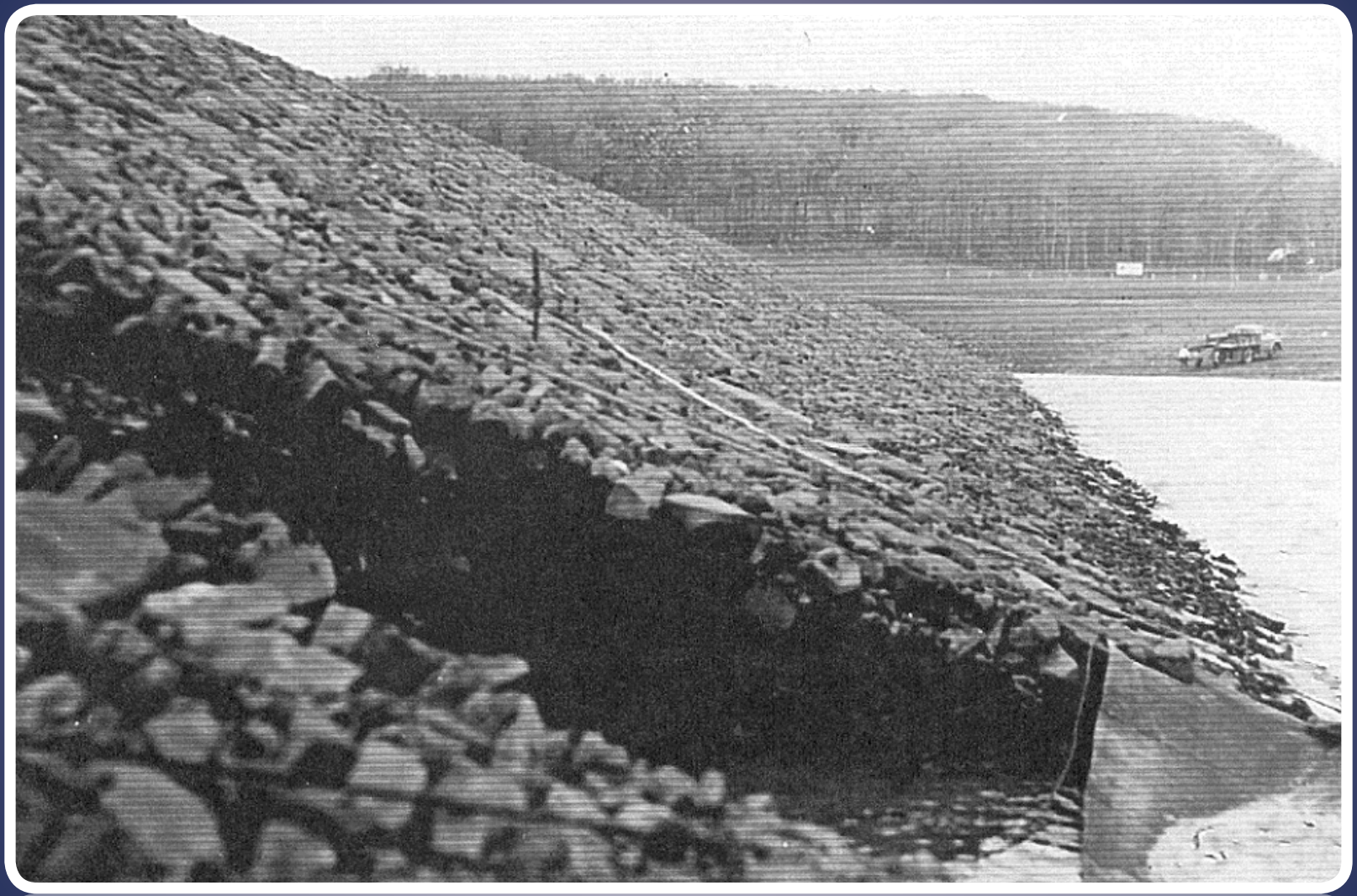
Lesson Learned

FEMA

NDSP
National Dam Safety Program



The first filling of a reservoir should be planned, controlled, and monitored.

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In October 2013, the Federal Emergency Management Agency's National Dam Safety Program sponsored the research and development of a compendium of dam incidents and failures with emphasis on the lessons learned from these events. This information is presented through FEMA's Lessons Learned Information Sharing website. For a complete listing of available lessons learned and case study summaries or to contribute your own content, please visit:

Dam Incidents and Failures Website

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The first filling of a reservoir should be planned, controlled, and monitored.

The initial filling of a *reservoir* is the first test that the *dam* will perform the function for which it was designed. A carefully managed first filling is crucial to the future success of a dam. According to a study completed by the Bureau of Reclamation on internal erosion *failure modes*, "approximately two-thirds of all *failures* and one-half of all dam incidents occur on first filling or in the first 5 years of reservoir operation." (1)

Dams are constructed primarily to impound and store a large body of water. During the construction of a new dam, *diversion channels and cofferdams* are used to prevent water from entering the construction area. However, when dam construction is complete, flow to the dam site resumes and the reservoir begins to fill with water. The first filling of a reservoir can be defined as the increase in water level behind the dam from the time construction is complete until it reaches the desired operating level. Depending on the location, type, size, and intended purpose of a dam, the duration and rate of its first filling can vary. Regardless of whether it takes several months, several years, occurs naturally, or with the aid of pumping units, the first filling of a reservoir should be planned, controlled, and closely monitored in order to reduce the risk of failure.

Because the first filling of a reservoir is a critical phase in the life for the dam, it is vital for dam operators and engineers to have as much control over the first filling as possible allowing as much time as needed for appropriate surveillance, including the observation and analysis of instrumentation data. The first filling should be scheduled to occur after construction of the dam and all necessary appurtenances (i.e. *spillways* and *outlet works*) have been completed as well as the installation of appropriate *instrumentation*. Specifications regarding the rate of reservoir rise should be developed to allow the dam to adjust to the forces it will experience as the water level behind it increases. These plans should be documented in a design memorandum that may also include "reservoir regulations during project construction, a water control plan, project surveillance, cultural site surveillance, flood emergency plan, public affairs, safety plan, and transportation and communications." (2)

View from downstream of rapid release of the Teton Reservoir after failure during the first filling. The first filling of the reservoir lacked proper planning and caused water levels to reach design elevations prior to the construction of the auxiliary spillway and outlet works.

In addition to dam failure, it is common for design, construction, and/or material deficiencies of a new dam to become apparent during the first filling. For example, evidence of *seepage*, cracking, and *erosion* are often noted when the reservoir is raised to new levels for the first time. Inspection and assessment of these potentially hazardous conditions prior to the completion of filling is

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important and it may be necessary to halt filling or in some cases lower the reservoir before the desired operating water level is achieved to investigate signs of seepage, cracking and erosion. Repairs to any project features that did not function as designed can be re-evaluated and modified to ensure the dam operates according to its original design.

(1) USBR & USACE. (2012). Internal Erosion Risks. *Best Practices in Dam and Levee Safety Risk Analysis*. Denver: U.S. Department of Interior, Bureau of Reclamation.

(2) USACE. (2004). *General Design and Construction Considerations for Earth and Rock-fill Dams, EM 1110-2-2300* Washington D.C.: U.S. Army Corps of Engineers.

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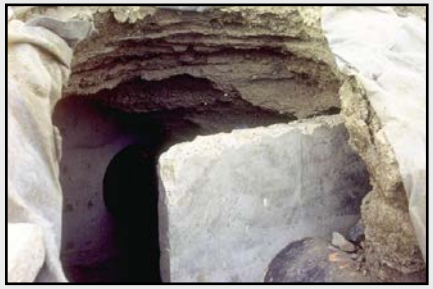

Name: Anita Dam
Location: Montana, USA
Type of Dam: Earthfill
Dam Height: 36 ft.
Date of Incident: March 26, 1997
Fatalities: 0
Property Damage: < $100,000

Name: St. Francis Dam
Location: California, USA
Type of Dam: Concrete
Dam Height: 205 ft.
Date of Incident: Mar. 12-13, 1928
Fatalities: 432
Property Damage: $7 Million

Name: Teton Dam
Location: Idaho, USA
Type of Dam: Earthfill
Dam Height: 405 ft.
Date of Incident: June 5, 1976
Fatalities: 14
Property Damage: $400 Million

Additional Relevant Case Studies

1. Penn Forest Dam (Pennsylvania, 1960)
2. Vajont Dam (Italy, 1963)
3. Austin/Bayless Dam (Pennsylvania, 1911)
4. Wister Dam (Oklahoma, 1949)

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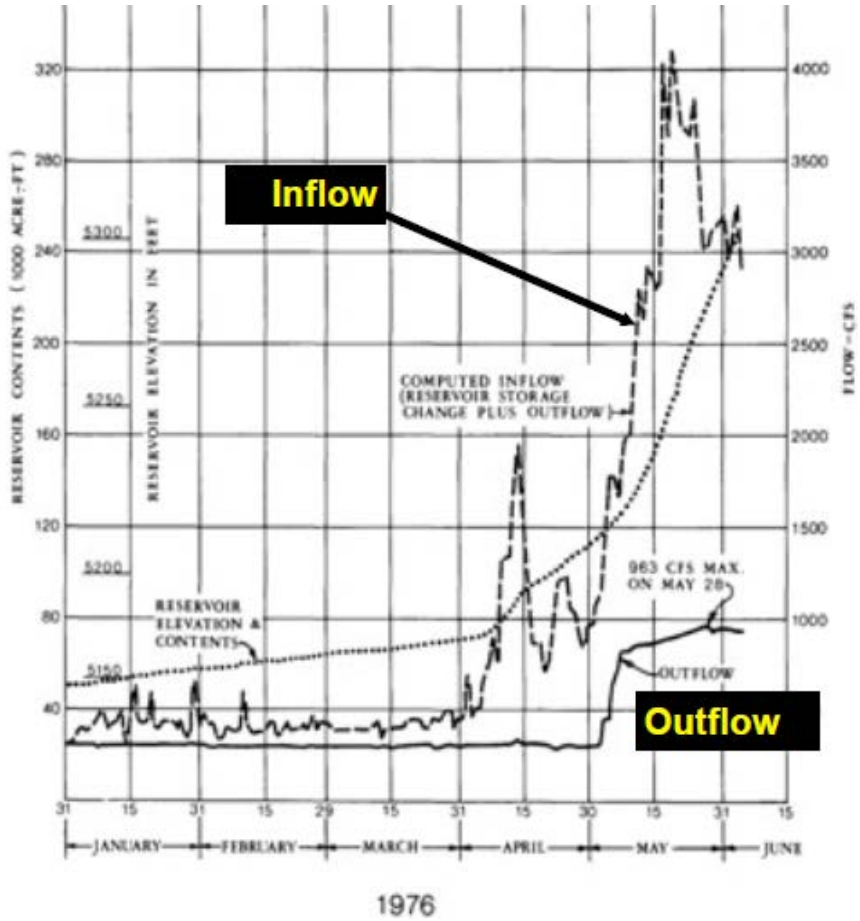

Graphical depiction of inflow, reservoir elevation, and outflow values recorded approaching the failure of the Teton Dam upon its first filling. Note dramatic increase in fill rate shortly before failure.

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Seepage observed on the downstream face of Blackmon Dam in Tasmania upon the first filling of the reservoir. Note location (mid slope) of initiating point of seepage. Failure avoided by quickly lowering water level behind dam.

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Aerial view of St. Francis Dam showing remains of concrete structure after failure upon first filling. Cracking and seepage most likely appeared at the dam as reservoir elevation rose to new maximum level, but lack of proper monitoring regime led to its failure. Note seepage issues can develop in the foundation rock as well as in an embankment dam.

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First filling of reservoir behind Austin Dam occurred due to unexpected snowmelt. Seepage on downstream face of the dam resulted. Note rapid unanticipated filling can result in lack of proper monitoring during filling.

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Instructional video by Dr. John Lowe III on filters, sinkholes, and rapid drawdown stability as part of the Federal Emergency Management Agency's Expert Video series on dam safety.

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Guidance documents containing the best practices for the first filling of a reservoir were not identified or were not yet developed at the time this lesson learned was created. Please refer to the Other Resources tab to access useful material related to the topic.

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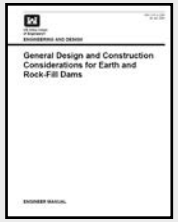
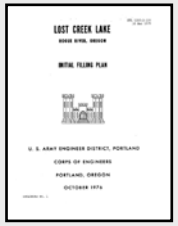


General Design and Construction Considerations for Earth and Rock-fill Dams, EM 1110-2-2300
Author: U.S. Army Corps of Engineers
Date of Publication: 2004

Management of Water Control Systems, EM 1110-2-3600
Author: U.S. Army Corps of Engineers
Date of Publication: 1987



Initial Reservoir Filling Plan, EM 1110-2-231
Author: U.S. Army Corps of Engineers
Date of Publication: 1979

Internal Erosion Risks
Author: U.S. Bureau of Reclamation & U.S. Army Corps of Engineers
Date of Publication: 2012