Participant Guide

Session 4: Operation, Maintenance, and Safety Inspection of Dams

What Will Be Covered in Session 4

Types of dams and spillways

Functions of dams

Dam operations

Maintenance issues

Maintenance activities

Inspection activities

Session 4 Learning Objectives

Define types of dams and spillways

Define functions of dams

Conduct dam operation procedures

Conduct dam maintenance procedures

Conduct dam inspection procedures

Inspect problems associated with earthen dams

Inspect problems associated with spillway systems

Inspect problems associated with concrete dams and structures

Gain access to and participate in the NPDP program

Materials

See Session 4 Powerpoints
Refer to Appendices B & C and Owners' Manuals on the CD

Types of Dams

Concrete and Rock Masonry Dams

- Gravity dams
- Arch dams
- Arch Gravity dams
- Slab and buttress (Ambursen) dams

Many of the larger well-know dams in the United States are constructed of concrete and typically are arch dams, gravity dams, and arch gravity dams. Some of the older dams in the United States are constructed of rock masonry and typically are gravity, arch, and arch gravity dams. The slab and buttress dam, named after the first designer of such dams, was a common dam design in the late 1940's and 1950's. Many are still in use today.

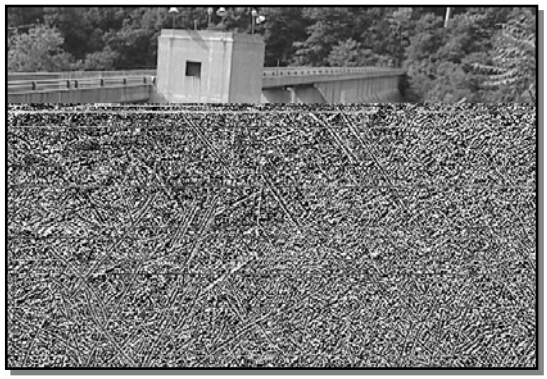
Earth and Rockfill Embankment Dams

Approximately 90 percent of all dams in the United States today are earthen embankment and rockfill embankment dams. Rockfill dams are typically designed as zoned embankments in areas where suitable soil fill materials are scarce. As such, most rockfill dams are located in the western United States.

Other Types

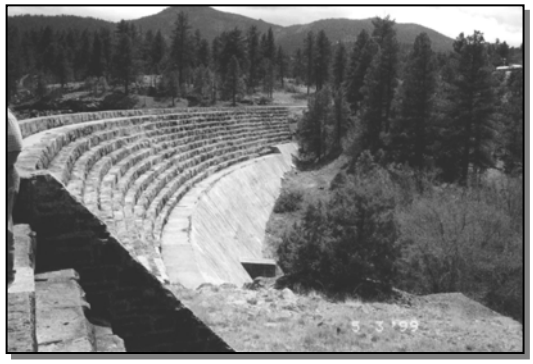
- Steel dam
- Inflatable Rubber dam
- Wood

Regardless of the type of dam, all dams must be properly operated, maintained, and inspected by owners, much the same as properly operating, maintaining, and inspecting one's residence or any other property.



Concrete Gravity Dam

Concrete Arch Dam



Masonry Dam

Concrete Buttress Dam

Earth and Rockfill Embankment Dam

Earthen Embankment Dam

Other Type: Rubber Dam

See Powerpoint Session 4 for additional examples.

Types of Spillway Systems

Types of spillway systems:

Conduit Spillway Systems

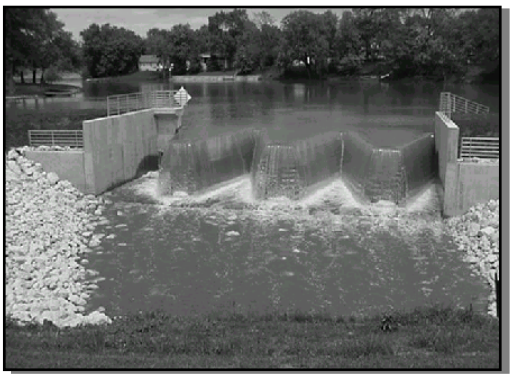
- Slanting Conduit Spillway
- Riser and Conduit Spillway
- Drop Box and Conduit Spillway
- Morning Glory Riser and Conduit Spillway

Open Channel Spillway Systems

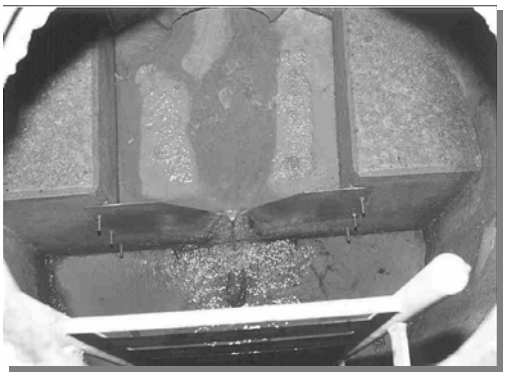
- Unlined earthen channel spillways
- Rock cut unlined channel spillways
- Concrete lined or concrete channel spillways

Concrete Weir/Spillway Systems

All open channel spillways will have some type of weir control at the inlet.



- Ogee section
- Broad-crested weir
- Sharp-crested weir
- Gated weir structures
- Drop Box Inlet
- Labyrinth



See Powerpoint Session 4 for additional examples.

Functions of Dams

Flood control

Power supply

Waste impoundment

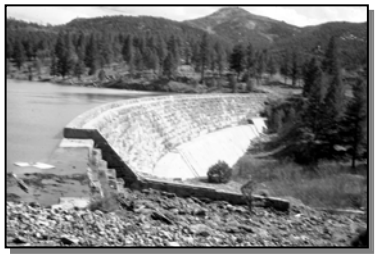
Water supply

Irrigation

Navigation

Recreation (Approximately 90 percent of all dams in the United States are recreational, or aesthetic attractions within residential developments.)

Power Supply



Water Supply

Waste Impoundment

Irrigation

The responsibility for proper operation, maintenance, and inspection of most dams falls upon private dam owner and/or homeowner associations and residential development groups. Proper operation, maintenance, and inspection of a dam is much like that of an older vehicle that is in need of extensive repair to make the vehicle desirably functional: There is usually a significant cost associated with repairing the vehicle. Once it is in good functional order the costs associated with continual proper operation, maintenance, and inspection are minimal. The better these activities are performed, the more economical these activities become, and the more efficient the vehicle becomes.

Dam Operations

An owner must:

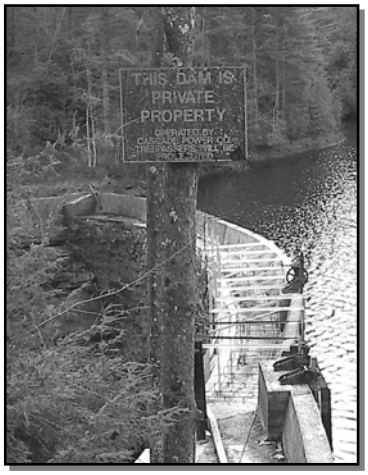
Keep good records

Perform periodic inspections

Maintain an Emergency Action Plan (EAP)

- The EAP must be updated so that all telephone numbers are kept current
- Downstream development is typically a continual activity and this activity can drastically change the contents of an EAP.

Be aware of the need for public safety

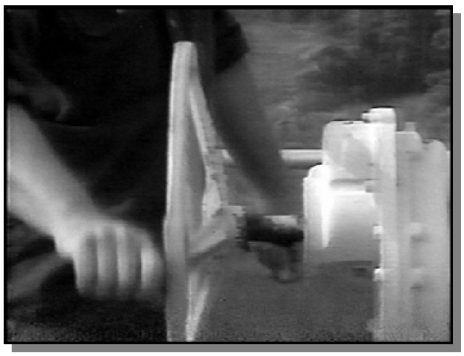


- Because dams are an attractive nuisance and can be dangerous to the public, access must be controlled.
- Proper operation for public safety includes proper warning signs, fencing, etc.

Understand Dam and Lake access control

- Dam and lake access is typically a continual concern.
- Proper operation is required to notify and monitor trespassers.

Test operation of bottom drains, siphon systems and gates/flashboards



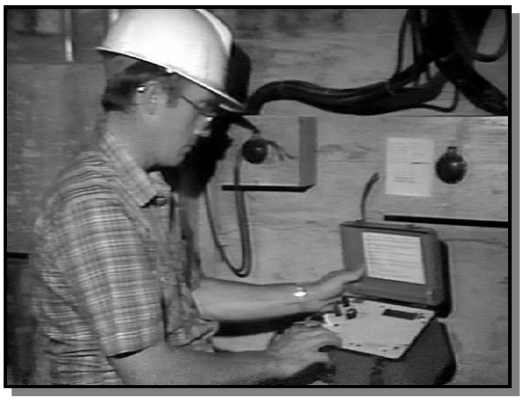
- Bottom drains, siphon systems, normal pool control gates and flashboards and other outlet control works must be operated on at least an annual basis for proper dam operation.
- If a bottom drain system is severely deteriorated, covered with lake sediment, and/or has not been operated in many years the dam owner must have this outlet system thoroughly inspected by a qualified professional engineer prior to operation.

Dam Operations (continued)

A dam owner must:

Fluctuate pool elevation: Fluctuation of normal pool elevations to control aquatic growth can be combined with the debris removal activity.

Remove floating debris: Proper dam operation involves the continual removal of floating debris that might clog outlet works and/or spillway systems.



Maintain and monitor Instrumentation Systems: Instrumentation and monitoring systems must be checked on a routine basis to collect vital data for evaluation of the performance of a dam.

Test Alarm/warning systems: Warning and/or alarm systems must be operated periodically to verify that these systems are operational.

Mitigate wildlife damage control: Undesirable wildlife that might burrow into the dam, undermine inlet and outlet works, and affect spillway systems must be controlled on a continual basis.

Dam Maintenance Factors

Factors that affect proper maintenance of dams:

1. Type of dam
2. Function of dam
3. Size of dam
4. Classification -- the higher the class the higher the standard of duty and standard of care required

And

Watershed characteristics

Characteristics of the contributing watershed, such as acidic drainage, siltation or a heavily developed watershed, can have significant impacts on the quantity of natural and man-made floating debris that can clog and/or block the following types of outlet works:

- Spillways
- Gates
- Flashboards

Spillway system characteristics

Some spillway system and trashrack designs require much greater maintenance activities than other spillway system and trashrack designs. Spillway systems and outlet works must be continually maintained to preclude reduced capacity during significant storm events.

Prevailing climatic conditions

Climactic condictions are often the most important factor affecting the level of maintenance activity. Mowing an earthen dam in the extreme northern U.S. or in the arid southwest once or twice per year may be sufficient to control woody vegetation and undesirable weed growth. Extended growing seasons in the southeastern U.S. may require that the dam owner mow a dam three or four times annually to control undesirable weed and woody vegetation growth.

Dam Maintenance Activities

A dam owner must:

- Nurture and mow grassed areas
- Remove woody vegetation
- Remove floating debris from outlet works
- Repair eroded/scoured spillways
- Control and repair wildlife damage
- Opening and closing of outlet gates to ensure operability
- Paint and repair metal components
- Grout and seal concrete joints/cracks
- Remove, repair and protect spalling concrete
- Repair embankment surface erosion
- Maintain and stabilize outlet channels
- Maintain or repair/replace warning signs
- Maintain instrumentation/monitoring systems
- Maintain upstream slope erosion protection
- Remove diseased trees on lake rim
- Remove sediment deposits at inlet
- Control and removal aquatic growth
- Maintain emergency access routes

Mowing

Repair Embankment

Remove floating debris

Remove trees & woody vegetation

Dam Inspection Activities: Embankment Sections

What to Look For:

- Stability of Embankment & Structures

- Erosion - Embankment Upstream & Downstream Slopes, Abutment Juncture, Spillways & Outlets

- Seepage - Through Dam, Abutment, Foundation, Around Structures

- Vegetal Cover - Type & Condition

- Deterioration/Cracking of Concrete Surfaces & Structures

Deep Seated Slope Failure

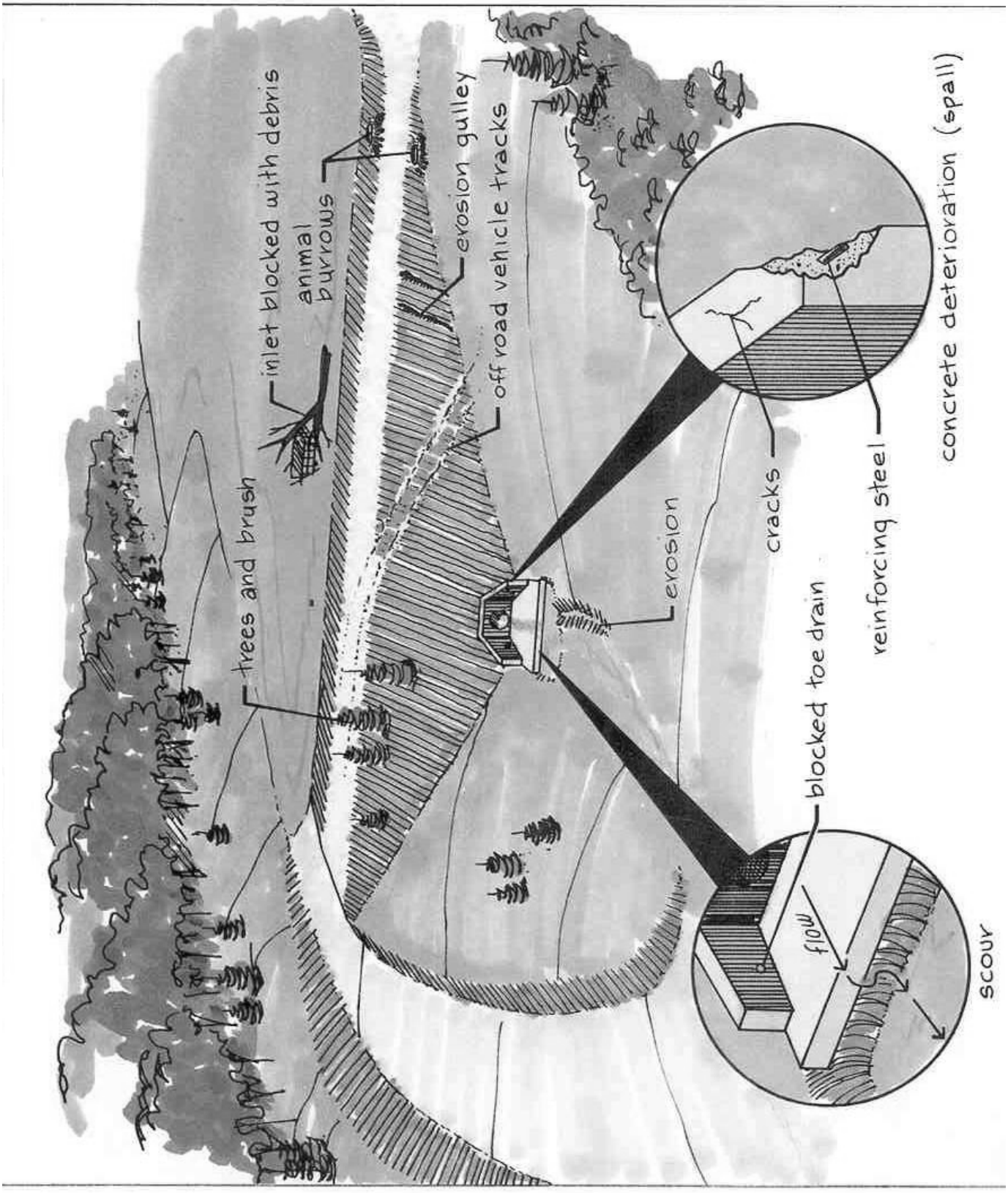
Shallow Slope Failure

Embankment/Earthen Dams

1. Embankment Slope Stability
    - Deep seated slope failures
    - Shallow or sloughing slope failures
2. Wave Erosion
3. Embankment seepage
4. Abutment seepage
5. Foundation Seepage
6. Woody vegetation growth
7. Wildlife damage
8. Sinkholes, depressions and/or dropouts
9. Sparse vegetation areas
10. Surface erosion and/or vehicular ruts

Wave Erosion

Abutment Seepage


trees and brush
inlet blocked with debris
animal burrows
erosion gulley
off road vehicle tracks
erosion
cracks
reinforcing steel
concrete deterioration (spall)
blocked toe drain
flow
scour

Piping or Boil

Wildlife Damage

Sinkhole/Dropout

Embankment Cracking

Dam Inspection Activities: Outlet Works

Outlet works materials can be made of:

1. Concrete pipes.

Weaknesses:

- Susceptible to settlement/joint misalignment
- Susceptible to cracking and spalling

Concrete

2. Metal pipes (CMP, DIP, steel pipe).

Weaknesses:

- Susceptible to corrosion
- Susceptible to deflection
- Susceptible to deflection and brittle rupture

Corrugated Metal Pipe (CMP)

3. High-density polyethylene piles.

Weaknesses:

- Susceptible to deflection (Polyvinyl chloride (PVC) pipes)
- Susceptible to weakened joints
- Susceptible to ultraviolet degradation

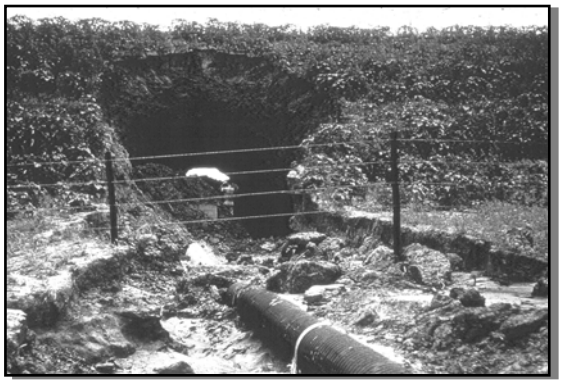
PVC Spillway Pipe

Common Conduit Spillway Problems

- Undermining of conduit outlet
- Seepage along spillway conduit
- Joint deterioration and/or separation
- Differential settlement along conduit
- Misalignment of spillway conduit
- Material deterioration

Undermining of Outlet Conduit

Outlet Conduit Deterioration



Seepage along Outlet Conduit

Joint Separation of Outlet Pipe

Common Open Channel Spillway Problems

Unlined earthen spillway channels

- Woody vegetation growth
- Erosion and scour
- Sparse and/or un-vegetated areas
- Channel slope instability
- Channel obstructions
- Wildlife damage

Unlined Earthen Channel Spillway Erosion

Unlined rock cut spillway channels

- Erosion and scour
- Misalignment
- Channel slope stability
- Channel obstructions

Deteriation of concrete and joints on concrete lined spillway channel

Concrete lined spillway channels

- Deterioration (spalling) of concrete
- Deterioration of joints and joint seals
- Undermining of concrete slabs
- Settlement and differential movement
- Lateral deflection of channel walls
- Joint separations and lateral movement
- Erosion and scour of outlet channel
- Freeze/thaw changes
- Alkali reactions
- Debris affecting concrete

Undermining of concrete slabs on concrete lined spillway channel

Concrete weir spillway structures – same problems as concrete channels

See Powerpoint Session 4 for additional examples.

Inspection of Concrete Structures

What to Look for:

1. Concrete deterioration
    - Cracking
    - Cavitation
    - Spalling
    - Efflorescence
2. Structural movements
    - Settlement
    - Lateral movements
    - Subsidence
    - Rotation
3. Seepage
    - Abutment seepage
    - Foundation seepage
4. Leakage
    - Vertical construction joints
    - Horizontal construction joints
    - Horizontal/vertical/diagonal cracks
    - Leakage water efflorescence and mineral deposits
5. Proper Operation of Gated Spillway Systems
    - Lifting devices
    - Pin connections and bolts
6. Proper Operation of Drainage Galleries and Drain Systems

Concrete Cracking

Concrete Spalling

Structural movements - lateral movement

Inspection of Concrete Dams

What to Look For:

1. Cracking - Diagonal, longitudinal, vertical or curved cracking at abutments or buttresses
2. Displacements or Offsets
3. Seepage flows at abutments or foundation
4. Drainage galleries - leakage, displacements & functioning of foundation drains
5. Efflorescence, spalling
6. Monitoring systems present & working

Drainage Galleries/Drain Systems

OM&I Resources on CD

- *OM&I Manual (Ohio Dam Safety Program)*
- *Dam Safety: An Owner's Manual (FEMA)*
- *SEED Manual (US Bureau of Reclamation)*
- *Impacts of Animals on Earthen Dams (FEMA)*
- *Impacts of Plants on Earthen Dams (FEMA)*
- *Conduits Through Embankment Dams* (FEMA)
- Internal Erosion of Earth Dams (ASDSO brochure)
- Ohio Dam Safety Fact *Sheets (*Ohio Dam Safety Program*)*
- Dam Seepage Monitoring Software *(Instructions for download and use on the CD)*
- *Best Practices: An Arkansas Example (*State of Arkansas*)*
- *Concrete Dam Inspection (*Chris Veesaert, US Bureau of Reclamation)
- *Embankment Dam Inspection* (Chris Veesaert, US Bureau of Reclamation)