ABSTRACT

MAINTENANCE & OPERATION OF DAMS TO PREVENT FAILURE

BY

PAUL C. RIZZO AND JEFFREY M. BAIR
Paul C. Rizzo Associates, Pittsburgh, PA

The authors have developed a presentation with the objective of passing on to Dam owners our experience as to how to operate and maintain a Dam in a safe manner. Our approach is to relate the causes of Dam failures and costly distress to operation and maintenance procedures. Topics to be covered include:

- Typical Dam Types including Earth, Concrete Gravity, Ambursen, and Timber Crib are covered. A brief description of each is provided with photographs.

- Various Dam failure modes are presented associated with each type of Dam.

- Discussions of several significant Dam failures complete with photographs.

- Specific examples of operation and maintenance deficiencies that can lead to failure of a Dam;

- What to look for during an inspection which could indicate potential problems.

- Summary of recommended operation and maintenance procedures for Dams.
Maintenance & Operation of Dams to Prevent Failure
Paul C. Rizzo & Jeffrey M. Bair
November 16, 1998

Objective

Pass on to owners of dams our experience as to how to operate and maintain a dam in a safe manner
Approach

Relate causes of dam failures and costly distress to operation and maintenance procedures.

Recommended References

- *Operation, Maintenance and Inspection Manual for Dams, Dikes and Levees*
  - by George Mills, ODNR

- *Fact Sheets published by ODNR*
  - WEB Site www.dnr.state.oh.us

- *Dam Failure Incidents NPDP*
  - WEB Site www.npdp.stanford.edu
Typical Dam Types

- **Earth Fill**
  - Most Common, Very Vulnerable**
- **Concrete Gravity**
  - Less Common, Less Vulnerable
- **Ambursen**
  - Least Common, Very Vulnerable
- **Timber Crib**
  - Less Common, Highly Vulnerable

Typical Earth Dam
Typical Timber Crib Dam
Earth Dam Failures

- Overtopping
- Piping
- Liquefaction (unlikely in Ohio)
- Slope Vegetation
- Rodents
- Drains & Outlet Works

Concrete Gravity Dam Failures

- Overtopping
- Severe Foundation Leakage
- Deteriorated Concrete
Ambursen Dam Failures

- Deteriorated Concrete
- Overtopping
- Severe Foundation Leakage

---

Timber Crib Dam Failures

- Deteriorated Concrete
- Overtopping
- Deteriorated Timbers
- Excessive Foundation Leakage
Overtopping Failures

- Basic inadequate capacity for storage & discharge
  - Spillway is too small
  - Spillway receiving area is inadequate
  - Inadequate crest elevation for storage
- Deformed crest
- Poorly maintained crest

Overtopping Failures

Vincent No. 2

- June 9, 1995 Colorado
- Overtopping occurred during a spring snowmelt flood. Spillway was obstructed by snow. Crest was overtopped at 5 locations, with the first one immediately over the outlet pipe. Failure was slow because of the superior erosion resistance of the clay section.
View of the Breach from Downstream Toe

Aerial View of the Breach
Downstream Slope at North Overtopped Area

BACK & DOWNCUTTING

Overtopping Failures

Lake Pauline
  – June 28, 1994, South Carolina
  – 5.5 inches/24 hours plus two upstream dam failures cause overtopping
  – Road closed and property damage
Example of Well-Maintained Crest

Well-maintained Crest
U/S Slope Wave Protection
Example of Poorly-maintained Crest
Piping Failure

Erosion of the soil by a seep on the downstream slope that progresses back toward the impoundment until a direct path or “pipe” is formed

Piping Failure

Evidence or “Clues”

- An increase in flow rate through an “old” seep
- Muddy or discolored seepage
- Sinkholes
- Whirlpool eddy currents in the impoundment
Piping Failure

- Once developed, very difficult to control
  - Evacuation is in order
  - Immediately Lower Impoundment
- If not fully developed,
  - Control it!!!
  - Efforts to stop it will probably fail!
  - Rapidly place coarse sand and gravel
  - Balance Water Pressure

Example Seepage with "Clues"
Example Showing Control “Fix”

SEEP

Example Showing Control “Fix”

SEEP
Example Showing Monitoring Weir

V-NOTCH WEIR

Piping Failure

Teton Dam
- June 5, 1976
- 11 Fatalities
- 25,000 homeless
- $400 million damages
- Warnings prevented more loss of life
- Occurred during initial filling
Teton Dam Failure Photograph 5/5

Piping Failure

Eureka Wastewater Holding Pond Dike

- July 8, 1995 --After a major storm
- 30 foot deep gullies on private property
- No fatalities
- Environmental Damage

Paul C. Rizzo Associates
Trees & Man-made Features

Trees
- Roots can cause piping
- Overturned trees can result in overtopping
- Brush prevents inspection and early detection of seepage & piping

Tree Roots Can Cause Piping
Overturned Trees Can Lead to Overtopping

Trees & Man-made Features

Man-made features

- Conduits & Drains can cause piping
- Slabs & Docks prevent inspection
- Pilings can cause piping
- Excavations for man-made features can lead to overtopping & stability failure
DRAINS CAN LEAD TO PIPING FAILURE

SLABS CAN INHIBIT INSPECTION AND LEAD TO OVERTOPPING
Rodents & Burrows

Groundhogs
- Burrows are above phreatic surface
- Tunnel network
- Evidence is mounds of fresh dirt in the spring
- Burrows can lead to seepage, then piping
- Controlled by fumigants or shooting
- Mowed vegetation

---

Rodents & Burrows

Muskrats
- Burrows begin 12 to 18 inches below water level and tunnel upward above water table
- Tunnels can be over 15 ft long
- Tunnels lead to seepage, then rapid piping
- Controlled with filters and riprap
- Eliminate vegetation below water level
- Controlled by trapping
Rodent Burrow Damage

Other Rodent Problems

Beavers

- Plug spillways & outlets, reduce capacity
- General nuisance
- Controllable by trapping (regulated)
- Controllable by removing cuttings
Recommendations

Know your spilling & storage capacities

- Translate into "easy to understand" terms
- Emergency Action Plan
- Upgrade Program if deficient

Recommendations

Seepage & Leakage

- Monitoring Program with weirs & piezometers
- Read & Record
  - Monthly, Quarterly, Semi-Annual
- Turbidity Measurements
Recommendations

• Keep the dam crest and slopes free of trees and brush
• Prohibit man-made structures on the crest and slopes
• Mow the crest and downstream slope
• Keep the spillway and outlet obstruction-free

Recommendations

• Inspect the dam bi-annually
  – Rodents
  – Seepage
  – Slumping
  – Vegetation
  – Spillway and Outlets
• Hire an Expert Inspector Every 5 Years