

United States Society on Dams



**USA Regulations and State of Practice
for the Closure of Tailings Dams**

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USA. REGULATIONS AND STATE OF PRACTICE FOR THE CLOSURE OF TAILINGS DAMS

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EXECUTIVE SUMMARY

PURPOSE AND SCOPE

Comprehensive closure planning for existing, new, and legacy Tailing Storage Facilities (TSFs) requires a thorough understanding of closure criteria and objectives. Closure regulations of states with significant mining activities in the United States of America (USA) were reviewed, along with tailings dam regulations promulgated by federal agencies to determine how they compare with industry practice. The authors also compared USA closure regulations with the closure criteria of international industry and professional organizations to understand the alignment or misalignment with the endorsed practices. This white paper discusses the industry practice and regulations of TSF closure for legacy and new mine sites. The purpose is to educate and inform the United States mining community regarding transitioning a tailings dam from operation to closure safely and environmentally responsible, considering its potential as a beneficial asset to the community.

JURISDICTIONAL REGULATORY AGENCIES AND ORGANIZATIONS

State regulatory programs for TSFs often include multiple state agencies, such as a combination of the environmental departments and State Engineer's Office for overseeing tailings dams' closure. Recently, the Association of State Dam Safety Officials (ASDSO) has chartered a Tailings Dam Regulatory Committee to set and accomplish specific objectives that support state dam safety programs that regulate tailings dams. ASDSO is currently updating the Federal Emergency Management Agency (FEMA) *Model State Dam Safety Program* (FEMA 316, 2007) on applicability to tailings dams. The US Society on Dams (USSD) is the lead organization for developing a FEMA technical guidance document to support and provide a technical basis for the *Model State Dam Safety Program* regulatory guidance document. The FEMA programs will enable state regulatory agencies to establish aligned objectives for closure and have a nationally recognized reference for technical guidance and national criteria within state programs. When completed and implemented, these two steps would improve alignment across the country regarding closure requirements for tailings facilities.

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Technical guidelines for closure are also available from international and national committees and organizations with goals to advance the mining sector's social and environmental performance. These organizations include the International Council on Mining & Metals (ICMM), International Committee on Large Dams (ICOLD), International Organization for Standardization (ISO). ICMM, in partnership with the United Nations Environment Program (UNEP) and the Principles for Responsible Investment (PRI), established the independent Global Tailings Review panel, which released the "Global Industry Standard on Tailings Management" in August 2020.

STATE OF PRACTICE CRITERIA

The state of practice considers industry guidance to address closure risks and responsibilities and meet regulatory requirements. TSF closure regulations include general goals or objectives, with more specific requirements detailed in permitting guidance documents for states with more mining activities. Common goals and objectives in these programs include:

- Eliminating the impounding capability
- Physical stability as a mine waste structure
- Geochemical stability
- Land use and sustainability
- Progressive closure of the TSF during the mine life, and
- Post-closure maintenance and monitoring.

Leading features in state regulatory programs provide specific safety, stability, reclamation, and management strategies that address tailings dam closure based on experience with mine closures and performance, or in response to international tailings dam incidents. Features of state programs that are specific to tailings dam closure include:

- Specific closure regulation or guidance
- Static and seismic slope stability criteria and analysis methodology guidance for closure
- Impoundment elimination criteria allowing for small ponds, wetlands, and other similar features
- Independent review and expert review panels
- Closure maintenance and performance, including Best Management Practices and post-closure financial assurance
- Sustainability requirements based on post-mining land use and site characteristics, considering technical and economic practicality and adaptive species.

State regulatory programs across the USA generally cite consistent TSF closure objectives, although the design and implementation approach and specific criteria vary considerably.

Comparing state closure regulations to closure guidance from international organizations such as ICMM, ICOLD, ISO, UNEP, and IFC shows alignment in the areas of geochemical stability (e.g., environmental controls) and progressive reclamation, but less

so in the areas of eliminating impounding capability, physical stability, land use and sustainability, and post-closure monitoring and maintenance.

EMERGING CLOSURE PHILOSOPHIES

In addition to current tailings stewardship regulations for closure, a summary of emerging closure philosophies are presented, including:

- Alternative tailings processing technologies (filtered tailings, paste tailings, dry-stacking)
- Mine waste co-disposal (tailings, waste rock, overburden/development rock)
- Risk-based closure
- Engineer-of-Record philosophies
- Renewable energy, and
- Reprocessing.

GOING FORWARD

This paper provided a review of USA closure regulations to determine the alignment with mining industry practice.

The authors encourage states to be active in review and provide input to the updating and development of FEMA guidelines for both state regulator programs and technical tailings dam safety guidance being prepared by ASDSO and USSD, considering the elements presented herein for closure and post-closure care.

Going forward, improvements to be considered for mine tailings closure practice include:

- Have a single closure guidance model that states can refer to for closure regulations, standards, and technical guidance
- Design mine tailings dams with closure in mind
- Consider mine tailings dams and impoundments as assets to provide a benefit to the community and recover costs for maintaining and monitoring a facility, and
- Have consistent and appropriate closure objectives and criteria for TSFs that may be different from design and operation requirements.

I. INTRODUCTION

Comprehensive closure planning for existing, new, and legacy Tailing Storage Facilities (TSFs) requires a thorough understanding of closure criteria and objectives. Closure planning is used to establish practices that deliver:

- Consistent implementation;
- Meeting closure objectives including impoundment elimination, physical and geochemical stability;
- Post-mining land use that meets property owner priorities while focusing on regional and local resource development and conservation plans, if established;
- Technical and economic practicality.

With the growing focus on environmental and social sustainability, the new closure drivers strive to ensure economic viability, physical stability, environmental integrity, social equity, and technical compliance. This paper provides a review of the United States of America (USA) closure regulations to determine how they compare with industry practice. It includes ideas on achieving closure objectives and opportunities to change closure from a liability to an asset.

Individual states regulate mine closure including impoundments for most mine tailings on State lands. The Federal government through the Mine Safety and Health Administration (MSHA) has jurisdiction for safety inspection, investigation of construction and operation issues, and for coal mine tailings is responsible for review and approval of engineering plans including closure of coal refuse slurry impoundments. The Federal government also regulates mine closure on Federal lands, whose regulatory framework is based, in part, on Federal policy such as the Clean Air Act and the Clean Water Act. Similarly, closure of abandoned and legacy mine sites are under Federal programs such as the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the Uranium Mill Tailings Remedial Action (U.S. Department of Energy) as well as state-specific programs. These regulations for closure of TSFs in the USA are varied and often overlapping without a consistent approach.

Purpose And Scope

This US Society on Dams (USSD) white paper discusses the current practice and regulations of TSF closure for legacy, existing and new mine sites in the United States. Closure regulations of the base and precious metal mines such as copper, lead, nickel, zinc, molybdenum, gold, and silver, among others vary from state to state, with limited jurisdiction under Federal programs. However, Federal programs with jurisdiction over coal mining provide a degree of standardization in closure requirements for coal refuse impoundments across states. The recent U.S. Environmental Protection Agency (EPA) regulations on Coal Combustion Residual (CCR) facilities address the closure of associated ash impoundments and are outside this paper's scope. However, the information can apply to CCRs and other industrial facilities.

USSD's Tailings Committee is charged with promoting safe, environmentally and socially responsible practices for tailings dams and collaborating with other national and international professional organizations involved with tailings dams.

Navigating This Document

Section II summarizes the State of practice in TSF closure criteria, including an overview of how different regulatory agencies in the USA address closure. Part III provides a review of State TSF closure requirements and technical standards and discusses the criteria for when a tailings dam becomes a mine waste structure. Emerging closure philosophies such as post-closure use of a TSF for power generation, among others, are discussed in Section IV. Ideas and opportunities for moving forward in the USA to develop consistent and sustaining closure requirements are provided in Section V, followed by conclusions in section VI.

II. JURISDICTIONAL REGULATORY AGENCIES AND ORGANIZATIONS

Federal regulation of TSFs began following the Buffalo Creek coal refuse impoundment failure in 1972, releasing approximately 132 million gallons of slurry. The resulting flood killed 125 people and destroyed downstream homes and businesses (Davies et al., 1972). The ensuing U.S. Surface Mining Control and Reclamation Act (SMCRA) (1977) provides coal mines with design, operation, and closure requirements for TSFs across the United States of America.

In 1994 the Environmental Protection Agency (EPA) published a document specifically targeted at tailings storage entitled Technical Report –Design and Evaluation of Tailings Dams. This document is focused on hard-rock mine tailings and is a version of Steven Vick's book entitled, Planning, Design, and Analysis of Tailings Dams (Vick, 1990) and presents the fundamentals of tailings storage. The EPA guidance on the design and evaluation of Tailings Dams includes little information on closure other than the statement that stability must be maintained from the initial trial embankment to site closure (EPA, 1994, Design and Evaluation of Tailings Dams EPA530-R-94-038 NTISPB94-201845).

The U.S. Nuclear Regulatory Commission (NRC) is an independent agency created by Congress in 1974 to ensure the safe use of radioactive materials for beneficial civilian purposes while protecting people and the environment. Regulations for closing uranium TSFs are in 10 CFR Part 40, Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content." In particular, the criteria in Appendix A cover the following:

- siting and design of tailings impoundments,
- disposal of tailings or wastes,
- decommissioning of land and structures,
- groundwater protection standards,
- testing of the radon emission rate from the impoundment cover,
- monitoring programs,
- airborne effluent and offsite exposure limits,
- inspection program of retention systems,
- design life for the closure of 10,000 years
- financial surety requirements for decommissioning and long-term surveillance and control of the tailings impoundment, and
- eventual government ownership of the tailings site under an NRC general license.

Recently, the Association of State Dam Safety Officials (ASDSO) has chartered an ASDSO Tailings Dam Regulatory Committee to set and accomplish specific objectives that support state dam safety programs that regulate tailings dams. ASDSO is currently updating the Federal Emergency Management Agency (FEMA) *Model State Dam Safety Program* (FEMA 316) on applicability to tailings dams. The US Society on Dams (USSD) is the lead organization for developing a FEMA technical guidance document to

support and provide a technical basis for the *Model State Dam Safety Program* regulatory guidance document. This technical guidance document, titled ***Unified Guidelines for Tailings Dams***, and will be a detailed technical reference for operators, engineers, regulators and others suitable for tailings dam projects. These FEMA programs will enable state regulatory agencies to establish aligned objectives for closure and have a nationally recognized reference for technical guidance and national criteria within state programs. When completed and implemented, these two steps would improve alignment across the country regarding closure requirements for tailings facilities.

Current State regulatory programs for TSFs often include multiple state agencies, such as a combination of the environmental departments and State Engineer's Office for overseeing tailings dams' closure. City and counties typically follow the State agencies for closure regulations.

Three U.S. universities (University of Arizona, Colorado State University, and the Colorado School of Mines) recently established a Tailings Center of Excellence to provide a learning space for educating practitioners on responsible and sustainable mine waste management. Additionally, the Tailings and Industrial Waste Engineering (TAILENG) research center has been established and centered at Georgia Tech, with the University of Illinois, Colorado State, and the University of California Berkeley. TAILENG will focus on research and coordinate with the Tailings Center for Excellence

Technical guidelines for closure are available from international and national committees and organizations with goals to advance the mining sector's safety, social and environmental performance. These organizations include the International Council on Mining & Metals (ICMM), Mining Association of Canada (MAC), International Organization for Standardization (ISO), and International Committee on Large Dams (ICOLD) along with country affiliates such as the Canadian Dam Association (CDA) and Australian National Committee on Large Dams (ANCOLD). Guidance documents from these and other organizations are being reviewed for the development of ***Unified Guidelines for Tailings Dams*** considering applicable criteria and practice for the USA for the entire TSF lifecycle including closure. Representative technical guidance publications are included in the Reference section at the end of the paper.

ICMM, in partnership with the United Nations Environment Program (UNEP) and the Principles for Responsible Investment (PRI), established the independent Global Tailings Review panel, which released the "Global Industry Standard on Tailings Management" in August 2020. The document sets standards for the safe and secure management of mine tailing facilities globally and includes principles applicable to closure and post-closure requirements. The standard establishes a framework for tailings management and requires feasibility, design, risk, and performance monitoring through closure and post-closure care. In addition, the International Finance Corporation (IFC), a sister organization of the World Bank and member of the World Bank Group, provides private sector funding in

developing countries. It provides tailing dam performance standards that its benefactors must comply with to receive financing.

III. SUMMARY OF STATE TSF CLOSURE REQUIREMENTS

The authors reviewed closure requirements in the twenty-seven States representing the different climate regions in the United States. The States selected are shown in **Figure 1**. State regulatory programs within the regions reflect requirements associated with the type and methods of mining, and environmental and climatic conditions. However, States within a region generally have different closure requirements.

State regulatory programs for closing a TSF include multiple state agencies. The agencies may have jurisdiction throughout the entire mining life cycle, or during certain phases such as operations or closure. The TSF may continue to be regulated as a dam until all elements of closure are demonstrated, including eliminating not only its impounding ability but also hazard potential classification in the event of tailings release and mobility.

State programs may have different regulations and programs for various minerals. Presently, states have separate coal and uranium programs, which are typically more detailed and consistent with federal requirements, with more general programs having jurisdiction for hard rock ore and processing.

The authors reviewed the TSF closure program for each of the twenty-seven states shown in Figure 1. The objective of the review was to understand the variability of TSF closure programs from state to state by comparing key components for TSF closure that include:

- Engineer responsible for TSF closure plan, or Engineer of Record responsible for design and implementation of TSF closure plan
- TSF reclamation plan including bonding and requirement for progressive reclamation Elimination of impounding capability and hazard potential
- Physical stability criteria
- Geochemical stability criteria
- Post-reclamation land use, care and maintenance

The authors were unable to find any two State TSF closure programs that addressed all of the above components and any two state TSF closure programs that addressed the same components. Table A-1 in Appendix A provides the results of the review of the TSF closure programs for the twenty-six states with respect to key closure elements, and the following section discusses some of the differences in objectives and criteria contained in the state programs.

IV. CLOSURE OBJECTIVES FOR MINE TAILINGS

TSF closure regulations include general goals or objectives, with more specific requirements detailed in permitting guidance documents for states with more mining

activities. Additionally, state programs with jurisdiction over coal mines and tailings impoundments must comply with Federal coal mining and reclamation programs that include more specific criteria for achievement of the closure objectives. Common goals and objectives in these programs include:

- Eliminating the impounding capability or continuing regulation under a dam safety program. Objectives include control of surface runoff, prevention of water storage within or behind the structure, and minimizing/preventing erosion of the dam, tailings, or cover materials. Regulatory requirements have a significant influence on the closure plan and the elimination of impounding capability. These requirements include the:
 - Design Storm Event for closure, which can be the 100-year return storm event, 500-year return storm event, or even the Probable Maximum Flood as a continuation of operational conditions until the hazard potential classification warrants otherwise.
 - Hazard Potential Classification of the closed tailings impoundment, where addressed, is generally dependent on the tailings' saturation and potential mobility unless implementation of the closure plan results in draining the tailings to reduce its mobility.

Regulatory guidance for grading and potential for backwater from hydraulic control structures installed at closure is limited. For example, grading at closure may provide gravity drainage from the former impoundment area through a notch or breach in the dam. The breach's size should be sufficient to keep the design storm from creating backwater and impounding beyond drainage channels and onto the impounding surface. The selection of the closure design storm may be different than under operating conditions.

- Physical stability as a mine waste structure, including erosion resistance and vegetation. Physical stability includes minimizing or preventing erosion, backfilling and grading for long term stability, continued stability and compatibility with post-mining land use, and vegetation consistent with the post-mining land use. A number of state programs further elaborate on the physical stability objectives, such as expectations for low maintenance, or tie objectives to stability criteria and reference standards for water dam safety other than a tailings dam. The following requirements from closure regulations may contribute to physical stability:
 - Diversion of Run-On water
 - Maximum outboard slope of the tailings dam
 - Seepage control
 - Pond Dewatering
 - A minimum factor of safety and acceptable performance for slope stability under long term static conditions

- Acceptable factor of safety against seismic loading and post-earthquake liquefaction
 - Resistance to failure considering liquefied strengths, if triggered
 - Static liquefaction potential
- Geochemical stability, including isolation and treatment of acid-forming and toxic materials (e.g., metals that leach from the tailings at concentrations harmful to human health and environment). Geochemical stability is aimed at minimizing the adverse impacts on air and water quality, vegetation and land use, and compliance with water quality standards. Like physical stability, some state programs emphasize closure strategy, such as elimination, to the greatest extent practical, any reasonable probability of adverse discharge from the facility, and exceedance of aquifer water quality standards at the applicable point of compliance. Control of fugitive dust emissions that could impact water and vegetation are also considered in geochemical stability.
 - Land use and sustainability, consistent with surrounding land use, or compatible with community development plans. State programs provide a range of objectives from Idaho's return of the land to a productive condition to New Mexico's restoration of the environment to a self-sustaining ecosystem. Arizona cites the development of vegetation consistent with post-mining land use, considering what is technically and economically practical given site-specific characteristics. Pennsylvania's program includes the requirement for post-closure land use constraints through deed restrictions to prevent alterations to the structure and use of the site that could negatively impact its safety or compromise environmental protection.
 - Progressive reclamation of the TSF during the mine life. State programs generally have provisions to encourage progressive reclamation during mine life, and may have objectives for timely TSF closure and reclamation upon cessation of operation. Progressive closure of a TSF impoundment area while other areas remain in operation, where feasible, can aid in developing procedures and reducing risks. During operation, progressive reclamation can be a requirement on TSF final downstream slopes to improve surface water management. State programs recognize requirements for tailings drainage that can affect closure timing to implement safe construction practices. Financial assurance for closure and consideration for closure during an unexpected mine shutdown is in some State programs.
 - Post-closure maintenance and monitoring before bond release includes erosion control and repair and reseeded as necessary to meet vegetation establishment criteria and achieve maintenance-free conditions to the extent possible. For states that provide guidance on the jurisdictional release of a closed tailings impoundment as a dam and impoundment structure, monitoring of consolidation characteristics

and pore pressure are required in addition to monitoring erosion and overall performance of the closure system. Monitoring may be required for decades depending on the condition of the TSF at closure.

Table 1 summarizes examples of goals and objectives from specific State programs for closing a TSF.

Table 1. State Regulatory Objectives for TSF Closure

Elimination of Impounding Capability
<i>New Mexico</i> requires controlling surface runoff to minimize erosion. <i>Idaho</i> will allow some areas of the TSF to have ponds for wildlife habitat, with a maintenance-free spillway or diversion to manage runoff and prevent water storage behind the tailings dam. <i>Pennsylvania</i> requires backfilling, grading, drainage control, and vegetation stabilization measures with positive drainage and elimination of the ability to impound water for TSF closure.
Physical Stability
<i>New Mexico</i> addresses long term stability with requirements to minimize erosion. <i>Idaho</i> requires the TSF at closure to be stable and in a maintenance-free condition. <i>Pennsylvania</i> requires backfilling, grading, and vegetation for stabilization measures and meeting static and seismic slope stability criteria. <i>Illinois</i> requires confirmation that the tailings are not flowable or would become flowable under seismic loading. <i>Minnesota</i> requires contouring the TSF, stabilization, and vegetation measures for physical stability. <i>Texas</i> reclamation requirements include control of erosion effectively and sufficiently to sustain vegetation where required and consistent with anticipated land use.
Geochemical Stability
<i>New Mexico</i> addresses the protection of groundwater resources in their closure requirements. <i>Pennsylvania</i> requires treatment and isolation of acid-forming or toxic materials and minimize adverse impacts on plant growth and land use. Minimize water quality changes so that approved post-mining land use is not adversely affected and comply with water quality standards. <i>Illinois</i> requires surface materials that cannot support vegetation covered with soil to a minimum depth of four feet. <i>Minnesota</i> requires dust control, hydrologic impact, and mitigating the impact on wetlands in their closure requirements.
Land Use and Sustainability

Table 1. State Regulatory Objectives for TSF Closure

<i>Arizona</i> requires the development of vegetation consistent with post-mining land use considering technical /economically practical given site-specific characteristics. <i>New Mexico</i> requires the restoration of the environment to a self-sustaining ecosystem after mining operations cease. <i>Pennsylvania</i> requires deed restrictions to prevent alterations to the structure and use of the site to impact its safety or compromise environmental protection negatively.
Progressive Reclamation⁴
<i>New Mexico</i> requires mines to restore the environment to a self-sustaining ecosystem with long-term and post-closure monitoring. <i>Arizona</i> requires developing vegetation consistent with post-mining land use, considering technically and economically practical given site-specific characteristics. <i>Colorado</i> requires complete reclamation within five years once a phase of the mine life is complete. <i>Idaho</i> mine closure includes returning the land to a productive condition relative to pre-mining land use. <i>Pennsylvania</i> requires deed restrictions to prevent alterations to the structure and use of the site that could negatively impact the safety of the structure or compromise the environment's protection.
Post-Closure Maintenance & Monitoring
<i>Alaska</i> requires financial assurance for permanent mine features if a closed TSF remains a jurisdictional dam. <i>Montana</i> requires that the Operation, Maintenance, and Surveillance Manual include monitoring parameters for closure, such as seepage, phreatic surface, and pore pressure. <i>Illinois</i> and <i>Pennsylvania</i> include monitoring of phreatic level and pore pressure in support of the jurisdictional release.

Leading Features of State Programs

Leading features in state regulatory programs provide specific safety, stability, reclamation, and management strategies that address tailings dam closure based on experience with mine closures and performance, or in response to international tailings dam incidents. Some of the key features of state programs that are specific to tailings dam closure include:

⁴ Progressive reclamation applies to the mine site in general without specific reference to the TSF in most State programs; where applicable, progressive reclamation includes the downstream slope of the tailings dam which for ring-type facilities, can represent significant acreage and improve surface runoff management. Progressive closure of TSF impoundment areas, where feasible, provide for developing procedures and reducing risks.

- Specific closure regulation or guidance that prominently addresses closure feasibility and risk assessments during the design phase to assess operation and closure targeting as-low-as-reasonably practical (ALARP) criteria (Montana, Alaska)
- Static and seismic slope stability criteria and analysis methodology guidance for closure, and procedures to address hazard potential in support of delicensing and relinquishment (Pennsylvania, Illinois)
- Impoundment elimination criteria allowing for small ponds, wetlands, and other similar features required for post-mining land use (Pennsylvania, West Virginia)
- Independent review and expert review panels required through closure (Montana)
- Closure maintenance and performance including Best Management Practices (South Carolina), and post-closure financial assurance (Alaska, Montana)
- Sustainability requirements based on post-mining land use and site characteristics considering technical and economic practicality (Arizona, Texas) and adaptive species of grasses with perimeter tree screens (Illinois) and ecosystem not requiring perpetual care following closure (Michigan).

Industry TSF Closure Criteria

The authors compared closure regulations of selected states with the closure criteria by the international and national committees described previously to understand the alignment or misalignment with the current regulation. **Table 2** provides a comparison of State and Industry TSF Closure Criteria.

Table 2. Comparison of State and Industry TSF Closure Criteria

Industry Closure Criteria	Common State Closure Criteria
Elimination of Impounding Capability	
ICMM considers the possible modes of failure that could occur post-closure. The TSF dam risk category determines the post-closure condition. ICMM provides approaches for adapting to climate change and the importance of understanding the overall site water balance without specific requirements on eliminating the impounding capability of the TSF as this may not always be feasible for a particular site. In addition, a water cover may be the only means for closure at some sites.	States simply require either eliminating the impounding capability of the TSF or continue in post-closure under a dam safety program. However, most dam safety programs are for water dams instead of tailings dams. The TSF closure objectives include surface water management, prevention of water storage within or behind the structure, and minimizing/preventing erosion of the dam, tailings, or cover materials as an absolute instead of reviewing failure modes and risk.

Table 2. Comparison of State and Industry TSF Closure Criteria

Industry Closure Criteria	Common State Closure Criteria
ICOLD provides conditions for impounding tailings by defining the three stages of closure, including transition, active care, and passive care. A TSF requires little to no maintenance in passive care and is a waste management structure with similar characteristics of the surrounding natural features. If the structure must remain as a dam, then spillways and other hydraulic structures should be in place to safely convey runoff from the facility to reduce the risk of failure.	States like New Mexico require controlling surface runoff to minimize erosion. Idaho will allow some areas of the TSF to have ponds for wildlife habitat, with a maintenance-free spillway or diversion to manage runoff and prevent water storage behind the tailings dam. Pennsylvania requires backfilling, grading, drainage control, and vegetation stabilization measures with positive drainage and elimination of the ability to impound water for TSF closure.
Physical Stability	
Some mine owners approach the physical stability of a tailings dam at closure different than during its operation. A tailings dam's operational life can be as short as less than 20 years, whereas closure is for perpetuity. Consequently, the design criteria for hydrologic and seismic minimum exceedance probability can be 1 in 5,000 years during operation to 1 in 10,000 years post-closure. ICM defines physical stability as a stable landscape that limits long-term erosion potential and environmental degradation. The tailings dam should have little risk to humans and the environment and be compatible with the post-closure land use. ICOLD provides conditions for stability, and it ranks providing a stable structure over the long term as the highest priority for closing a TSF. The geochemical, ecological, and other forms of stability is not achievable without a stable structure. Dam break analysis methods for a TSF is becoming more advanced in simulating	Physical stability requirements for tailings dams vary from State to State and tend to use vague statements like "maintenance-free condition," "be stable," "no flowable tailings under seismic loading." Illinois, Pennsylvania, and a few other state programs include specific prescriptive stability criteria for closure and relinquishment of tailings dams.

Table 2. Comparison of State and Industry TSF Closure Criteria

Industry Closure Criteria	Common State Closure Criteria
non-Newtonian tailings flows to predict inundation limits from a hypothetical breach. For a TSF that cannot transition to a mine waste structure, a dam break analysis focused toward credible failure modes provides a means to assess failure's consequences and to inform emergency response plans.	
Geochemical Stability	
The industry and States are in alignment with geochemical stability objectives for tailings dams. Both the industry and States are motivated to protect the environment. Industry uses isolation and treatment as necessary for acid-forming and toxic materials.	States provide specific requirements for the protection of groundwater resources in their closure requirements. Minimize water quality changes so that approved post-mining land use is not adversely affected and comply with water quality standards. Some states still rely on prescriptive requirements such as a minimum depth of cover soil over non-supporting vegetation tailings instead of other methods that can achieve the same goal.
Land Use and Sustainability	
The industry is leading the way in post-closure land use and sustainability. ICM, for example, suggests providing a clear definition for post-closure land use at the beginning of the mine project so that Land use and sustainability can be part of the TSF design and operation. ICM also provides specific methods for good practices in post-closure planning, such as developing maps of the post-closure landscape and evaluations for post-closure land use for universal capability areas as part of mine planning.	State guidance and regulation for post-closure land use are general without suggestions and advice for developing a mine with post-closure in mind. For example, some States require restoration of the environment to a self-sustaining ecosystem after mining operations cease with limited options in post-closure uses.
Progressive Reclamation	
Progressive closure and reclamation is the ongoing effort to advance closure activities during the mine operation, recognizing that it can take an extended period for TSF closure and initiating closure in some areas	State programs include progressive implementation and timely reclamation performance during mine operation with provisions to complete timely restoration within a period after cessation of activity.

Table 2. Comparison of State and Industry TSF Closure Criteria

Industry Closure Criteria	Common State Closure Criteria
during operations can aid in developing procedures and reducing risks. Industry and States are in line with progressive reclamation since most States release portions of the closure bond once a part of the TSF is closed successfully.	
Post-Closure Maintenance & Monitoring	
The industry is changing the post-closure care maintenance and monitoring process for the tailings dam that remains functioning as a dam. There are good practices by mine owners and industry organizations such as ICMM and ICOLD on monitoring.	Some States with active mines require monitoring specific parameters such as seepage, phreatic surface, and pore pressure for those facilities that continue to function as a dam after closure. Many of the requirements are from water dams that may not apply to a tailings dam.

The industry promotes early planning for closure in the feasibility and design stage (ICMM, 2019), including evaluation of the role of technologies to improve tailings characteristics and attain physical and geochemical stability for the long term (MAC sponsored study; KCB, 2017). As a TSF progresses through operation, the industry recommends the operator update closure plans and implement measures during operation to transition and enhance closure practices (ICMM, 2019). Also notably, ICMM participated as a co-convenor in the Global Tailings Review and supports the establishment of the resulting Global Industry Standard for Tailings Management (GTR, 2020), and is continuing to develop and improve guidance for tailings dam closure. International organizations such as ICMM and ICOLD provide a forum for mine owners and engineers to create state-of-art closure guides based on successful closures in the different parts of the world that the mines operate. In the United States, organizations like ASDSO, FEMA, and USSD are beginning to look at closure from a regional perspective. In general, States seem to borrow technical criteria from water dam and environmental regulations instead of having a program focused on TSF closure practice, which would benefit both the industry and State in managing the closure as an asset instead of a liability.

V. EMERGING CLOSURE PHILOSOPHIES

Before the 1970s, the efforts to close a TSF were minimal, with many TSFs left to the elements after mining was complete. With the reorganization of the Federal Water Pollution Control Act in 1972, known as the Clean Water Act, early TSF closure improvements began with the emergence of strategies for conventional slurry tailings

deposits. TSF closure typically included consolidation, capping in place, cover placement, and revegetation. Filtered, paste and dry stack tailings technologies in the 1990s provided options to remove free water in the tailings to improve physical and geochemical stability and subsequent land use. Mine owners also experimented with co-disposing tailings and waste rock during this time. The emergence of risk-based closure philosophies in the 2000s saw closure planning elevated in priority, leading to the view of 'progressive reclamation' and the requirement of including reclamation plans, permits, and bonding as mandatory for upfront mine permitting. In 2018, the role Engineer-of-Record (EoR) provided accountability for owners, operators, and design engineers. Since 2018, the large and relatively flat area of TSFs has provided opportunities for renewable energy. And, finally, market fluctuations, and increases in mineral values, have made reprocessing of tailings deposits a potentially viable alternative while at the same time making TSF closure an asset instead of a liability.

Filtered, paste and dry stack tailings technologies are becoming more effective in meeting operational requirements, and are expected to provide opportunities for innovation in closure planning by reducing or even eliminating solidification/stabilization steps required at traditional tailings impoundments. Co-disposal is an emerging technology with several different forms that vary by degree of mixing. Combined tailings and waste rock typically is used as backfill in an open pit or placed in paddocks or cells with berms constructed of waste rock. Potential advantages of co-disposal include; 1) better physical strength of the combined waste materials than the waste materials alone; and 2) better geochemical stability with a combined waste material by acid rock drainage reduction. Scaling this approach to large mine production continues to be a challenge.

There are a small number of mines in the USA that co-dispose mine waste. The Greens Creek mine in Alaska mixes approximately 50 percent of the filtered tailings with waste rock. The mixed material is end-dumped at a ratio of 1 to 3.2 rock to tailings by mass, then spread by a bulldozer and compacted with a smooth drum vibratory roller. The mine backfills the underground workings with the remainder of the filtered tailings for stabilization (Habte and Bocking 2017). The Dunka Mine in Minnesota encapsulated approximately 262,000 tons of high sulfur content waste rock in a section of the TSF (MDNRDLM 2001). Coal mines have also experimented with co-disposal of coal slurry (Williams et al. 1995), including the use of limestone or even coal combustion ash as part of long-term operations and closure plan implementation.

Risk-based closure planning entails 'beginning with the end' in mind, with risk management philosophies tied to financial terms and long-term environmental protection. In some sectors, unlined tailings facilities gave way to requirements for leak/seep collection/detection systems for long-term protection of groundwater and surface water resources. Slope regrading and waste management structuring are critical strategies for mitigating the long-term risks of structural instability. Cover systems protect the tailings from water leaching metals and acids into groundwater and surface water. The evolution of risk-based planning has also seen the emergence of up-front risk evaluation as a condition of acceptance. Engineering tools added to risk evaluation include flood inundation modeling, potential failure mode analyses, and advanced deformation

modeling under seismic and static loading conditions. Advances in predicting behavior of a tailings dam allows using performance criteria for the design, operation and closure specific to the site conditions.

In early 2017, the Geoprofessional Business Association (GBA), supported by USSD, held an EoR workshop that culminated in the publication of the USSD-endorsed document titled "Proposed Best Practices for the Engineer of Record (EoR) for Tailings Dams" (GBA, 2018). The GBA document provides the framework for the EoR for the full life-cycle of the TSF, including the closure and post-closure phases. Several initiatives followed to clarify the roles and responsibilities of the EoR, including ones in Canada led by the Canadian Dam Association (CDA), British Columbia Ministry of Energy & Mines (BCMEM), the Mining Association of Canada (MAC), and the Alberta Dam Integrity Advisory Committee (DIAC), among others. The Montana Department of Environmental Quality (DEQ), in cooperation with the Montana Mining Association, created metal mine regulations introducing the EoR and independent review requirements for active TSFs in 2015. Many international mining companies now have a TSF EoR program in place.

Developing closed mine waste facilities for renewable energy production, such as photovoltaic solar power, hydroelectric power, bio-energy, wind power, and geothermal energy, presents the potential to provide numerous benefits to mining companies and their communities. In the interest of providing beneficial long-term land use from renewable energy production, philosophies have emerged since the late 1990s that present opportunities for mining companies and regulatory agencies to collaborate to incorporate renewable energy development at active mining and legacy mine sites. The potential advantages of using closed tailings facilities for renewable energy generation include:

- Decreasing carbon and methane emissions from conventional fossil fuel energy sources
- Reduced operating power costs
- Federal, State, and local tax incentives
- Returning the land to productive use and other economic and ecological benefits.

Although attractive, much more work is needed in the post use of a TSF for renewable energy including addressing long term liability and other legal issues.

The U.S. Environmental Protection Agency (EPA) considers future land use an integral part of its cleanup programs and provides numerous resources and incentives for developing renewable energy programs. They have developed partnerships with the U.S. Department of Energy, the U.S. Department of Housing and Urban Development, and the U.S. Department of Agriculture to promote renewable energy projects. The EPA's Superfund Redevelopment Initiative and Abandoned Mine Lands Program began making tools and information available to encourage owners of Superfund sites and other

impacted lands to consider beneficial uses of their properties following cleanup, including renewable energy projects in the late 1990s. EPA's Abandoned Mine Lands Team (AMLT) provides technical and analytic support to communities and other mining site stakeholders to explore alternative energy opportunities by providing pre-feasibility energy analyses and other forms of technical support. In 2008 the EPA developed the RE-Powering America's Lands Initiative to promote renewable energy development on current and formerly contaminated lands, landfills, and mine sites. The initiative identifies the renewable energy potential of contaminated lands and serves as a resource for parties interested in reusing these lands for renewable energy development. The EPA and its federal, state, tribal, local, utility, community, and private sector partners have explored new renewable energy facilities for these properties. **Table 3** provides examples of renewable energy projects.

Table 3. Examples of EPA-Identified Renewable Energy Projects at Former Mine Sites

Project	Location	Energy	Contributing Partners
Questa Mine	Questa, NM	Solar	Chevron
Mission Mine	Sahuarita, AZ	Solar	ASARCO
McKinley Mine	Tse Bonita, NM	Solar	NTUA ¹ , Chevron
Summitville Mine	Rio Grande County, CO	Hydro	EPA, CDPHE ² (abandoned)
Iron King Mine-Humboldt Smelter	Dewey-Humboldt, AZ	Solar, Bio	EPA, (abandoned)
Leviathan Mine	Alpine County, GA	Wind, Solar	Atlantic Richfield, EPA
Gilt Edge Mine	Lead, SD	Wind	EPA, (abandoned)
Jeddo Mine	Hazelton, PA	Hydro, Geo	EPA, (abandoned)

¹ Navajo Tribal Utility Authority

² Colorado Department of Public Health and Environment

While the ability to take advantage of emerging closure philosophies is tied to community acceptance through public permitting, even closure implementation under more traditional approaches will benefit from stakeholder engagement and communication. It is noted that several of the principals in the GISTM include communication, information disclosure, and other practices to facilitate community engagement and understanding that extends beyond TSF operation and into closure.

VI. GOING FORWARD

TSF closure generally requires implementing a phased program to eliminate impounding capacity, maintain physical and geochemical stability, and establish post-mining land use for a structure that can represent a high hazard potential to human health and the environment downstream of the facility. While regulatory programs are based on objectives to maintain safety and protect the environment, successful reclamation is ultimately dependent on the responsible parties' practices. **Table 4** provides a guide of closure practices for responsible parties, including the regulator, design engineer, and owner/operator. This guidance came about from a workshop of mine owners, design

engineers, and regulators at the USSD 2017 San Antonio Workshop on Tailings Dams Failures and Lessons Learned (USSD 2017). The guidance in **Table 4** highlights the discussion on closure from the workshop with supplemental input by the authors. The authors also recommend further review of the international guidance currently available as listed within the Reference section, as well as being developed by ICOLD and ICMM in considering both regulatory program and industry practice improvements in the USA.

Table 4. Closure Practice Imperatives

Party	Closure Practice Imperative
Regulator	1. Promote consistency in national TSF regulation, including support development of the FEMA Model State Dam Safety Program, including closure requirements through active review and implementation 2. Promote the development of a national TSF dam safety guidance document to provide specific design, construction, operation, and closure criteria, including practices for developing plans and submittals for regulatory approval 3. Delineate the EoR responsibilities, including continuing the role during the implementation of closure and participation during post-closure monitoring 4. Clarify the operation, maintenance, and surveillance manual requirements, including requirements for closure implementation and post-closure care 5. Definition of Construction, Operations, and Closure Submittals including Closure Quantifiable Project Objectives (QPOs) and Performance Monitoring reports 6. Provide a custodial transfer program and guidance for the operator to transfer the land ownership back to the pre-mine owner or another party following closure.
Designer & Engineer	1. Stormwater and process water management and separation from TSFs, including during and after the closure 2. Evaluate closure conditions for potential hazard classification considering measures to address tailings mobility, including establishing Quality Performance Objectives (QPOs) for the Operation, Maintenance and Surveillance (OMS) Manual 3. Recognition of dam safety risks, and commitment to identify and mitigate the risks extending through the closure and post-closure care 4. Promote the maintenance of the project organization chart for personnel accountability and responsibility (e.g., RACI Project Organization Chart) even in the closure phase 5. Maintain a deviation accountability record into the closure phase to guard against acceptance of non-performance, and support compilation of the incident log and reporting 6. Develop the mine plan with closure in mind
Facility Operator	1. Evaluate TSF risk and reduce potential consequences through closure, including long term structural containment and possible tailings mobility 2. Establish and maintain the personnel accountability and responsibility project organization chart through the closure and into post-closure care 3. Conduct and continue independent reviews that extend into closure implementation

	4. Operate the TSF with closure in mind 5. Conduct failure modes and effects analysis (FMEA) with the implementation of an action plan to address findings through operations, closure, and into post-closure care 6. Prepare detailed as-constructed plans, construction documentation reports, performance monitoring, and incident logs
Professional Organizations	7. Professional organizations in the USA that are part of the TSF community may consider a formal establishment of a tailings closure subcommittee.

State regulatory programs across the USA generally cite consistent TSF closure objectives, although the design and implementation approach and specific criteria can vary considerably. States such as Alaska, Illinois, Montana, and Pennsylvania have established regulatory guidance for TSF closure and dam safety. The 2017 San Antonio USSD Workshop participants recognized the need for improvements to the design, operation, and closure of TSFs in the USA, including suggesting a national TSF regulatory and technical guide, among others.

The authors encourage the states to be active in review and providing input to current initiatives underway by FEMA and implemented by ASDSO and USSD to establish tailings dam regulatory program guidelines and technical dam safety guidelines with consideration of the elements presented in Section II. A national dam safety guideline for TSFs should include the vision of establishing a USA specific TSF manual that provides for criteria and practices including closure and post-closure care. A framework for developing tailings dam safety programs at the state level include:

1. Closure objectives include risk-based post-closure land use, hazard potential reduction, closure performance monitoring, and sustainable post-closure maintenance, such as those cited in some of the state programs presented in Section III.
2. Addressing state dam safety program requirements independent of technical criteria or methodology (considering planned updates to the FEMA model state dam safety program); require TSF projects to include management systems for planning and risk assessment; intelligent design, construction, operation, closure, and post-closure maintenance; monitoring and surveillance; technical review and update; reporting; and financial assurance. Closure planning and risk assessment should demonstrate technical and economic feasibility for post-mining land use under zoning and regional/community development plans and post-closure maintenance sustainability.
3. Consider the 2020 Global Industry Standard on Tailings Management (GISTM) in updating regulations and TSF requirements relative to closure such as:
 - a. The maintenance of a knowledge base throughout the TSF life cycle, with attention to information such as tailings production rates, deposition records, physical and geochemical testing, pore pressure and seepage monitoring history.

- b. Integrate risk management into TSF life-cycle including closure and post-closure maintenance
 - c. Identify performance objectives that are relevant to closure plans, closure implementation, and post-closure maintenance for monitoring and reporting
 - d. Implement management and governance requirements that extend into post-closure and include accountable mine representative and independent Engineer of Record for TSFs
 - e. Maintain emergency response and long-term recovery plans into post-closure care until the TSF no longer represents a significant or high hazard potential or unacceptable risk
4. The technical criteria and methodology in regulations should reference guidance documents published by recognized independent dam safety organizations.
 5. Requirements for specific closure design criteria such as maximum slope or minimum factor of safety should include provisions for alternatives that are supported by independent dam safety organizations.

Closure criteria is not a one size fits all approach, but must be flexible to suit a specific site, region, or climatic condition. Alternative methods must be supported by case histories, risk assessments, monitoring programs, and other measures reviewable by the regulator. To the extent available, reference FEMA dam safety documents.

VII. CONCLUSIONS

This paper provided a review of USA closure regulations to determine the alignment with mining industry practice. The purpose is to educate and inform the United States mining community regarding transitioning a tailings dam from operation to closure as a beneficial asset to the community rather than a liability.

Technical guidance for tailings dam closure is limited at the federal level (MSHA, EPA and NRC), and focuses on designing an operating tailings dam with little attention to closure, which has a much longer design life. Initiatives by FEMA and implemented by ASDSO and USSD are underway to bridge this gap, and more reform at the State level may be needed to align with the industry. Nevertheless, the industry has moved forward in developing tailing dam closure technical guidance through ICMM, ICOLD, ISO, UNEP, IFC, and others. Comparing the closure guidance from these organizations to State closure regulations shows alignment in geochemical stability (e.g., environmental controls) and progressive reclamation. Less so in eliminating impounding capability, physical stability, land use and sustainability, and post-closure monitoring and maintenance.

New closure philosophies and techniques are emerging. These include:

- Closure planning and progressive reclamation;
- Reprocessing tailings to recover economic metals;
- Co-disposal of tailings and other waste like overburden;

- Renewable energy (i.e., solar power farms, bio-energy, wind power, geothermal, etc.); and
- Risk-based closure to provide the best closure approach given a set of risk likelihood and consequences.

Going forward, improvements to be considered for mine tailings closure practice include:

- Have a single closure guidance model that states can refer to for closure regulations and technical guidance toward achieving national consistency
- Design and operate mine tailings dams with closure in mind
- Consider mine tailings dams and impoundments as assets to provide a benefit to the community and recover costs for maintaining and monitoring a facility, and
- Have consistent and appropriate closure objectives and criteria for TSFs that may be different from design and operation requirements.

Tailings dams are more complex and expensive than many other mine elements, requiring responsible and cost-effective closure programs. Effective closure is a critical aspect of making an economic resource in the USA.

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APPENDIX A

Table A.1: Components of TSF Closure Programs for Selected States

Figure A.1: United States Climatically Consistent Regions

Table A.1
Components of TSF Closure Programs for Selected States¹

STATE	REGULATORY AGENCIES	ENGINEER OR ENGINEER OF RECORD* REQUIRED?	RECLAMATION PLAN REQUIRED?	RECLAMATION BOND REQUIRED?	PROGRESSIVE RECLAMATION REQUIRED?	PRESCRIPTIVE RECLAMATION PHYSICAL STABILITY REQUIREMENTS					PRESCRIPTIVE GEOCHEMICAL STABILITY	POST- RECLAMATION LAND USE
						CLOSURE SLOPES	DESIGN SEISMIC EVENT	DESIGN FLOOD	SAFETY FACTORS	REVEG		
Alaska	Dept. Natural Resources Div. Mining, Land and Water		X	X	X					X		
Arkansas	Dept. Environmental Quality		X	X	X	X				X	X	X
Arizona	Office of the Arizona State Mine Inspector Div. Mined Land Reclamation Dept. Environmental Quality		X	X						X		X
California	Dept. Conservation Div. Mine Reclamation Regional Water Quality Control Board Div. Safety of Dams Water Resources Control Board	X	X	X	X	X	X	X	X	X	X	X
Colorado	Div. Reclamation, Mining and Safety		X	X	X	X				X		X
Georgia	Div. Environmental Protection		X	X								X
Idaho	Dept. Water Resources		X	X		X				X		
Illinois	Dept. Natural Resources		X	X		X	X			X	X	
Kentucky	Dept. Natural Resources, Energy and Environment Cabinet	X	X	X		X	X	X	X	X		X
Michigan	Dept. Environmental Quality Dept. Environment, Great Lakes, and Energy		X	X	X					X		X
Minnesota	Dept. of Natural Resources	X	X	X						X	X	X
Missouri	Dept. Natural Resources, Mining Commission		X	X						X		
Montana	Dept. Environmental Quality	X	X	X	X			X		X	X	X

¹ The purpose of Table A.1 - Components of TSF Closure Programs is to illustrate the variety of TSF closure requirements in the United States. The information was primarily based on an internet search and may not reflect the specific policies and requirements imposed by an individual State. Definitions presented at the end of the table are intended to reflect the general use of terms in the state regulatory program documents for comparison purposes, and are not necessarily consistent with other published industry guidance which may be more descriptive. The reader should contact the appropriate State Agency to determine the specific requirements for a TSF closure along with definition of terms.

Table A.1
Components of TSF Closure Programs for Selected States¹

STATE	REGULATORY AGENCIES	ENGINEER OR ENGINEER OF RECORD* REQUIRED?	RECLAMATION PLAN REQUIRED?	RECLAMATION BOND REQUIRED?	PROGRESSIVE RECLAMATION REQUIRED?	PRESCRIPTIVE RECLAMATION PHYSICAL STABILITY REQUIREMENTS					PRESCRIPTIVE GEOCHEMICAL STABILITY	POST- RECLAMATION LAND USE
						CLOSURE SLOPES	DESIGN SEISMIC EVENT	DESIGN FLOOD	SAFETY FACTORS	REVEG		
Nevada	Div. Environmental Protection, Bureau of Mining Regulation and Reclamation		X	X	X	X	X		X	X	X	X
New Mexico	Dept. Energy, Minerals and Natural Resources Dept. Environment	X	X	X	X		X	X	X	X	X	X
New York	Dept. Environmental Conservation Div. Mineral Resources		X	X		X				X		X
Ohio	Dept. Natural Resources Div. Mineral Resource Management		X	X						X	X	X
Oregon	Dept. Geology and Mineral Industries Mineral Land Regulation & Reclamation		X	X	X	X				X	X	
Pennsylvania	Dept. Environmental Protection	X	X	X	X	X	X	X	X	X		X
South Carolina	Dept. Health and Environmental Control		X	X	X	X				X		
South Dakota	Dept. Environment and Natural Resources		X			X		X		X		X
Texas	Only mining regulated is uranium (NRC) and coal		X	X				X				X
Utah	Dept. Natural Resources Div. Oil, Gas, and Mining		X	X								X
Virginia	Dept. Mining, Minerals & Energy		X	X	X	X			X	X		X
Washington	Dept. Natural Resources Dept. Health		X		X					X		
West Virginia	Dept. Environmental Protection	X	X	X		X				X		X
Wyoming	Dept. Environmental Quality		X	X						X		X

***Table A.1 Heading Definitions**

Engineer –Licensed professional engineer qualified in TSF closure plan design.

Engineer of Record –Licensed professional engineer qualified in TSF dam design and construction to supervise or otherwise provide technical expertise to the Owner in support of the tailings dam closure and post-closure.

Reclamation Plan - Provides how the closure of the Tailings Storage Facility will meet the State TSF closure requirements. It provides the basis for closure cost estimate suitable for developing financial assurance and provides the criteria for mine operations that can be applied to the TSF regardless of future mine plan changes.

Reclamation Bond –A mechanism for the TSF closure financial assurance

Progressive Reclamation –Progressive closure is the implementation of reclamation activities during the operating life of a mine.

Prescriptive Reclamation Physical Stability Requirements –Prescribed design parameters to achieve physical stability for non-coal TSFs (Coal mining TSFs in most states include prescriptive parameters).

Closure Slopes –The maximum inclination of the tailings dam downstream slope at closure that contributes to long term physical stability as to eliminate or material erosion to the terrestrial or aquatic receiving environment at concentrations that are harmful.

Design Seismic Event –The magnitude of the earthquake required for the closure design of the TSF which may different then used during the operation period.

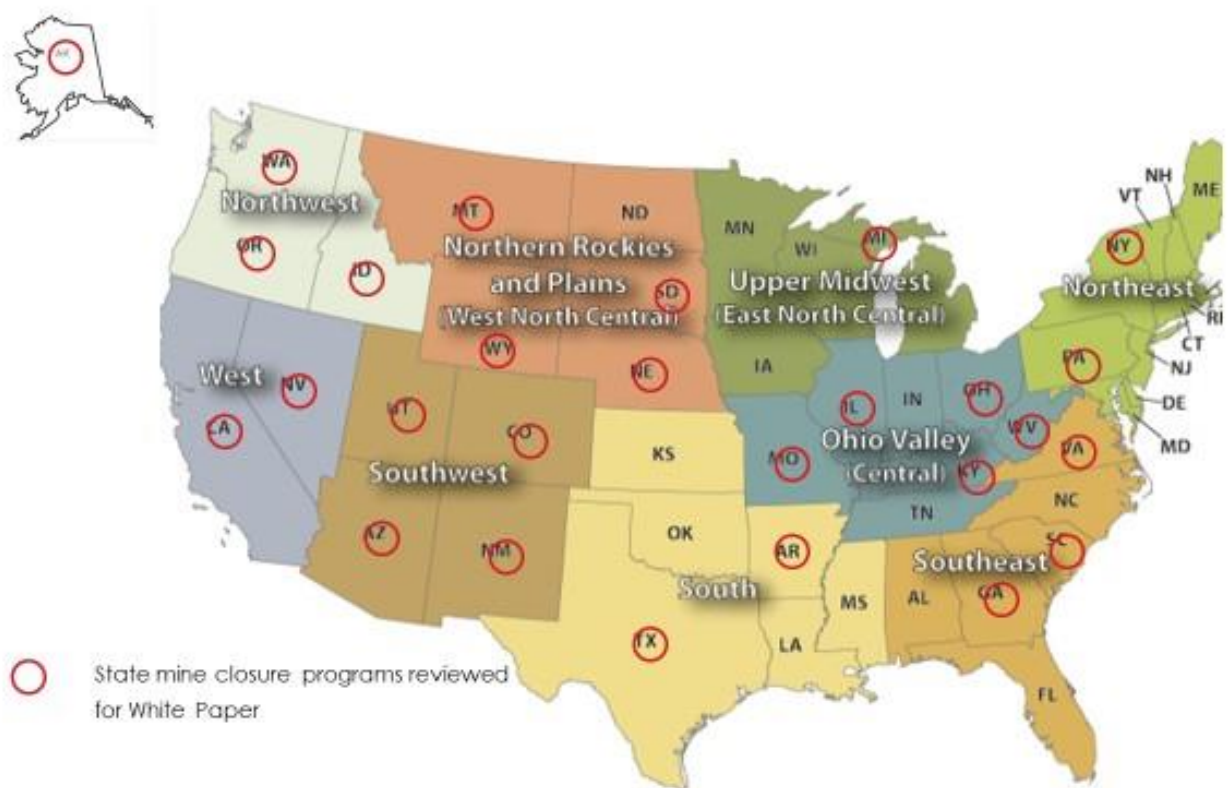
Design Flood –The climate scenario for the TSF closure design criteria.

Safety Factors –A value that expresses how much stronger a system is than it needs to be for an intended load.

Revegetation –The type and arrangement of vegetation required for the TSF closure.

Prescriptive Geochemical Stability –The components of the TSF closure that mitigate contaminants from migrating into the receiving environment at concentrations that are harmful to human health and the environment.

Post Reclamation Land Use - Requirements for developing the post closure use of the TSF that are compatible with the surrounding lands or achieves an agreed alternative productive land use.



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Figure A.1: United States Climatically Consistent Regions

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