operator or the engineer/designer of record or the construction manager should store such records diligently until a summary construction report is prepared, typically annually per seasonal work or at the end of discrete construction projects Construction records and reporting assure both the dam owner/operator and the regulatory agency that the approved design has been correctly constructed and all plans diligently implemented.

Construction records and reporting assure both the dam owner/operator and the regulatory agency that the approved design has been correctly constructed and all plans diligently implemented.

2.6. Engineer acceptance

The engineer/designer of record should provide a written notice of acceptance of construction clearly indicating that the construction record reflects the intent of the approved design. See the *Model State Dam Safety Program* (FEMA 316) for recommendations about engineering certifications. All engineering requirements must be consistent with state engineering licensing statutes and regulations.

3. Operation

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems
▪ Requirement for operation, maintenance and surveillance (OMS) programs and manuals for any tailings dam system as necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. ▪ Requirement for regular updates of OMS programs to maintain current documents and address changing conditions
Considerations for Regulators
▪ How complex is an OMS program for a tailings dam system? ▪ Why is an OMS manual important?
Recommendations
▪ OMS programs should be based on critical controls identified in a risk management program, performance objectives of the tailings facility, operating requirements of the industrial processes, instrumentation and monitoring plans, contingencies for unusual circumstances, corporate tailings and water management policies and protocols, continuous improvement and assurance reviews

Operation, maintenance, and surveillance (OMS) requirements are fundamental to the day-to-day management of a tailings facility and include activities such as ongoing construction of a tailings dam system, tailings transport and deposition, water management and treatment, facility maintenance, instrumentation monitoring, inspections and surveillance. Most importantly, all operations must be conducted to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption.

OMS requirements for tailings dam systems are the sole responsibility of the tailings facility dam owner/operator and the focal point of corporate tailings and water management policies and protocols as described in Section 4.1 of Chapter III. For corporate tailings and water management policies and protocols to be effective, OMS activities should be:

- integrated into the overall site and tailings facility OMS Program and risk management plan for the tailings dam system
- documented in an OMS Manual and consistently implemented as outlined in the manual
- reviewed and updated on a regular basis and as appropriate, particularly when the dam is raised, or when the risk management plan or tailings and water management policies and protocols are updated

The tailings dam operator is responsible for internal reviews to find operational efficiencies and improvements, implement controls identified during risk management and to provide assurances that the OMS is accomplishing the objectives of the operation.

The MAC guidelines outline the development and implementation of effective tailings management systems (MAC 2019a) and OMS Manuals (MAC 2019b). The following sections include summaries of what a regulator should consider and expect when reviewing an OMS program for a tailings management system. These sections draw significantly from the MAC guidelines which should be referenced for additional information.

3.1. Operations, maintenance and surveillance (OMS) Program

Considerations
Useful questions to ask about OMS programs include:

- Are performance objectives and other criteria including critical controls clearly outlined?
- Has a framework been developed which facilitates informed decision making, communication, action, effective risk management and management of change?
- Are the roles and responsibilities of all stakeholders in the OMS program clearly defined?
- Is a system in place for communicating and training stakeholders (operations personnel, consultants, contractors, regulators, etc.) in the requirements of the OMS program?
- Is the OMS program site-specific and reflect the unique conditions of the facility?
- Are regular continual improvement reviews of the OMS system being conducted and documented, with actions to improve taking place?

The OMS Program for a tailings dam system must be site-specific and reflect the unique conditions of the facility. The program must be up-to-date and used on a continuous basis. An effective OMS Program for a tailings dam system will:

- provide a framework for OMS activities including scheduling and notifications
- document and communicate OMS practices and training to operators, their employees, contractors, consultants and regulators
- outline performance objectives and other criteria including critical controls and contingencies
- outline a framework for effective risk management, decision-making and change management
- document the roles, responsibilities and levels of authority of personnel involved in managing the tailings facility

3.1.1. PERFORMANCE OBJECTIVES

Performance objectives are goals for successful management of a tailings facility and are typically established based on:

- design intent of the tailings dam system
- risk management plan
- regulatory and legal requirements
- environmental goals
- key stakeholders
- closure plan and post-closure land use

Performance objectives should consider:

- tailings dam system including tailings processing, transport and placement requirements
- tailings deposition, beach development, consolidation, geotechnical properties and volumetrics
- embankment slope stability
- seepage containment or control
- water management, treatment and discharge
- climate limitations
- surveillance
- closure and reclamation activities and features
- post-closure requirements

Performance objectives are developed by the dam owner/operator and engineer/designer of record and are quantified where possible into QPOs such as described in Section 1.5.4 of Chapter V. The performance criteria specify the expected or acceptable range of performance for each QPO or other indicator, and thresholds or limits that may require increased monitoring or some specific corrective action. Such performance criteria may be linked to critical controls and trigger action response plans (TARP) as discussed in the following sections.

3.1.2. CRITICAL CONTROLS

Considerations for Regulators
Useful questions to ask about critical controls include:

- Have potential failure modes and causes using risk assessment techniques been identified?
- Have risk controls specific to potential failure modes and causes been identified?
- Have risk controls deemed to be critical to the dam owner/operator or on a facility-specific basis been identified?
- Has a "risk owner" and "critical control owner" been allocated for that risk?
- Have critical controls and respective performance criteria, observable performance indicators, QPOs, and surveillance requirements been defined?
- Have these been integrated into the OMS requirements and other onsite management systems (e.g., TARPs that identify preventative contingency measures with pre-defined actions before control is lost, mitigative actions after loss of control, or redundant systems)?
- Are critical controls reviewed for implementation and effectiveness at a frequency appropriate with the frequency of control execution?
- Are critical controls tracked and reported to demonstrate implementation of actions to address critical control deficiencies?
- Where deficiencies have been identified, are these reported to the responsible parties including the regulator and the accountable executive officer?
- Are critical controls periodically reviewed and updated based on current risk assessments and past performance?

Critical controls must be carefully developed, implemented or constructed, and monitored to prevent or mitigate an adverse event. Critical controls are site-specific and may be structural or technical (e.g., seismic buttress to increase stability, tailings beach length to control the phreatic surface in the embankment and reduce seepage, freeboard limits to reduce risk of overtopping), operational (e.g., pumping capacity to prevent overtopping), or governance-based (e.g., recommendations of independent technical review panel).

Determining critical controls is the responsibility of the dam owner/operator and the engineer/designer of record through the design process described in Section 1 of Chapter V and the risk management process as described in Section 2.3 of Chapter III. Critical controls are of significant interest to the regulator to ensure protection against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption.

Controls are typically designated as critical controls if:

- implementation of the control would significantly reduce the likelihood or incremental consequence of an adverse event or condition
- removal or failure of a control would significantly increase the likelihood or consequences of an adverse event or condition that poses an unacceptable risk, despite the presence of other controls
- the control would prevent more than one failure mode, or would mitigate more than one consequence
- other controls are dependent upon the control in question

3.2. OMS Manual

Considerations for Regulators
Does the OMS Manual:

- Include a description of the tailings facility including site conditions, key design criteria, information on key design elements (raising methodology, drainage features, etc.), tailings management strategy, water management strategy, environmental considerations and controls and hazard potential classification?
- Is the OMS Manual evaluated and updated regularly to address changing conditions?
- Contain or provide clear guidance on where to find standard operating procedures (SOPs) for operation and construction activities?
- Identify and describe the various infrastructure that is involved in tailings management and requirements (procedures, frequency, reporting) for preventative, predictive and corrective maintenance?
- Include plans and procedures associated with temporary shutdowns and subsequent re-starts which impact the tailings and water management strategies?
- Include contingency plans for significant events, both natural (e.g., flooding, earthquakes) and operational (e.g., tailings delivery pipeline failure)?
- Detail the surveillance program including requirements for ongoing performance monitoring and routine and event driven inspections, clearly defined roles and responsibilities, and documentation and notification requirements?
- Use a TARP framework in the surveillance plan for determining when action is required and what action must be taken? Are the triggers linked to performance objectives which are used to identify deviation from normal or expected behavior?
- Define TARPs for all credible failure modes?

- Provide details on the instrumentation in place, including installation details, maps with instrument locations, reading frequencies and threshold values?
- Provide guidance for maintenance and replacement schedule of the instrumentation?
- Provide clear linkages to the Emergency Action Plan or Emergency Response Plan(s)?
- Provide document control to allow for regular updates to address changing conditions?

The following sections describe the development, content and updating of an OMS Manual for a tailings dam system. The OMS Manual should contain the information needed for the intended operation to be conducted safely and should be developed to the detail necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption.

3.2.1. DEVELOPMENT APPROACH

A tailings facility OMS Manual should be written by a dam owner/operator with input from the engineer/designer of record and directed to employees who will use and update the OMS Manual to maintain the safe and correct operation of the tailings dam system. The OMS Manual should be written in clear, concise language in an easily accessible and searchable format, utilizing maps, figures, photographs, flow diagrams, charts and tables as appropriate to illustrate concepts, performance objectives and critical controls. The OMS Manual should be updated regularly to incorporate experience and specialized knowledge of operations employees at the site, make the manual more useful, and help prevent that specialized knowledge and experience from being lost through personnel changes. OMS Manuals written to the regulator because of a regulatory requirement for an OMS Manual should be rejected. Generic, “cookie cutter”, out-of-date, or unused OMS Manuals represent deficiencies.

The OMS Manual should include, as a minimum:

- Facility description (Section 3.2.2)
- Operating activities (Section 3.2.3)
- Maintenance requirements (Section 3.2.4)
- Surveillance program for performance monitoring (Section 3.2.5)
- Trigger action response plans (Section 3.2.6)
- Temporary cessation, care and maintenance, and contingency planning (Section 3.2.7)
- Regulatory requirements including reporting (Section 3.2.8)
- Personnel roles, responsibilities and communication protocols (Section 3.2.9)

Additional limited discussion on these components is provided in the following sections.

3.2.2. FACILITY DESCRIPTION

The OMS Manual should document the current description of the tailings facility, which should include:

- General facility description and site conditions
- Description of the tailings dam system, expected nature and characteristics of the tailings, tailings production rate, life of mine plan, tailings dam type and construction methods, raise schedule, etc.
- Tailings dam system characteristics (e.g., embankment dam construction, key performance features such as underdrains, other components, etc.)
- Dimensions, useful data, and key design criteria such as geotechnical, hydrology, environmental criteria, etc.
- Environmental controls including seepage collection systems, water treatment and discharge systems, dust control, etc.
- Hazard potential classification, summary of consequences of adverse events, and reference or links to tailings dam emergency action plan and site emergency response plan as described in Chapter VI

3.2.3. OPERATING ACTIVITIES

Operating activities related to tailings processing, transport and placement, process water storage and recycling, seepage collection, water treatment and discharge, and other operational requirements should be documented and described in the OMS Manual. Some activities may extend beyond operations and ongoing construction phase of a tailings facility and continue during temporary shutdowns or when a facility is transitioning into closure and reclamation activities. The operations section of the OMS Manual should outline the procedures for operating the tailings facility in accordance with the design intent (i.e., performance objectives) and risk management plan for the facility (i.e., critical controls). Typical key topics in the operations section of the OMS Manual include:

- **Performance objectives and critical controls**
  - See Section 3.1.1 and 3.1.2 of Chapter V
- **Operating procedures**
  - The OMS Manual should describe the operation and construction procedures of the tailings dam system through standard operating procedures (SOPs). SOPs are a set of established or prescribed methods to be followed that may include procedures, standards, practices,

protocols, instructions, rules, etc. SOPs should include reference to performance objectives and critical controls. Pre-defined actions to be taken if associated performance criteria deviate from defined ranges should be included in TARPs, as discussed in Section 3.2.6 of Chapter V. SOPs should include a description of the potential ramifications of not responding to deviations

- **Tailings transport and placement**
  - The OMS Manual should summarize the site-specific, long-term tailings transport and placement strategy, and specific practices that need to be implemented during facility operations to achieve key aspects of the plan (e.g., dust management strategies, beach development, closed configuration). Shorter-term specifics on day-to-day operations should be documented in SOPs such as a tailings deposition plan including spigot discharge locations and limits, beach management, rotation schedules, etc.
- **Ongoing construction**
  - The OMS Manual should describe the requirements and plans for ongoing construction and raising of the tailings storage facility that are in place to ensure adequate storage capacity for water and tailings. Such construction may be continuous or episodic. Regulatory requirements for construction should be included in the OMS Manual
- **Water management**
  - Water management is critical to the successful and safe operation of a tailings facility. The OMS Manual should clearly outline the water management procedures associated with the tailings dam system during conditions of normal operations and under operational upsets or extreme weather events. The OMS Manual should include a summary of the expected water balance and operating controls required to manage water under all conditions including freshwater diversions, decant pond size and location, decant systems and pump barges, reclaim and discharge rates, freeboard maintenance, etc. A water balance forecast should be included demonstrating the projected water elevation with statistical confidence limits overlaid with the construction raise schedule. The water management plans and procedures must be evaluated through the risk management program and included in the performance objectives, critical controls and TARPs
- **Site access and security**
  - The OMS manual should describe the site access to the tailings facility and control of that access, as well as pertinent security requirements
- **Information management**

- The OMS Manual should outline the site information management system and document control plan including task order generators, record keeping systems, and other features or requirements

3.2.4. MAINTENANCE REQUIREMENTS

The OMS Manual should include maintenance requirements to continue operation of the tailings facility in accordance with the performance objectives. The manual should identify and describe:

- infrastructure (e.g., civil, mechanical, electrical, instrumentation, etc.) associated with the tailings facility with maintenance requirements
- the corresponding maintenance activities, which can be categorized as:
    - preventative – regular maintenance of equipment (e.g., scheduled oil changes, calibration of equipment)
    - predictive – pre-determined maintenance completed in response to performance criteria not being met (e.g., clearing spillway blockage)
    - corrective – repairs of the tailings facility to prevent further deterioration (e.g., unplugging of drains, repair of erosion scours)

The OMS Manual should include detailed descriptions of the maintenance activities or links to additional information (e.g., manufacturer's equipment manuals, SOPs, etc.). For preventative maintenance activities, the frequency of the maintenance should be defined. In the case of predictive and corrective maintenance, a clear linkage should be established between surveillance results (e.g., heavy snowfall; equipment observed to be operating poorly) and maintenance requirements.

The OMS Manual should also include instructions for reporting requirements that are required. Reporting requirements may include checklists, forms, equipment logs, work history, frequency and cause of problems, component reliability, quality control records, communications and activity records, photographic summaries, inventory of spares, materials, tools and equipment, and change orders.

A surveillance program should be developed, implemented and documented in the OMS Manual to assess if the tailings dam system is operating and performing in accordance with its design intent, and in compliance with regulatory and corporate policy requirements.

3.2.5. SURVEILLANCE PROGRAM

A surveillance program should be developed, implemented and documented in the OMS Manual to assess if the tailings dam system is operating and performing in accordance with its design intent, and in compliance with regulatory and corporate policy requirements. The surveillance program should be integrated with the TARPs by providing the quantitative and qualitative performance indicators that identify deviation from normal or expected conditions that can lead to a potential failure mode with a credible probability of occurrence under the adverse conditions. The surveillance program is intended to identify the triggers that result in actions in the TARP which could also lead to activating the emergency action plan for the tailings dam or site emergency response plan as discussed in Chapter VI.

The objectives of the surveillance program are to:

- record and document performance over time
- evaluate if the facilities are being operated according to their design intent
- identify operational and maintenance requirements based on surveillance outcomes
- communicate surveillance results to inform actions according to the TARP

The implementation framework should be focused around a “plan-do-check-act” cycle to foster continual review and improvement, as well as to routinely scrutinize whether the surveillance program is meeting performance objectives and risk management objectives. This is a key component of the surveillance program because a typical complex, modern tailings facility is progressively constructed and operated over time, and the surveillance program must be accurately targeted.

The surveillance program should focus on potential failure modes that can be detected and select performance parameters and QPOs that can be effectively monitored in the field against predefined trigger alert levels.

The surveillance program should include the following components:

- QPOs, critical controls and other indicators to identify deviation from normal or expected behavior, prompting further examination and/or investigation
- Routine and event driven visual, survey, instrumentation, or water quality monitoring activities performed at defined points and including instrumentation and performance reviews by designated site personnel and the engineer/designer of record or approved designate
- Regular inspections and reviews by internal and external experts and third parties who are independent of the operations team and the engineer/designer of record, to confirm facilities are operating as designed including annual performance reports and periodic dam safety inspections and evaluations as described in Section 2 of Chapter IV
- Notification and response procedures to communicate unusual conditions or potential dam safety situations based on TARPs or other documents such as the emergency action plan for the

tailings dam or the site-wide emergency response plan as described in See Chapter VI depending on the severity of the situation

- Documentation and reporting requirements related to surveillance activities such as responsible party, distribution list, reporting deadlines, and frequency

3.2.5.1.Inspections

Various inspections should be carried out by designated, qualified personnel as appropriate to the type of inspection. OMS Manuals should clearly indicate the requirements for the types of inspections including:

- Routine inspections such as daily and monthly inspections by trained site personnel
- Event driven inspections in response to an unusual event such as a large storm or earthquake
- Periodic inspections such as annual performance reviews, or safety inspections and evaluations by qualified engineers as required by regulations

The OMS Manual should provide the following:

- Scope, frequency and personnel responsible for routine inspections
- Events required to trigger an event-driven inspection (e.g., rainfall intensity and/or duration, earthquake) and personnel responsible
- Schedule for the various inspections including inspections required by regulations
- Documentation and reporting requirements for inspections as described in Section 2 of Chapter IV

3.2.5.2.Instrumentation

Instruments such as flow meters, piezometers, inclinometers, and survey monuments are installed within tailings dam systems and monitored to provide information on performance parameters that cannot be detected through visual inspections, cannot be observed with sufficient precision or accuracy, and/or need to be monitored at high-frequency or continuously. Instrumentation monitoring data may be used for different purposes, which could range from collecting data to build a historical database (e.g., climate data) to providing real-time dam safety performance information (e.g., measuring a rising phreatic surface in a dam, or movement along a weak layer in a dam foundation). A crucial element of an instrumentation surveillance plan geared toward dam safety is a clearly defined linkage between the monitoring parameter for each instrument and the respective, credible, detectable failure mode; for example, a rain gauge is directly related to monitoring for the maximum design flood. The design and construction documents should include an instrumentation plan that specifies spacing, type of instrumentation and construction details and OMS Manual should include frequency and procedures for monitoring. The plans should provide allowance for additional instrumentation or increased monitoring frequency when unusual readings or observations occur.

An OMS Manual should include the following related to instrument monitoring:

- location and description of each instrument, including calibration requirements
- parameters to be monitored by each instrument and frequency of data collection
- instrument thresholds that are related to a TARP
- personnel responsible for data collection, reduction and communication
- data collection, quality control and documentation procedures
- Functional test procedures
- Maintenance and replacement requirements

A crucial element of an instrumentation surveillance plan geared towards dam safety is a clearly defined linkage between the monitoring parameter for each instrument and the respective, credible, detectable failure mode.

3.2.6. TRIGGER ACTION RESPONSE PLANS

Trigger action response plans (TARPs) are predefined action plans, linked to key performance indicators or critical control alarms, intended to reduce the likelihood and/or severity of an emergency if unusual conditions are observed. Simply defined, a specific trigger action response would describe the following: "if this situation is observed, take the following actions within the indicated timeframe and alert the following people." TARPs should be integrated into the OMS Manual with a clear linkage to the emergency action plan or site wide emergency response plans as described in Chapter VI. An example TARP for a hypothetical dam overtopping event is summarized in Table V-1. Note that it may not be possible to link quantifiable trigger levels to all failure modes; for example, the emergence of a seepage face on the downstream slope of the dam, regardless of the flow rate, may be an unusual condition that signals filter clogging or piping failure. The OMS Manual should provide general and specific guidance on determining alert levels which should be linked to the TARPs.

3.2.7. TEMPORARY CESSATION/CARE AND MAINTENANCE AND CONTINGENCY PLANNING

The OMS Manual should include procedures associated with temporary shutdowns and subsequent re-starts when the tailings deposition plan and water management will be impacted. For example, seepage collection systems may need to remain operational even if tailings deposition ceases for any reason. Failure to operate and maintain critical systems could lead to severe consequences ranging from water quality violations to catastrophic failure of the tailings dam. Contingency plans should include procedures for responding to significant events such as water balance reviews. For example, a flood recovery plan should be developed that includes provisions for discharging stored flood water that encroaches into the surge capacity as shown in Figure V-5, and a plan for addressing potential environmental permit implications associated with flood discharge though an emergency spillway. These procedures should be coordinated with the change management as described in Section 3.2.9 of Chapter V.

TableV- 1. Example of a Trigger Action Response Plan (TARP)

Alert Level	Trigger Type and Level	Actions
Normal Operating Conditions	Pond Elevation< *x ft*	▪ Operate per normal conditions described in OMS manual
Unusual Condition (conditions are outside of expected normal dam safety behaviour)	Pond Elevation *x ft ≤ Pond Elevation < y ft*	▪ Commence or increase pumping out of impoundment ▪ Mobilize additional pumps ▪ Inform engineer/designer of record, regulators and other key stakeholders for situational awareness
Emergency Level (Dam is potentially unstable or situation is rapidly developing)	Pond Elevation *y ft ≤ Pond Elevation < z ft*	**Activate Emergency Action Plan**
Urgent Emergency/Crisis (Dam breach is imminent or has occurred)	Dam is Overtopping	**Activate Emergency Action Plan**

3.2.8. REGULATORY REQUIREMENTS AND REPORTING

Regulatory requirements for tailings facilities should be clearly understood by the tailings dam owner/operator and described in the OMS Manual and the tailings and water management policies and protocols, if necessary. Reporting requirements including content and frequencies should be clearly indicated. See Section 2.4 of Chapter IV for more information about reporting requirements for tailings dam systems.

3.2.9. ROLES, RESPONSIBILITIES AND COMMUNICATION

Persons directly or indirectly involved in management of the tailings facility must understand their roles, responsibilities and communication procedures for successful operation of a tailings dam system. The OMS Manual should describe:

- **Roles and the RACI Framework**
  - A RACI (responsible, accountable, consulted, informed) matrix may be used in an OMS Manual to describe roles and relationships between personnel, contractors and consultants including the engineer/designer of record. If a RACI matrix is not included, the OMS Manual should include an equivalent framework that outlines the roles of key personnel responsible for the operation and safety of the tailings facility. The OMS Manual should:
    - include an organizational chart and descriptions of roles, responsibilities, and level of authority of key personnel or groups involved in tailings management, including the engineer/designer of record and other qualified personnel involved in tailings facility operation and management
    - clearly describe the relationship between the dam owner/operator and any contractors and consultants
    - outline the lines of communication between personnel related to tailings management internally and with external parties, including regulators
    - describe who is responsible for surveillance, and who is responsible for TARPs, if critical controls are challenged and respective performance criteria are not met
- **Training**
  - The OMS Manual should outline the minimum knowledge and competency requirements for qualified personnel in various positions. Training requirements need to be identified to ensure that competencies are met and updated or refreshed, as appropriate. Training programs should be developed and implemented to ensure that appropriate training is provided to qualify personnel involved in operating and inspecting a tailings dam system. See Section 2 of Chapter VII for information about training opportunities.
- **Change Management**
  - Operating adjustments to the tailings dam system may become necessary due to unknown features not discovered during the site exploration and design process or unanticipated events during construction and operation. Examples include mineralogy changes in the waste rock and ore body, industrial process changes (mine mill grind, etc.), gradation changes in dredge deposits, site conditions not originally detected or anticipated, geohazard occurrences during the construction period such as extensive precipitation, changes in supply chain and product selections by contractors, and other unforeseen circumstances including temporary shutdowns and pre-mature closure.
  - All OMS activities are expected to identify changes that must be managed, including those linked to performance objectives, risk controls, and critical controls The OMS Manual should reflect and reference provisions for change management in tailings and water management

policies and protocols and other corporate commitment, management or governance processes.

- The OMS Manual should undergo ongoing development and review and be updated on a regular basis, typically every few years or when there is a significant change to tailings management. The OMS Manual should also identify changes in operations in the event of a temporary shutdown or other foreseeable changes (e.g., increased production rate, increases in tailings dam height), or changes between life phases of the tailings dam such as reclamation activities concurrent with operations, closure and the post-closure scenario.

- Succession Planning
  - Changes in personnel can be a source of risk in tailings management, and succession planning is a tool to help manage that risk. The development and implementation of succession plans would typically be outside the scope of an OMS Manual. However, an OMS Manual development team needs to identify roles or positions for which succession planning would be important to manage risks. An OMS Manual describes knowledge and competency requirements, transition plans, and handover procedures for those roles or positions.

3.3. Corporate commitments and evaluation

Considerations for Regulators
Useful questions to ask about corporate commitment to the OMS program and continual improvement processes include:

- Has the dam owner appointed an executive with overall accountability for tailings management?
- Does the dam owner/operator have a tailings management review process in place to confirm that the OMS program is achieving its goal including reducing tailings dam system risk, and to identify areas for improvement?
- Are the findings of the management review process documented?
- Are suggested actions clearly defined with accountability?
- Is a mechanism in place to confirm actions are carried out in a timely manner?

Corporate tailings and water management policies and protocols are the most effective control measures to reduce risk of adverse incidents with tailings dams systems (Morgenstern, 2018). The descriptions summarized here are intended to help the regulator understand the significant risk reduction opportunities provided by a responsible tailings dam owner/operator for a complex modern industrial facility such as a large mine.

Continual improvement is a key objective of the “plan-do-check-act” cycle in the operation of a tailings facility and evaluation of system performance is required to ensure continual improvement. The following subsections describe three elements of evaluation. These processes are summarized based on the guidance provided in the industry standard *A Guide to the Management of Tailings Facilities* (MAC 2019a). These principles are most appropriately included and developed in corporate tailings and water management policies and protocols. A full discussion of corporate commitments and evaluation is outside the scope of the *Tailings Dam Supplement*.

3.3.1. PERFORMANCE EVALUATION

Performance evaluation is carried out within all areas of the tailings and water management policies and protocols with the following key objectives:

- confirm that the key performance objectives for the tailings dam system are being met and that the systems in place to monitor those objectives are adequate
- assess the effectiveness of risk management programs and measures, including implementation and monitoring of critical controls for the tailings dam system
- identify gaps or deficiencies and inform updates to the risk management approach and OMS Manual

The frequency of performance evaluation varies depending on which aspect of the tailings and water management policies and protocols are being evaluated. For critical controls, evaluation could occur on a daily, hourly or continuous basis. More general evaluations such as for the OMS Manual, RACI matrix, or tailings and water management policies and protocols may be carried out with less frequency.

For performance evaluation to be effective, findings and areas for improvement must be clearly documented, actionable and assigned to a responsible individual(s). Reporting requirements for performance evaluation should be clearly defined. Note that an annual performance evaluation of the tailings dam system by a qualified engineer is a recommended regulatory requirement described as an inspection under Section 2.5.2 of Chapter IV.

3.3.2. ASSURANCE

Assurance is an oversight process, distinct from performance evaluation, that ensures that the tailings and water management policies and protocols are being effectively executed. The assurance process can be carried out by internal or external parties to the operations and may take different forms:

- Audits assess and report on whether the tailings and water management policies and protocols are being executed as stipulated. Audits are typically not intended to determine the root-cause of non-conformances in the system, or comment on the effectiveness of the tailings and water management policies and protocols

- Evaluations of effectiveness go beyond audits and assess whether tailings and water management policies and protocols are achieving the desired objectives. These assurance reviews should assess performance of the management of the tailings dam system if internal or external factors change. An independent technical review panel as described in Section 4.3 of Chapter III may be an example of this type of assurance mechanism; however, such a responsibility would need to be clearly defined in the terms of reference for panel engagement

3.3.3. MANAGEMENT REVIEW FOR CONTINUAL IMPROVEMENT

The results of performance evaluation and assurance reviews provide the basis for determining where improvements can be made at any level as opportunities are discovered. Key components of the management review process include evaluation of:

- the status of actions from previous management reviews
- overall performance of the tailings and water management policies and protocols to ensure ongoing suitability, or need for changes to the system
- overall performance of the tailings dam system including compliance with all regulatory requirements
- effectiveness of the risk management system
- adequacy of the resources (human and financial) committed to tailings management

The management review should identify and evaluate the impact of changes since the previous review that are relevant to the tailings management review. Such changes may include:

- regulatory requirements
- evolution of industry “best practice”
- factors that could influence the nature and significance of potential impacts of the tailings facility on the external environment or vice versa
- the risk profile of the operation including the tailings dam system

The outcomes of the management review should be documented and include:

- conclusions related to performance of the tailings and water management policies and protocols and the tailings dam system
- action plans for addressing non-conformances and opportunities for improvement

- modifications to the tailings and water management policies and protocols or the tailings dam system
- enhancement to human and financial resources to help ensure effective tailings management

4. Closure and Reclamation

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems
▪ Authority to require financial assurance sufficient to close and reclaim a tailings facility and provide the post-closure care and maintenance as necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption ▪ Authority to approve plans to modify tailings dam systems into a closed configuration ▪ Authority to make jurisdictional determinations of regulatory requirements for the post-closure phase of the tailings dam including the authority to enforce or waive compliance
Considerations for Regulators
▪ What are the care and maintenance requirements of a tailings dam in the closed configuration? ▪ Does the tailings dam remain under regulatory jurisdiction in the closed configuration? ▪ Who is responsible for closing a tailings dam system? ▪ Whether closure is planned or not, who is responsible for the closed tailings dam and for how long?
Recommendations
▪ Closure designs for all tailings dam systems should be screened for performance requirements and inspection and maintenance requirements necessary to ensure that performance remains safe ▪ Use risk management methods to evaluate tailings dam in closed configuration and determine post-closure regulatory requirements necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption

As described in Section 1 of Chapter III, tailings dams are unique from water dams in several ways. A contrast in the closure aspect helps understand a key difference pertinent to this section. A water dam is built to impound a renewable resource to serve demand for water for an indefinite period of time, but if that demand goes away, the dam can be removed, and the area of the former reservoir can be restored or reclaimed. A tailings dam is built to impound a limited amount of sediment, and when it is full, the structure must remain in place to contain the sediment indefinitely after closure and reclamation. In other words, the function of a tailings dam is to retain deposits of sediment; therefore, breaching a tailings dam below the elevation of a spillway at the end of its operational life is usually not an option. Rather, the tailings impoundment in the closed configuration becomes a permanent constructed landform whose operational life may be more similar to a full landfill than a classic dam. The degree to which long-term monitoring, maintenance, and inspections are required, and the parties responsible for these tasks, are questions which must be considered.

The various other differences between water dams and tailings dams will have an influence on the performance of the tailings dam system in the closed configuration and dictate the post-closure inspection and maintenance requirements. Several criteria must be considered for determining if a closed tailings dam should remain a dam under strict regulatory oversight, or if modified regulatory requirements or deregulation can occur for the landform remaining after the tailings deposition is complete and the facility is reclaimed. The tailings dam system must be carefully evaluated to determine the financial and regulatory requirements for the closed configuration. For example, if a closed tailings dam is passively stable and safe without active maintenance requirements, it could be excused from dam safety regulations, even though other regulatory requirements may still apply. If the closed tailings dam requires active oversight and maintenance to be safe, the tailings dam may be subject to dam safety regulations indefinitely, and funding for facility maintenance and related costs must be available.

Closure is herein considered a discrete process intended to achieve the "post-closure" or closed configuration, wherein the tailings dam enters the final, permanent phase of life.

The following discussion provides information on planning for closure of a tailings dam system, unplanned closure, transitioning through closure and reclamation of the tailings facility, and the post-closure phase of the tailings dam as described in Section 4.4 of Chapter V. In *Sustainable Design and Post-closure Performance of Tailings Dams, Bulletin 153* (2011), the International Commission on Large Dams defines closure as:

> The planned final cessation of tailings disposal into the tailings dam and the modification/engineering of the tailings dam with the objective of achieving long-term physical, chemical, ecological and social stability and a sustainable, environmentally appropriate after-use.

The CDA echoes these important components of responsible tailings dam closure, further described as a "process of establishing a configuration [that] can be achieved during or after mine operations" (CDA, 2014). As previously noted, the *Tailings Dam Supplement* is not limited to tailings dams at mine operations; rather, it is applicable to any industry that produces a waste or milled product similar to tailings that requires disposal in a containment facility similar to a tailings dam.

Closure is herein considered a discrete process intended to achieve the "post-closure" or closed configuration, wherein the tailings dam enters the final, permanent phase of life. Reclamation herein infers some attributes developed during the closure of a tailings facility necessary to meet existing federal, state or local regulatory requirements for land reclamation in the closed configuration. A detailed discussion or definition of reclamation is beyond the scope of the *Tailings Dam Supplement* and otherwise considered incidental to closure to avoid conflicts. In any case, reclamation details should be included in the final closure design subject to regulatory approval.

Reclamation herein infers some attributes developed during the closure of a tailings facility necessary to meet existing federal, state or local regulatory requirements for land reclamation in the closed configuration. A detailed discussion or definition of reclamation is beyond the scope of the Tailings Dam Supplement and otherwise considered incidental to closure to avoid conflicts.

Closure may occur either as planned or may occur pre-maturely for some unforeseen reason such as bankruptcy of the dam owner/operator. With respect to regulatory requirements in the post-closure phase, three different scenarios of closed tailings dams can be generally described as:

- Tailings dams that require active care and OMS for an indefinite period of time after closure and subject to applicable tailings dam safety regulations
- Tailings dams that may require active care and limited OMS for a discrete period of time after closure and reclamation to ensure that post-closure performance objectives are being met, that are designed and demonstrated to be passively stable and safe as a landform with sufficiently low, tolerable risks, and may qualify for limited regulation or de-regulation after a discrete surveillance period
- Tailings dams that do not require active care and maintenance in the closed configuration, that are designed and demonstrated to be passively stable and safe as a landform with sufficiently low, tolerable risk and may be de-regulated from tailings dam safety oversight after a relatively short surveillance period

Additional details on these three closure scenarios are described in Section 4.4 of Chapter V.

4.1. Planned closure and reclamation

A dam owner/operator should begin planning for closure and reclamation as part of the initial tailings dam design phase as described in Section 1 of Chapter V. At a minimum, the engineer/designer of record should develop a closure and reclamation concept that considers the disposition of decant water from tailings consolidation, the cover necessary to reclaim the surface of the tailings deposit, stormwater diversions, channels and spillways to pass surface runoff, and seepage from the tailings dam. This is important because the closed tailings facility envisioned by the engineer/designer of record may influence decisions necessary for operations. In addition, the costs to close and reclaim the tailings facility and conduct post-closure monitoring, maintenance, and inspections, as necessary, must be estimated in advance to determine the financial assurance necessary to accomplish the work. The dam owner/operator is clearly responsible for conducting the work to close and reclaim the tailings facility, but the parties responsible for post-closure care and OMS should also be identified in early planning and agreed to by the regulatory agency, especially where public lands and multiple stakeholders are involved.

4.1.1. CLOSURE AND RECLAMATION PLAN

A closure and reclamation plan should be developed by the responsible parties and submitted to the appropriate regulatory authorities for review. The closure and reclamation plan should clearly articulate closure objectives that are succinct, site specific and consistent with the objectives described in Section 4.1 of Chapter V. The closure and reclamation plan should describe the tailings facility in the closed configuration based on the scheduled life of the project at the time the plan is developed. The level of detail of the plan should be commensurate with the current operating state of the tailings facility with the level of detail increasing as described in Section 4.1.3 of Chapter V. The closure and reclamation plan should be updated regularly. Contingencies should be included for temporary and pre-mature closure during operations of the tailings facility in the event of an unplanned closure as discussed in Section 4.2 of Chapter V. Planning for different contingencies helps ensure more accurate cost estimates for financial assurance as discussed in Section 4.1.2 and 4.1.3 of Chapter V.

The closure and reclamation plan should include:

- Steps to transition from an operating tailings facility to a closed and reclaimed tailings dam
- Roles and responsibilities of the parties involved including the tailings dam safety regulator
- Schedule for closure transition period and estimated date of planned closure
- Required post-closure activities to ensure the safety of the tailings dam such as inspection, monitoring, maintenance, reporting and respective schedules

The risks posed by a closed facility will likely have changed compared to those of the operating facility, so a risk assessment as described in Section 2.3 of Chapter III may be necessary to determine the performance requirements, critical controls and hazard potential classification in the closed configuration, so the appropriate TARPS and emergency response actions can be identified. Depending on the hazard potential classification of the closed tailings dam, a post-closure Emergency Action Plan as described in Section 1 of Appendix VI may be required.

At a minimum, a closure and reclamation plan should attempt to forecast facility management and oversight requirements as far into the future as possible. This may be influenced by the reclamation requirements in addition to details of the specific tailings dam design in the closed configuration. Closure and reclamation requirements may also be articulated under other authorities such as mine reclamation, water quality and solid waste regulatory programs.

4.1.2. FINANCIAL ASSURANCE COST ESTIMATES AND POST CLOSURE REQUIREMENTS

Cost estimates for financial assurance for closing a tailings facility should be developed with the regulatory permit application process and updated over the life of the operation. The costs to comply with tailings dam safety regulatory requirements through closure and reclamation, and in the post-closure phase, should also be included in the closure cost estimate. In order to refine those cost estimates as closure approaches, additional information developed during operations on project conditions that affect costs can be incorporated in the estimate, including actual construction and maintenance histories and more fully developed details for the closure design and construction, and post-closure OMS requirements, as necessary to ensure a stable and safe structure.

The financial assurance requirements of the tailings dam in its closed configuration will be significantly affected by the maintenance requirements necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. The cost estimate is also affected by the surveillance requirements and the post-closure monitoring scenario as described in Section 4.4 of Chapter V. On the low end, a small, closed and reclaimed tailings dam without any significant maintenance requirements may be considered passively stable and safe with financial assurance requirements limited to closure and reclamation costs, and perhaps a limited surveillance period. In the middle, a large, closed and reclaimed tailings dam that perhaps does not have adverse environmental impacts from seepage after a period of time, may be qualified for limited regulation or de-regulation under conditions of meeting performance requirements after a discrete period of surveillance. On the high end, a closed tailings dam that requires long-term care and active OMS indefinitely to ensure stability, safety and adequate performance may require site-specific memorandums of agreement and financial instruments such as trusts, annuities, endowments or permanent funds. These three closure scenarios are described in detail in Section 4.4 of Chapter V. These scenarios may follow a closure planned by the tailings dam/owner operator, or when a default on obligations occurs for some reason such as a bankruptcy, resulting in claims against financial assurance instruments. Unplanned closure is discussed in additional detail in Section 4.2 of Chapter V.

The scope of the financial assurance requirements will depend on the time frames that financial assurance is required. Considering the unique aspects of the closed tailings dam that transitions to a landform similar to a landfill when appropriately designed, a post-closure, thirty-year monitoring period similar to landfills regulated under Subtitle D of RCRA may be an appropriate model for a large, complex tailings dam system subject to multiple regulatory authorizations, otherwise meeting water quality standards passively, with limited or no water treatment or maintenance requirements. See Section 4.4 of Chapter III and Appendix C for more detailed discussions of financial assurance for tailings dams.

4.1.3. DEVELOPING ADDITIONAL DETAIL FOR CLOSURE OVER TIME

Planning for closure and reclamation should begin during the conceptual design. For small, short-term tailings dam operations, the full, detailed, closure design may be required for regulatory authorizations to begin construction and operation. However, in typical complex modern mines, only the foundation level features needed for the closed configuration, such as liner systems and underdrains, will be constructed with the starter dam and subsequent raises, and the final closure construction may be decades in the future. Consequently, the detailed design necessary for closure construction is typically deferred. The closure and reclamation plan should be updated throughout the operating phase of the facility and in a continual state of refinement up until a detailed design for the closed configuration of the tailings dam is developed (ICOLD, 2013). This process helps refine the cost estimate for financial assurance, which should be updated regularly to ensure that the appropriate funding is available at the end of the scheduled operating phase of the tailings facility, or in the event of an unplanned closure.

4.1.4. RISK FROM CLOSED TAILINGS DAMS

Considerations for Regulators
Useful questions to evaluate risk from closed tailings dams:

- Are active monitoring, maintenance and inspection requirements necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption?
- Is the geotechnical slope stability evaluated using factors of safety, seismic design criteria, and liquefaction analysis in sufficient detail to determine tolerable risk for a catastrophic embankment failure or other loss of containment?
- Does closure surface water management depend on water being routed around or through the impoundment?
- Does the tailings deposit require a “wet” cover or open water pond in the closed configuration for chemical stability of the tailings?
- Does the spillway design depend on the tailings dam to impound water to attenuate the inflow design flood from the design precipitation event?
- Does the seepage meet water quality standards or require collection and treatment prior to discharge?
- Does the closure cover design prevent tailings dust from becoming airborne?
- Will failure of surface reclamation lead to extensive erosion including the tailings deposit or compromise the post-closure land use?

Conducting a risk assessment on the closed configuration as described in Section 2.3 of Chapter III is highly recommended to aid the dam owner/operator and the regulator to evaluate the various risks posed by a closed tailings facility. Closed tailings dams fail less frequently than operating tailings dam systems (ICOLD, 2001) because the risks associated with tailings dams in the post-closure environment differ from those posed during operations. At closure, risk can be reduced by eliminating the impounded water, dewatering the tailings mass, and stabilizing the embankment to create a landform. Toward this end, tailings dam closure scenarios frequently include placing a cover of some type over the tailings once the standing water is removed, routing surface water over or around the facility, and collecting seepage. Routine maintenance items may include repairs to seepage collection and water treatment systems, clearing diversion ditches and spillways and repairing erosion. Visual inspections and instrument monitoring (e.g., piezometers, inclinometers, survey monuments) and evaluations may be part of post-closure requirements necessary to mitigate risks and to ensure long term stability and safety.

The challenge presented by trying to anticipate the monitoring and maintenance requirements for a closed tailings facility requires forecasting anticipated site conditions far into the future. The risks to a closed facility will include chronic degradation and deterioration of system components, in addition to acute, rare events such as a large magnitude earthquake or flood. This emphasizes that tailings dam designs must meet extreme performance requirements during operations, and additional extreme performance requirements critical for long term stability after closure. Consequently, the design basis memorandum discussed in Section 4.1.5 of Chapter V must be revised for closure. Tailings consolidation, interstitial water release, closure cap settlement, surface and seepage water management, embankment condition, climate change and geomorphic succession are some of the time-dependent variables which should be evaluated and planned for when assessing post-closure timeframes. A risk assessment targeting the post-closure phase can aid in identifying which system components should be evaluated and reinforced as necessary to ensure long-term landform stability and safety.

In addition to the physical components of the tailings dam, other components of the containment system should not be overlooked as possible threats to public health and safety including the chemical constituents and toxicity of the tailings. The impounded tailings may pose a risk from liquefaction under certain conditions, from acid rock drainage/metal leaching or other constituents, or as a chronic source of airborne dust or erosion sediment. Addressing all of these considerations may be necessary at closure.

4.1.5. REVISING THE DESIGN BASIS MEMORANDUM

A closed and reclaimed facility will evolve over time due to geomorphic processes as system components trend toward a condition of quasi-static equilibrium. The embankment will settle, tailings will consolidate, soil may weather and degrade, seepage will likely reach a steady state condition, and vegetation succession will evolve. The maintenance requirements during the post-closure phase will differ from those for operations. The detailed design of a closed tailings dam should anticipate these maintenance requirements and be developed through the process described in Section 1 of Chapter V including the development of a revised DBM and respective QPOs that specifically address the closed tailings dam. This may include different seismic and hydrologic design criteria for the closure design than used in the operating design, which may be informed by a risk assessment and specific technical and regulatory requirements. Landform designs, residual material properties, extreme seismic and precipitation events and long timeframes should be considered.

The construction of modifications necessary for closure and reclamation should be subject to the applicable provisions of Section 2 of Chapter V, and the post-closure OMS requirements should be developed as described in Section 3 of Chapter V. OMS requirements for the closed configuration are expected to be significantly different based on the post-closure scenarios described in Section 4.4 of Chapter V and the following should be considered for the closed tailings dam:

- Systems and components requiring monitoring, care, and maintenance
- Revised performance objectives and critical controls, if required

- Scope and schedule for inspection, monitoring and maintenance
- Capital improvement schedule (e.g., system replacement) if anticipated
- Inspection and reporting requirements
- Trigger levels for response actions
- Regulatory requirements

Because unexpected conditions may arise, provisions for adaptive management should be included in the closure and reclamation plan, and in the post-closure OMS requirements, if active oversight and maintenance are required to ensure the stability and safety of the tailings dam in the closed configuration.

4.2. Unplanned closure

An unplanned closure may occur for any number of reasons but frequently fall into two general categories:

- An industrial process such as mining may halt operations, suspend tailings production, and place the tailings dam system into care and maintenance/temporary closure as described in the OMS manual developed under Section 3 of Chapter V. Some mining regulations may require closure and reclamation if operations do not resume within relatively short time periods such as 3 to 5 years. This may lead to early closure of the tailings dam system by responsible parties as described in Section 4 of Chapter III into one of the closure scenarios described in Section 4.4 of Chapter V.
- A dam owner/operator declares bankruptcy and is unable or unwilling to manage the tailings facility. Other obligations are not fulfilled, the financial assurances are claimed whether adequate or not, and an adverse situation develops requiring enforcement actions as described in Section 2 of Chapter II. Regardless, the tailings dam must eventually be closed into one of the closure scenarios described in Section 4.4 of Chapter V to appropriately mitigate the risk of the tailings dam.

An unplanned closure is often a financial decision, and there are often warning signs well in advance. Proper governance and oversight by the regulator mean active and regular engagement with the dam owner/operator in order to maintain a situational awareness of any pending changes in commitment to facility management. During a temporary closure, a tailings dam owner/operator must continue to provide appropriate levels of oversight to ensure the safety of the tailings dam. If an operator defaults for any reason, and fails to fulfill the requirements of facility oversight, an orderly transition to a new responsible party is imperative to avoid a lapse in facility management.

In a default scenario, the question becomes, “who will assume this responsibility?” Oversight may fall to a “lead” permitting agency or underlying landowner or land manager, depending on the nature of the authorizing statutes and regulations for the main industrial facility or project, land ownership, financial assurance claims, legal settlements or lawsuits. There may be instances where there are overlapping regulatory permits or responsibilities and enforcement actions, and these jurisdictional divisions will need to be addressed by the parties involved. Ideally, a clear understanding of regulatory duties and responsibilities in the event of a default, including financial responsibility, should be established during the initial permit review process. A full discussion of insolvent operations and the management of residual risks associated with abandoned waste impoundments and brownfield properties are outside of the scope of the *Tailings Dam Supplement*. However, the tailings dam safety program must maintain regulatory oversight of the tailings dam system under these circumstances as necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption.

As described in Section 4.4 of Chapter V, each tailings dam is unique in the post-closure phase and may require different levels of post-closure management. In the event of a default, some variation on the following checklist is recommended for the tailings dam safety program:

- Initiate claim on financial assurance
- Site inspection and assessment
- Records search for operating history, and monitoring and maintenance requirements
- A detailed engineering evaluation and risk assessment so that any changes to the current configuration may be identified and planned as necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption
- Update (or develop) and implement an OMS program
- Update (or develop) and implement an Emergency Action Plan, if required
- Assess long-term monitoring, maintenance and budget requirements, and modify plans accordingly
- Implement closure and reclamation plan

4.3. Transitioning through closure process

4.3.1. IMPLEMENTING THE CLOSURE AND RECLAMATION PLAN

The primary party responsible for tailings facility closure is usually the entity holding the permit or authorization for construction and operation of the tailings dam system as described in Section 4 of Chapter III. Typically, the responsible party conducts the closure and reclamation using their own funds, then seeks release of financial assurance obligations after reclamation objectives have been achieved. This may include partial closures and concurrent reclamation while operations continue in other areas of the tailings facility or the industrial operation. The closure transition phase can be precarious as the tailings dam impoundment is nearing the design capacity. Challenges can include limitations on operating pond storage capacity, changes in water management procedures, inaccurate tailings production forecasts resulting in more or less tailings than the available storage capacity, closure design changes, installation of covers that may include complex engineering design features such as drains and geosynthetic materials constructed on soft tailings, construction of closure spillways that change freeboard limits, and demolition or removal of appurtenant facilities. Other requirements that occur during the transition phase may include identifying or establishing post closure operating entities, establishing financial or trust relationships and implementing surveillance programs.

The closure transition phase can be precarious as the tailings dam impoundment is nearing the design capacity.

4.3.2. REGULATORY REQUIREMENTS

The tailings dam safety regulator is tasked with ensuring the tailings facility is closed according to the approved plan and/or permit conditions. All permits and legally binding documents should be reviewed prior to closure to understand the obligations of the responsible parties. The tailings dam safety regulator should review the closure and reclamation plan with the responsible parties so there is a clear understanding about plan conditions and permit requirements. It is imperative that all permits, authorizations, and plans are current and have been accepted and reviewed by the authorizing agencies. Legal disputes arise from time to time and having accurate, current, and legally binding paperwork in order is the first step in resolving any conflicts.

The tailings dam safety regulator should review the closure and reclamation plan with the responsible parties so there is a clear understanding about plan conditions and permit requirements.

In some jurisdictions there may be multiple permits issued for a tailings facility depending on local, state and federal regulations, and often there is a Memorandum of Agreement or Memorandum of Understanding or similar documents outlining regulatory coordination when there are overlapping authorities. As a facility nears closure, the tailings dam safety regulator should coordinate with the other regulatory agencies who have legal standing so there are clear lines of communication, roles and responsibilities. That is why it is important for the agencies to identify which regulatory authorities will oversee and regulate the tailings facility once it is closed because there may be more than one.

In addition, the regulator should ensure that all financial assurance requirements remain current, including cost estimates, and post closure agreements are in place for transferring responsibilities and funding, as required based on the post-closure scenarios described in the following section.

4.4. Post-closure scenarios

Unlike a water dam which can be decommissioned by breaching the embankment, a tailings facility is a permanent fixture on the landscape and requires careful design and evaluation to ensure long-term stability and safety. The climatological environment is always slowly changing, and tailings dams will be subject to the same natural forces that are shaping the landscape on which they sit. Eventually, natural processes such as storm events, erosion, weathering of soil, animal and anthropogenic activity, wildfire, seismicity and gravity will slowly degrade the tailings dam. While many of these processes occur slowly, all have the potential to alter the form and function of the tailings dam and cause adverse conditions to develop. Determining if de-regulation of a tailings dam can be approved is a difficult task, because often there are no obvious endpoints or conditions where one can say the risk posed by the tailings dam has been entirely eliminated.

> *Each tailings facility is unique and will require different post-closure management and timeframes, therefore regulatory requirements for each case must be considered individually.*

Nevertheless, if the risk of adverse incidents for the closed configuration of the tailings dam can be reduced and determined to be in a tolerable range, limited regulatory requirements or de-regulation may be considered. Significant variabilities across industries and regions make universal application of regulatory criteria challenging. Each tailings facility is unique and will require different post-closure management and timeframes, therefore regulatory requirements for each case must be considered individually. The general descriptions for three closure scenarios described in the following sections are intended to assist the regulator in making the jurisdictional determination for post-closure regulatory requirements. De-regulation of a tailings dam approved by the dam safety regulatory agency should not be interpreted to release a tailings dam owner/operator from potential liability in the post-closure scenario.

The tailings dam safety regulatory agency should make a specific jurisdictional determination of whether the closed tailings dam requires tailings dam safety regulatory oversight during the post-closure surveillance period including assessing the hazard potential classification as discussed in Section 2.1 of Chapter IV. Any tailings dam that requires active, long-term care and maintenance as described in Section 4.4.1 of Chapter V to protect against loss of life, economic loss, property damage, environmental impacts and lifeline disruption must be regulated indefinitely and the financial assurance requirements described in Section 4.1.2 of Chapter V must be provided. De-regulation or limited regulatory requirements may be considered for a tailings dam in the post-closure scenarios described in Section 4.4.2 and 4.4.3 of Chapter V. Risk assessments should be considered in all jurisdictional determinations as described in Section 2.3 of Chapter III.

4.4.1. POST CLOSURE SCENARIO 1 – LONG-TERM CARE, MAINTENANCE AND DAM SAFETY REGULATION

Long-term care and maintenance of some closed tailings facility may be necessary for hundreds of years (AER, 2020; CDA, 2014; ICOLD, 2013). With the potential for such indefinite, long-term liability, and the uncertainties inherent in forecasting so far into the future, adaptive management concepts must be included in the oversight process. To protect against loss of life, economic loss, property damage, environmental impacts and lifeline disruption, the OMS program described in Section 3.1 of Chapter V must be adapted to the specific, closed tailings dam based on a revised DBM as described in Section 4.1.5 of Chapter V. A tailings dam with high levels of uncertainty and risk surrounding future post-closure conditions is not eligible for de-regulation and must remain under dam safety regulation indefinitely. Financial assurance agreements as discussed in Section 4.1.2 of Chapter V may, to the extent practicable and consistent with statutes and regulations, include long-term administrative costs and regulatory fees to ensure sustainability of oversight in addition to all direct and indirect costs for the OMS, as necessary to maintain a safe tailings dam in a stable and satisfactory condition.

A tailings dam with high levels of uncertainty and risk surrounding future post-closure conditions is not eligible for de-regulation and must remain under dam safety regulation indefinitely.

Typical features of a tailings dam system in this scenario may include:

- Active maintenance requirements to ensure storm water management systems are functioning properly; cleaning of spillways; repairing erosion damage on covers and embankments
- Performance monitoring for critical controls as described in Section 2.2 of Chapter IV and Section 3.1.1 and 3.1.2 of Chapter V, based on risk assessments as described in Section 2.3 of Chapter III, as necessary to ensure geotechnical slope stability, seepage detection and collection systems, underdrain systems and surface water management systems are operating within safe parameters
- Active monitoring for both facility performance and environmental protection
- Water covers, large open water ponds, or detention basins on top of tailings deposits in valley fills that require diversion or attenuation of flood events through bypass channels or restricted spillways
- Cover systems, spillways and embankments that require active vegetation management such as clearing natural reinvasion or mowing to meet performance objectives
- Poorly drained, unstable tailings deposits whether due to inherent, geological or mineralogical properties regardless of processing, or design features such as geomembrane liners
- Tailings dam embankment construction methods that cause the design to depend on the strength of hydraulically deposited, contractive tailings subject to liquefaction or brittle failure, to retain the contents of the tailings deposit in a liquified state

- Marginal slope stability designs based on calculated safety factors and deformations under static and seismic design loads developed using standard methods with limited detail, without any redundancy such as flattened slopes or other landform engineering features
- Tailings dam system components that must continue to function and perform as necessary to ensure tailings dam stability such as underdrains
- Highly mineralized tailings or contaminated sediments including potentially acid rock drainage/metal leaching tailings or other materials that require active seepage collection and water treatment systems to meet water quality discharge standards
- Tailings facilities where the protection of the surrounding environment is dependent on the function, performance and stability of the closed tailings dam
- High or significant hazard potential classification in the closed configuration

4.4.2. POST CLOSURE SCENARIO 2 – CONDITIONAL DAM SAFETY REGULATION

All tailings dams should be designed for closure and reclamation to reach a quasi-steady state equilibrium with the surrounding environment as near to the pre-construction condition that is possible. Tailings dams that are closed and reclaimed as landforms may require some level of ongoing care and maintenance for a discrete period of time to ensure performance objectives are met, such as the establishment of vegetation or water quality. All features should be designed to be passively stable and safe without active monitoring or maintenance to ensure containment of tailings. Periodic monitoring and maintenance may be required for transient features that are expected to be retired such as water treatment systems necessary for the interim period. Frequently there are permit requirements for water, air, wildlife or some other natural resource monitoring which remain in place during post-closure until certain statutory requirements or standards are met. Similarly, the dam safety monitoring period may be discrete, typically from 5 to 30 years, similar to post-closure monitoring periods for solid waste landfills regulated under Subtitle D of RCRA. Limited dam safety regulatory requirements or de-regulation may be considered under the condition that performance parameters are met after the discrete, dam safety monitoring period.

> *Tailings dams that are closed and reclaimed as landforms may require some level of ongoing care and maintenance for a discrete period of time to ensure performance objectives are met. All features should be designed to be passively stable and safe without active monitoring or maintenance to ensure containment of tailings.*

Typical features of a tailings dam system in this scenario may include:

- Dry covers with no large open ponds or detention basins on the tailings deposit
- Off channel or out-of-valley fills with no significant contributing areas requiring run-on diversions

- Valley fills with diversion channels or spillways with large capacities to pass design floods without any attenuation provided by a reservoir impounded by the dam
- Surface features such as covers, channels, spillways and embankment slopes that are erosion resistant, or insensitive to erosion or clogging from vegetation, snow or ice blockage, or adjacent slope instability
- Relatively free draining tailings deposits and embankment materials including robust underdrains that are not reliant on pumping or other active operational requirements to manage seepage or prevent build-up of groundwater in structural components
- Tailings dam embankment construction methods that do not depend on the strength of hydraulically deposited tailings, regardless of liquefaction potential, to retain the contents of the tailings deposit in a liquified state
- Designed for closure and reclamation as a landform with geomorphic stability demonstrated by robust slope stability designs based on calculated safety factors and deformations under static conditions and chronic and extreme seismic loads; erosion prevention and spillway designs based on extreme hydrologic events including climate change; and, redundancy such as flattened slopes, safety factors on hydraulic components, or other landform engineering features such as buttresses or relatively wide embankments
- Benign or mineralized tailings that are not acid rock drainage/metal leaching, otherwise chemically stable, regardless of processing, and do not require indefinite, active seepage collection and water treatment systems to meet water quality discharge standards; however, seepage collection and water treatment or monitoring may be required for a discrete period of time to establish and evaluate equilibrium conditions
- Require monitoring for both facility performance and environmental protection during the discrete monitoring period to determine that performance objectives defined as conditions for de-regulation are met
- Significant or low hazard potential classification during the conditional monitoring period, but low hazard potential if performance objectives are met sufficiently to de-regulate the dam

4.4.3. POST CLOSURE SCENARIO 3 – LONG-TERM DAM SAFETY DE-REGULATION

Tailings dams are a responsibility and a liability that must be managed. However, not all tailings dams require the same level of care, maintenance and monitoring in the post-closure phase. Risk assessment as described in Section 2.3 of Chapter III is a useful tool for determining the requirements necessary to reduce risk and maintain the safety of the tailings dam. If the risk of failure in the closed configuration is low enough, dam safety regulatory requirements may be reduced to long-term care and maintenance agreements with limited monitoring and maintenance schedules or be deferred. Typical features of the tailings dam system in this scenario may include:

- Dry, well drained, erosion resistant covers over tailings deposits or no cover requirements
- Off channel or out-of-valley fills with no significant contributing areas requiring run-on diversions
- Surface features such as channels, spillways, and embankment slopes that are erosion resistant, or insensitive to erosion or clogging from vegetation including natural reinvasion, or snow or ice blockage, or adjacent slope instability
- Free draining tailings deposits and embankment materials including robust underdrains that are not reliant on pumping or other active operational requirements to manage seepage or prevent build-up of groundwater in structural components
- Short, low head tailings dams with downstream embankment construction methods that do not depend on the strength of hydraulically deposited tailings to retain the contents of the tailings deposit in a liquified state
- Designed for closure and reclamation as a landform with geomorphic stability demonstrated by robust slope stability designs based on calculated safety factors and deformations under static conditions and chronic and extreme seismic loads; erosion prevention and spillway designs based on extreme hydrologic events including climate change; and, redundancy such as flattened slopes, safety factors on hydraulic components, or other landform engineering features such as buttresses or relatively wide embankments
- Benign, chemically stable, tailings with limited processing such as dredge spoils or placer tailings with no seepage collection or treatment needed to meet water quality discharge standards
- Adverse facility performance does not result in extensive runouts or other environmental impacts
- Low hazard potential classification
- A risk assessment as described in Section 2.3 of Chapter III to determine limited dam safety regulatory requirements or support de-regulation

If the risk of failure in the closed configuration is low enough, dam safety regulatory requirements may be reduced to long-term care and maintenance agreements with limited monitoring and maintenance schedules or be deferred.

Chapter VI – Emergency Planning and Incident Response

1. Emergency Action Plan

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems

- Emergency action plans for any tailings dam based on the hazard potential classification
- Regular updates and plan exercises at a sufficiently frequent interval to ensure responsibilities are well understood and current for emergency responders

Considerations for Regulators

- The emergency action plan must include the actions necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption

Recommendations

- Emergency action plans consistent with the guidance of *Emergency Action Planning for Dam Owners* (FEMA 64, 2013) and a site emergency response plan for major operations with complex response requirements such as large industrial projects
- All tailings dams should be regularly evaluated for changes in downstream development over long service lives that could change hazard potential and EAP requirements
- Integrate or coordinate emergency action plan with community emergency response plan or local first responders' planning activities where communities are at risk from a tailings dam

Emergency action plans (EAP) should be required for all tailings dams with high or significant hazard potential classifications through all of the life phases. Low hazard potential tailings dams must be evaluated for incremental increases in consequences as expansions occur that could change the hazard potential and trigger an EAP requirement. All tailings dams should be regularly evaluated for changes in downstream development over long service lifes that could change hazard potential and EAP requirements. The EAP should be consistent with the content and format recommended in *Emergency Action Planning for Dam Owners* (FEMA 64) and *Emergency Action Planning for High Hazard Dams* (FEMA 608). The EAP, and the OMS described in Section 3 of Chapter V, should also include requirements for regular exercise and updates of the EAP. The detail of the EAP must be sufficiently developed as necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption.

2. Emergency Response Plan

The EAP for the tailings dam should be incorporated with the emergency response plan for the overall project development and/or the local community emergency response plan where the tailings dam is located. A detailed review of industrial and community emergency response planning and coordination is outside the scope of the *Tailings Dam Supplement*.

Chapter VII – Program Execution and Administration

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems
▪ Provide dedicated tailings dam staff and to conduct technical reviews and inspections, with provisions to contract expert technical support ▪ Provide for program support including information management, contracting provisions, and travel ▪ Provide fee structure or otherwise provide funding and resources for tailings dam safety regulatory program
Considerations for Regulators
▪ Is your tailings dam safety regulatory program adequately funded? ▪ Is your staff qualified and provided with recurrent training opportunities? ▪ Are staff members dedicated to tailings dam safety reviews?
Recommendations
▪ Provide dedicated staff members to gain specialized experience with tailings dams ▪ Provided training opportunities for staff and tailings dam/owner operators ▪ Included information management system such as GIS platforms and emerging technologies stay current with technology and improve efficiency and efficacy of regulatory program ▪ Do not subject dam safety technical reviews and authorizations to public process. ▪ Disclose reporting and authorizations consistent with department policies

1. Program Staffing and Funding

Regulations should provide for dedicated tailings dam staff, contracted technical support and fees to review design and construction permit application, OMS manuals, dam safety inspections, EAPs, risk mitigation plans, and closure and reclamation plans to ensure regulatory oversight for complex projects, especially where long-term care and maintenance of the tailings dam and dam safety regulation are required for the post-closure scenario described in Section 4.4.1 of Chapter V. If department policy requires public process, notice or posting for dam safety authorizations as discussed in Section 2.2 of Chapter III, additional technical and administrative staff should be included.

2. Program Staff and Tailings Dam Owner/Operator Education and Training

Tailings facilities are complex systems and tailings dams may be subjected to sophisticated engineering analyses and risk assessments. Specialized training for tailings dam engineers, designers, regulators and tailings dam owner/operators is imperative to ensure the safety of the tailings dam system, from design through construction, operation, closure and into the post-closure phase. Because tailings dams are unique, program budgets should include resources to allow staff to attend specialty conferences and workshops pertinent to tailings dams. Tailings dam safety regulators and tailings dam owners and operators should exchange training opportunities and promote training whenever possible. Training specific to tailings dams, tailings and mine waste management are provided by an increasing number of organizations and include:

- ASDSO Training Center
- USACE Risk Management Center
- EPA Clu-in
- USSD Conferences and Workshops
- Tailings and Mine Waste Conference Series
- The Tailings Center of Excellence
- Tailings and Industrial Waste Engineering Center (TailENG)
- Landform Design Institute
- Tailings.info

3. Information Management

Because tailings dam design, construction and operation typically evolve over an extended time period, sophisticated information management such as GIS platforms should be included in tailings dam regulatory programs in order to maintain ready access to current project documents and regulatory authorizations. This should include methods to track requirements for regulatory submittals such as periodic safety inspections, special studies, risk assessments, mitigation efforts, submittals from applicants, and enforcement actions.

Furthermore, technology has resulted in instrumentation and monitoring devices that collect extremely large quantities of data that must be evaluated in a performance monitoring program as described in Section 2.1 of Chapter IV and Section 1.5.2 and Section 3 of Chapter V. Consequently, new technologies are emerging to efficiently and effectively evaluate this information, a concept referred to as “Big Data” (Bachus, 2020). The Big Data concept uses post processors with specialized applications and alert trigger levels and other parameters designed to facilitate evaluations and reporting required under Section 2.4 of Chapter IV, and monitoring required under Section 3.2.5 and 3.2.6 of Chapter V. This allows dam owner/operators and engineers to manage and interpret more data more quickly and more reliably, contributing to the reduction of risk from tailings dam systems. Regulatory programs must be adaptable to emerging technologies.

Finally, many state agencies have document retention policies which direct those records be purged after a certain number of years. Design, construction, monitoring and inspection records for tailings dams should not be subject to records disposal policy and should be retained permanently, or at least 10 years after the tailings dam is closed, or for the duration of the post-closure scenario described in Section 4.4 of Chapter V.

Chapter VIII – References and Disclaimer

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2. Disclaimer

The above references do not represent comprehensive documentation of available reference material. Additional references may be available in the public domain. Research is ongoing and technology is continuously changing so no guarantee is provided that the above references are accurate or represent the most current information or technology in the field at the time of publication. The user is obligated to become familiar with the most recent developments in the science and technology of tailings dam safety and design. No information contained in the *Tailings Dam Supplement* is intended to provide technical guidance or legal advice and any use of the material is at the sole risk of the user. See Section 2.3 of Chapter III for information on risk management.

No information contained in the Tailings Dam Supplement is intended to provide technical guidance or legal advice and any use of the material is at the sole risk of the user. See Section 2.3 of Chapter III for information on risk management.

Appendix A – Summary of Uniform Dam Safety Regulatory Guidelines for Tailings Dam Safety

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems

Authorities

- Tailings dam safety regulatory programs must have well-defined statutory and regulatory authority
- Tailings dam safety regulations should be coordinated with other regulations and regulatory agencies to preclude duplicative regulatory requirements and conflicts
- Clearly indicate or reference tailings dam safety enforcement authority in dam safety statutes and regulations governing the regulatory agency

Public, Stakeholder, and Owner Information

- Provide definition of tailings dam in statutes or regulations
- Clearly defined requirements in regulation necessary for the regulatory agency to support an informed decision to issue or deny authorizations and contest appeals
- Clearly defined administrative regulations to support agency policy for public process and official public notice in tailings dam regulatory actions and decisions
- Clearly indicate whether interim authorizations necessary to develop the appropriate detail over the subsequent project phases including closure may be subject to public process or public notice
- Clearly indicate requirements to identify a qualified applicant and other parties responsible for the tailings dam system in the regulatory permitting process
- Require demonstration of financial responsibility to ensure tailings dam closure and post-closure performance to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption
- Financial assurance in appropriate form consistent with state law to secure the performance of closure and reclamation and post-closure requirements against a default by the dam owner/operator, with the amount of financial assurance subject to approval by the regulators on a site-specific basis
- Construction, operation and closure authorizations contingent upon demonstration of compliance with financial assurance requirements

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems

Existing Tailings Dams

- Inspection requirements and responsible parties including routine and extraordinary inspections, performance monitoring, inspection reporting frequencies, dam safety reviews and standardized inspection and evaluation formats

- Authority to require independent inspections and reviews based on hazard potential classification or when indicated by risk assessments
- Publication of inspection reports should be consistent with state policy
- All existing tailings dams must be assigned a hazard potential classification and a condition assessment rating subject to periodic review and update
- Allow considerations of risk in design, construction, operation, closure and post-closure phases of existing tailings dam systems in dam safety decisions
- Provisions for modifying existing tailings dams because of industrial operational requirements or measures necessary to control risk

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems

Design, Construction, Operation and Closure

- Authority to require, review, observe, or waive information developed in the design process as necessary to determine compliance with respective statutes and regulations and to determine that sufficient level of detail is developed in planning the design, construction, operation, closure and reclamation of the tailings dam system to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption.
- Requirement for detailed design report describing the tailings dam project development and plan; site investigations and characterizations; hydrology, seismology, and other technical studies; design basis memorandum; engineering evaluations demonstrating the expected performance of the tailings dam system under approved loading conditions during operations and closure; and detailed construction drawings and specifications
- Authority to require independent reviews by specialized engineering experts on intervals commensurate with the risk and the complexity of the specialized subject under review
- Approval authority for construction drawings, technical specifications, construction quality assurance and quality control plans, and construction documentation records
- Approval authority for changes that can affect the safety of the tailings dam system
- Requirement for operation, maintenance and surveillance (OMS) programs and manuals for any tailings dam system as necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption.
- Requirement for regular updates of OMS programs to maintain current documents and address changing conditions
- Authority to require financial assurance sufficient to close a tailings facility and provide the post-closure care and maintenance as necessary to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption
- Authority to approve plans to modify tailings dam systems into a closed configuration
- Authority to make jurisdictional determinations of regulatory requirements for the post-closure phase of the tailings dam

Uniform Dam Safety Regulatory Guidelines for Tailings Dam Systems

Incident Response

- Emergency action plans for any tailings dam based on the hazard potential classification

▪ Regular updates and plan exercises at a sufficiently frequent interval to ensure responsibilities are well understood and current for emergency responders
Program Execution and Administration
▪ Provide dedicated tailings dam staff and to conduct technical reviews and inspections, with provisions to contract expert technical support ▪ Provide for program support including information management, contracting provisions, and travel ▪ Provide fee structure or otherwise provide funding and resources for tailings dam safety regulatory program

Appendix B – History of Tailings Dam Supplement

1. Coordination with Other Standards

The *Tailings Dam Supplement* was developed to be consistent with emerging standards and initiatives as described in the following sections and referenced in other locations.

The Tailings Dam Supplement is narrowly focused to address regulatory guidance for tailings dam systems, and specifically intended to limit or exclude guidance on corporate policies, broad stakeholder engagement and detailed technical engineering.

1.1. Performance Based Risk Informed Safe Design

Open and candid communication between the dam owner/operator, the engineers, and the regulator is a hallmark to effectively reduce the risk from tailings dams. In "Geotechnical Risk, Regulation and Public Policy" (2018), Dr. Norbert R. Morgenstern described the complex evolution of tailings dam history and regulation and concluded:

> The responsibility for improving the safety culture associated with the performance of tailings storage facilities through all cycles of their life resides primarily with the operators. While regulators also have a role, it is necessarily subordinate to the role of operators. Experience reveals that the advance of this safety culture to the goal of zero failures requires intrusion into not only the activities of the operator, but also into the activities of the engineer(s). However, this intrusion must not be so prescriptive that it needlessly limits the creative input from both the operator and the engineer.

Every regulator should strive to maintain the boundaries between regulation and design and operation of the tailings storage facility while ensuring the safety of the dam. To ensure the safety of the tailings dam, Dr. Morgenstern suggests that the regulatory requirements are based on a "tailings management system" concept that incorporates principles described as "Performance Based Risk Informed Safe Design, Construction, Operation and Closure (PBRISD) [sic]." The individual concepts are not new, but Dr. Morgenstern suggests these concepts must be integrated with a current geotechnical standard of care including the "observational method" (Peck, 1969). (Be aware that the Observational Method has limitations predicting brittle behavior that can develop in hydraulic fills common with tailings dams.) Dr. Morgenstern describes a "precautionary risk-informed design process" that covers the phases in the life of the tailings dam and includes risk assessments at various stages of development from concept through closure. The following information summarizes Dr. Morgenstern's descriptions of PBRISD and its integration with the regulatory interests outlined in the *Tailings Dam Supplement*.

- **Stage 1 (Conceptual)**
  - A qualified operator must be identified that states commitments to internationally recognized corporate policies (Dr. Morgenstern specifically recommends guidelines published by the Mining Association of Canada) and clearly identifies the "Accountable Executive Officer," other responsible parties, and the "engineer-of-record." See Section 4 in Chapter III for information on qualified applicants.
  - An independent technical review panel may be required based on the risk of the tailings dam, with appropriate agreements that outline terms-of-reference, transparency, indemnification and other important information. See Section 4.3 in Chapter III for information on quality assurance and independent technical review panels.
  - An uncertainty assessment based on a review of the various engineering models that will be used to evaluate the project and the assumptions used to build those models must be considered and resolved over time. The guidelines provided in the Tailings Dam Supplement address these uncertainties in the design process outlined in Section 1 of Chapter V. This process begins with considerations identified in the conceptual design that directly affect risk including the type of tailings dam and tailings processing system, site selection, and key design features, from the foundation to the final configuration, that must be investigated and evaluated in the detailed design.
  - A potential problems analysis is described by Dr. Morgenstern as the "first formal risk analysis for all options under consideration" at an early stage of project development necessary to identify "what could go wrong." This effort is intended to influence project decisions and identify risk to be addressed in subsequent design efforts. See Sections 2.3 of Chapter III and 1.3 of Chapter V for information on risk identification in the conceptual design.
  - A multiple-accounts analysis (Robertson, 1999) should be developed to review the site and tailings management system alternatives that considers both "corporate and other stakeholder values" in a structured, decision focused document. See Section 2 in Chapter III for information on making these types of decisions.
- **Stage 2 (Feasibility)**
  This stage covers a broad span in the project development where key parties carry out detailed planning and design in preparation for an active operation. Dr. Morgenstern describes popular concepts in this stage.
  - Engineer of record is described imperatively as "integral to a tailings management team and dedicated to the safety performance of the facility." A person rather than a company is assumed, and the challenges for fulfilling that role including continuity and succession are described. See Section 4.2 in Chapter III for information on responsible persons.

- The designer is identified as a "crucial role in all aspects of this [stage]." Fragmentation of the design effort by "procurement practice" (i.e., low bidder) is discouraged, and Dr. Morgenstern calls for guidance on "procurement policy and the risks that might be generated by multiplying design interfaces." See Section 4.1 in Chapter III for information on corporate and dam owner commitment and management policies including tailings and water management policies and protocols.

- The design basis memorandum (DBM) is described as a "critical" living document that "supports all design criteria and related methodology." The DBM includes important information to support the observational method in a "precautionary-based design" and as the risk of the project increases, performance objectives are included to transform the process into a "performance-based design" which Dr. Morgenstern describes as enhancements to safety and efficiency. (The DBM should note the Observational Method has limitations predicting brittle failures). See Section 1.5.4 in Chapter V for discussion on the DBM as described herein.

- Risk assessments in the form of probable failure modes analysis "methodology" is recommended at 30% and 70% completion of the "development plan." See Section 2.3 in Chapter III and 1.3 in Chapter V for information on failure modes assessment.

- Quality management plans are necessary to distinguish between quality assurance and quality control, provide guidance on conflict resolution and development of critical construction documentation. See Section 4.1 and 4.3 in Chapter III for recommendations for corporate commitments and quality assurance, and Sections 2.1 and 3.3 of Chapter V for information on construction quality assurance/construction quality control (CQA/CQC) planning and execution and operational "assurance".

- Documentation should be compiled and maintained including design and as-built records. GIS platforms are recommended for information management. See Section 4.1 of Chapter III on corporate commitments to information management, Section 2 of Chapter IV for inspection requirements, and Sections 1.5, 2.1, 2.4, 2.5, 2.6, and 3.2 of Chapter V for design, construction, and operation documentation requirements and Section 3 of Chapter VII for recommendations for information management by regulators.

- **Stage 3 (Construction and Operations)**

  - Construction is assumed following Stage 2 and tailings dams are recognized for concurrent construction and operation. Emphasis is placed on the "Operations, Maintenance and Surveillance Manual" (OMS Manual) for guiding operations during this phase of a tailings management facility. See Section 3.2 in Chapter V for information on OMS Manuals.

- **Stage 4 (Closure)**

  - Closure planning is assumed to occur in all previous stages along with plans for mine, water and tailings management. Additional detail is expected for closure design as time progresses to the extent that a new DBM is developed for the tailings storage facility in the closed configuration. Attention is called to the imperative value of as-built documentation in assessing future performance and "on-going safety assessments". See Section 4.1 and 4.4 of Chapter III for information on corporate commitments and financial assurance, and Sections 1.1, 2.4, and 4 of Chapter V for information on closure planning.

The *Tailings Dam Supplement* progresses beyond Dr. Morgenstern's recommendation for regulatory requirements to be based on a "tailings management system" that includes PBRISD, to recommend commitments to "tailings and water management policies and protocols" as a primary responsibility of the dam owner, as described in Section 4.1 of Chapter III.

1.2. Global standard

In 2020, a convention of global entities formed the "Global Tailings Review" (GTR) to establish an international standard of care for the management of tailings with the stated goal of zero harm to people and the environment, and zero tolerance for human fatality. The United Nations Environment Programme (UNEP), the International Council on Mining and Metals (ICMM) and the Principles for Responsible Investments (PRI) assembled a panel of internationally recognized experts to develop a consistent standard in the wake of the 2019 tailings dam disaster in Brumadinho, Brazil. The three "co-conveners" are intended to represent the perspectives of stakeholders and regulators, mine owners and operators and investors, respectively, in order to present a collaborative and balanced approach to the challenges of a critical industry operating around the world. The challenges are magnified because the governments, geology, minerology, climate, technology, and human interests are as different as the countries and resources where mining occurs.

The development of the *Tailings Dam Supplement* faced the same challenges because of similar diversity across the US However, this effort benefited from the maturity of dam safety programs in the US and Canada led by the National Dam Safety Program developed after the tailings dam failures at the Buffalo Creek Mine in 1972 and other significant incidents. These events led to the formation of the Association of State Dam Safety Officials (ASDSO), representing a broad cross-section of state and federal regulatory agencies, dam owners and engineering experts, and the first publication of the *Model State Dam Safety Program* in 1987.

The genesis of the *Tailings Dam Supplement* began in 2015 after tailings dam failures at the Mount Polley Mine in British Columbia, Canada and the Samarco Mine in Minas Gerais, Brazil. The ASDSO Tailings Dam Regulatory Committee was formed and the resultant work included the *Gap analysis of the National Dam Safety Program* with respect to tailings dams, etc. (ASDSO, 2018) that reviewed dam safety publications of the Federal Emergency Management Agency (FEMA) for applicability to "tailings dams, dams at mines, coal waste dams, coal combustion residue (CCR) dams, similar facilities or tailings dam closure". The gaps included deficiencies in the level of detail and currency of regulatory guidance applicable to tailings dams in the Model State Dam Safety Program (FEMA 316). Consequently, the scope of work for the Tailings Dam Supplement was narrowed to address regulatory guidance for tailings dam systems, and specifically intended to limit or exclude guidance on corporate policies, broad stakeholder engagement and detailed technical engineering. In the meantime, a joint effort began between the United States Society on Dams and FEMA to address the technical gaps in the NDSP, leading to the publication of the *U.S. Guidelines on Tailings Dam Safety* as a technical companion to the *Tailings Dam Supplement*.

The drafting of the *Tailings Dam Supplement* occurred concurrently with, but independent from, the Global Industry Standard on Tailings Management (GISTM) published by the GTR on August 5, 2020. However, the Tailings Dam Supplement is narrowly focused on tailings dams regardless of the industry and is directed toward regulators, whereas the GISTM is broadly focused on tailings management exclusively for the mining industry and is directed to the operator (GTR, 2020).The GISTM addresses the following six topics:

I. Affected communities
II. Integrated knowledge base
III. Design, construction, operation and monitoring of the tailings facility
IV. Management and governance
V. Emergency response and long-term recovery
VI. Public disclosure and access to information

The GISTM includes fifteen principles under those topics such as Principle 4 under Topic III, "Develop plans and design criteria for the tailings facility to minimize risk for all phases of its lifecycle, including closure and post-closure" and Principle 8 under Topic IV, "Establish policies, systems and accountabilities to support the safety and integrity of the tailings facility." Each principle includes a list of requirements such as Requirement 4.1:

> Determine the consequence of failure classification of the tailings facility by assessing the downstream conditions documented in the knowledge base and selecting the classification corresponding to the highest Consequence Classification for each category in Annex 2, Table 1. The assessment and selection of the classification shall be based on credible failure modes, and shall be defensible and documented.

The GISTM includes the following three annexes:

1. Glossary
2. Consequence classification tables
3. Summary tables

Annex 2 describes low, significant, high, very high and extreme consequence ratings based on specific loss of life and criteria for environmental, social, cultural, health, infrastructure and economic impacts. Annex 3 includes specific flood and seismic design criteria and specific roles and responsibilities of key personnel mentioned in the standard such as the "Responsible Tailings Facility Engineer" and the "Engineer of Record."

The GTR also published documents supporting the development of the GISTM including the pertinent white paper, "The Role of the State" by Professor Mark Squillace of the University of Colorado Law School (GTR, 2020b). The author encourages the development of state regulatory programs staffed by qualified and experienced personnel and describes the expectations for the state as a regulatory agency over mining, in contrast to the GISTM which is directed toward the tailings dam owner/operator. Further, the paper states:

> Effective State oversight requires a comprehensive understanding of the planning and engineering necessary to build, operate, maintain, and ultimately close tailings facilities.

And:

> …three particular areas where the State can and should play a prominent role:
>
> (1) the permitting (or licensing) of facilities
>
> (2) financial assurance and insurance requirements
>
> (3) inspections and enforcement of regulated facilities

The *Tailings Dam Supplement* is consistent with these concepts and the GISTM, where tailings dam safety related requirements are listed, but does not address other issues faced by industry or corporate practices beyond the extent it effects the safety of the tailings dam system. For example, the *Tailings Dam Supplement* defers using the term "tailings management system" used in the GISTM, even though the term was used by Dr. Morgenstern in describing a regulatory system based on PBRISD as discussed in Section 1.1. Instead, as noted, the *Tailings Dam Supplement* refers to tailings and water management policies and protocols as the responsibility of the dam owner as discussed in Section 4.1 of Chapter III, tailings dam systems as described in Section 1 of Chapter III, and tailings processing and transport systems as described in Section 1.2.1 of Chapter V. The *Tailings Dam Supplement* intentionally avoids technical guidance and there are no definitions for the responsible persons listed in Section 4.2 of Chapter III.

Important subjects described in the GISTM that diverge from common standards in the US are the consequence classifications and specific design criteria for hydrologic and seismic parameters. The consequence system in the *Tailings Dam Supplement* is based on the hazard potential classifications described in the *Model State Dam Safety Program* (FEMA 316) and *Hazard Potential Classification System for Dams* (FEMA 333) which are consistent with the National Dam Safety Program in the US. This three-tier system limits the high hazard potential to "probable loss of life" without quantification, and all other impacts are in the low or significant classifications.

Important subjects described in the GISTM that diverge from common standards in the US are the consequence classifications and specific design criteria for hydrologic and seismic parameters.

While specific, credible design criteria standards for tailings dams are welcome, these criteria may conflict with *Federal Guidelines for Dam Safety* and state specific criteria widely used in the US. For example, the minimum inflow design flood recommended for low hazard potential dams in federal guidelines is the "1% annual chance exceedance flood" commonly known as the "100 -year flood" (FEMA, 2013a), while Table 2 in Annex 3 of the GISTM lists the "1/200 annual exceedance probability" for low consequence class tailings dams, a slightly more conservative standard. The GISTM also describes the design criteria for high, very high and extreme consequence classifications ranging from "1/2457" to "1/10,000" annual exceedance probabilities, while the federal guidelines and many states refer to the Probable Maximum Flood for high hazard potential dams. The GISTM specifically states "conformance with the Standard does not displace the requirements of any specific national, state or local governmental statues, laws, regulations, ordinances, or other government directives" and that "Operations are expected to conform with the Requirements of the Standard not in conflict with other provisions of law." A point-by-point review of the GISTM with the *Tailings Dam Supplement* or the publications of the National Dam Safety Program was not conducted.

1.3. Other references

Notable international references related to tailings dams include publications of the International Commission on Large Dams (ICOLD), the Australian National Committee on Large Dams (ANCOLD), the Canadian Dam Association (CDA) and the Mining Association of Canada (MAC). ICOLD has published several tailings dam documents such as *Tailings Dams—Risk of Dangerous Occurrences* (ICOLD, 2001) and coincidentally released a draft of guidelines for tailings dam safety during the development of the *Tailings Dam Supplement*. Information presented in the *Tailings Dam Supplement* is generally consistent with ICOLD guidelines, but is tailored to be specifically addressed to regulators, whereas the ICOLD bulletin must necessarily inform the much broader audience of its membership and includes significant technical details specifically excluded from the *Tailings Dam Supplement*, as previously noted. ANCOLD guidelines were developed for dams in Australia and include uniform, relevant content as presented in Figure V-5 of Chapter V. In 1998, MAC first published the *Guide to the Management of Tailings Facilities*, followed by guidance on developing OMS programs in 2003, popularly known as the "MAC Guidelines" (MAC, 2019a). In addition, MAC launched the *Towards Sustainable Mining* initiative in 2004 that includes corporate requirements for member organizations. Section 3 of Chapter V is generally modeled on MAC Guidelines. The *Dam Safety Guidelines* published in 2007 by the CDA are internationally recognized, and in 2014, the CDA published the supplement *Application of Dam Safety Guidelines to Mining Dams.* In the runout from Mount Polley, regulatory agencies in the Canadian provinces of British Columbia and Alberta, as well as the State of Montana, published updated statutes and regulations applicable to mine tailings dams. Alberta regulations written primarily for the colossal tailings dams of the oil sands industry were recognized by Dr. Morgenstern in 2010 as "the best in the world" (Morgenstern, 2010). Notably, Alberta developed the first dam safety program in Canada in 1978, contemporaneously with the National Dam Safety Program in the US, resulting in a similarly mature program.

In order to help provide consistency for the benefit of industry and engineering consultants, as well as to promote dam safety and to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption, the *Tailings Dam Supplement* was developed in consideration of these well-known references and the more recent publications since 2014. The *Tailings Dam Supplement* borrows the concept of the CDA by serving as a dependent supplement to the *Model State Dam Safety Program* (FEMA 316), but as previously noted, is targeted to regulators and is intended to be generally consistent with the requirements of the British Columbia and Alberta regulations. However, the *Tailings Dam Supplement* and the *Model State Dam Safety Program* (FEMA 316) do not have the authority of regulations under publications of the National Dam Safety Program. The authority must be established for the respective US regulatory agency as described in Chapter II.

Appendix C – A discussion on financial assurance for tailings dams

- **Why is financial assurance necessary?**
  - As noted in the *Tailings Dam Supplement to the Model State Dam Safety Program*, once closed, tailings dams may require some level of care and maintenance to maintain form and function, but this comes at a financial cost. If the dam owner/operator has ceased the activity that required the impoundment, there may no longer be a revenue stream to operate the tailings dam system depending on the dam owner/operator financial condition and whether it has a diversified asset base. Even if the facility remains open and activities continue, there may come a time and for whatever reason, when this responsibility is abdicated. Or, economic and business reasons can lead to bankruptcy, leading to pre-mature closure of tailings dams in some circumstances. To address these situations, statutes and regulations must require qualified applicants to demonstrate financial responsibility to guard against such events and allow state agencies to act as a trustee, if necessary. This includes sufficient funds to close a facility prematurely and to provide for the long-term care and maintenance, which are distinctly different costs.

    For this discussion, financial assurance means monies that are available to the regulatory agency, regardless of the funding source, for closure, reclamation, management, monitoring, and maintenance of a tailings dam system when the dam owner/operator will not or cannot continue in its capacity, or transfers its obligation, as the responsible party to protect against loss of human life, economic loss, property damage, environmental impacts and lifeline disruption. If required, the details of this oversight and the respective financial assurance will depend on site specific conditions. See Section 4.1.2 of Chapter V of the *Tailings Dam Supplement* for a discussion on financial assurance and the various post-closure scenarios described.

- **How is financial assurance estimated?**
  - An important step in calculating financial assurance liabilities involves defining the details of the monitoring and maintenance required for the tailings dam system in the closed configuration and respective cost estimates. The schedule for monitoring and maintenance during operation can provide a rough initial guide to what may be needed post-closure, but closure and reclamation plans developed during initial design and updated throughout the life of the facility (at important milestones or stage-gates) and more detailed engineering plans at closure provide the best source for post-closure monitoring and maintenance requirements. Frequently, these requirements are a condition of the underlying operating

authorization or dam permit, and even though the original dam owner/operator is absent, this does not absolve the new responsible party (or the regulator) from following a similar schedule to what was provided in the closure and post-closure monitoring plans.

When estimating the cost of financial assurance, assume the regulatory agency will be the responsible party for managing the tailings dam system unless provisions are available for alternative post-closure custodial organizations. Therefore, assume the actual field work will be contracted to a third party, with the regulator providing contract administration and regulatory oversight which may occur within different divisions of the agency. Cost adjustments to reflect the cost premium associated with contracted work, along with the indirect costs to the regulatory program for assuming oversight of the tailings dam should be accounted for in the cost estimate and agency budget projections after claims on the financial assurance occur. To develop more accurate cost estimates:

– Define scale and scope of closure, reclamation, monitoring and maintenance requirements
– Account for capital expenditures including replacement costs during the post-closure phase
– Use risk management to identify cost centers and risk controls
– Be precise in describing each line item and each task; avoid “lumping” tasks
– Assume all work will be performed by third-party contractors and use blue book methods for estimating costs
– Provide cost references, justification for values selected, and assumptions
– Include overhead, administrative and management costs for implementation period

Cost estimates should include all overhead, administrative and management costs if an alternative post-closure custodial organization is agreed upon, in addition to monitoring, maintenance, inspection and capital replacement costs for the tailings dam system. Post-closure designs that include reclamation to landform and/or passive care status should require less effort to maintain and monitor, therefore the financial assurance burden for these types of facilities would be less.

- **When is financial assurance required?**
  - Perhaps the most difficult and controversial aspect of long-term care and maintenance is defining the term for this care. As has been remarked on earlier, once a tailing’s dam service life is over, the embankment cannot be breached as is done with conventional water dams. The tailings are typically a waste product and may pose a physical or chemical risk if released, which can pose a threat to human health, safety and the environment. Ensuring

containment through care and maintenance of the tailings dam system for an indefinite period may be the primary risk control to safeguard against this threat.

Establishing a trust fund that can receive funds from a financial assurance instrument, or be funded directly, for care and maintenance using discounted cash flow (DCF) analysis is one option for addressing long-term needs. A DCF calculation is relatively straight-forward but requires assumptions regarding out-year annual care and maintenance costs, selection of a discount rate and other factors. To implement this approach, the state must have statutory authority to receive financial assurance funds and, in some cases, to establish a trust fund, and a mechanism for implementation that allows funds to be accessible to the regulatory authority when required. A Memorandum of Agreement, financial assurance instruments, and other documents should be drafted and reviewed with legal assistance. Spending authorizations for regulatory agencies may be subject to legislative appropriations, further complicating the process. Requiring, estimating and agreeing upon financial assurance should occur during the permitting application process and all agreements should be in place before regulatory authorizations are issued. Waiting until the project is underway or until there are signs of financial distress, will jeopardize the regulator's ability to secure adequate financial assurance from the dam owner/operator in the event of a default.

- **What is different about financial assurance between the closure and post-closure phases of a tailings dam?**
  - Developing financial assurance for a tailings dam in the post closure phase poses additional challenges to that of financial assurance for mine closure and reclamation. The amount and form of financial assurance for closure and reclamation may be substantially different from the amount and form of financial assurance for the long-term care and maintenance of the tailings dam for the duration of the post-closure phase. On a site specific or jurisdictional basis, regulatory agencies should establish financial assurance that includes closure, reclamation and post-closure scenarios. In the post-closure scenario where financial assurance is required, and where the operator is no longer financially capable of meeting its obligations and the property is not transferred to a third party, the financial assurance instrument is converted or replaced with actual funds that may be invested in a trust administered by the responsible regulatory agency or other approved trustee. The net gains from the invested trust, interest minus inflation and other expenses, are used to fund the annual operating costs of long-term monitoring and maintenance, and, if required, water treatment. Significant considerations include:
    - A number of assumptions must be used to estimate the present value of a principal amount that, if invested appropriately, would return annual and regular payments to reimburse expenses incurred by the parties responsible for post-closure expenses over the period that monitoring, maintenance, and water treatment are required. The assumptions are subject to many variables, including expense estimates, rates of interest and inflation. Those assumptions also include that all statutes and regulations are appropriately developed and detailed to address all aspects of the financial

assurance requirements including financial instruments, trustee relationships and other considerations

- The maintenance items, capital replacement features and any other long-term operational requirements including administrative and regulatory costs are accurately identified to provide relatively precise cost estimates using standardized methods such as described by the *Cost Estimating Requirements Handbook* published by the National Park Service (NPS, 2011); or methods recommended by trade associations such as the American Association of Cost Estimators, the Society of Cost Estimating or the International Cost Estimating and Analysis Association

- Commodities prices such as fuel remain constant at some average or conservative value including considerations for inflation

- A conservative, real rate of return can be realized based on a static inflation rate, predictable tax liabilities, insurance costs and other indirect costs that affect useable value

- Financial accounts are actively managed to ensure growth targets are met

- Agreements are in place to adjust the value if growth targets are missed

- Financial assurance requirements and respective cost estimates are tied to foreseeable scenarios

- A post-closure operating entity is identified as the beneficiary of the trust to receive disbursements in the case of a default or other agreement, under the obligation to conduct the work

A year-by-year post-closure cost schedule can be constructed. The cost schedule, which includes both operating costs and equipment replacement, is then repeated on periodic basis, typically every 50 to 100 years. This cost schedule is then run through a net present value calculation, and that calculation repeated for as many cycles as is necessary until the last period analyzed contributes an insubstantial amount to the present value of the post-closure, financial assurance cost estimate.

See *Training Guide for Reclamation Bond Estimation and Administration for Mineral Plans of Operation Authorized and Administered under 36 CFR 228A* (USFS, 2004) and Section 4.4 in Chapter III and Section 4 of Chapter V of the *Tailings Dam Supplement* for additional discussion on financial assurance and closure for tailings dam systems.