Participant's Guide

Session 3: Dam Failure Modes and Case Histories

What Will Be Covered in Session 3

- Circumstances that can cause your dam to fail
- How to gain access to the five-day forecast information from the National Weather Service web site
- The many ways a dam can fail
- Case histories of small dam failures
- Recognizing that properly maintained dams are less likely to fail

Session 3 Learning Objectives

- Recognize circumstances and ways a dam can failure
- Gain access to the five-day forecast information from the National Weather Service web site
- Recognize that dams do fail if not properly maintained

Materials

- See Session 3 Powerpoints
- Video: ***Dam Failure Case Histories***

Circumstances that Cause Dams to Fail

Failure often occurs due to a combination of factors, i.e. inadequate design (spillway capacity) combined with an extreme event (rainfall).

1. **Extreme Events**

    a. Rainfall
    b. Wind
    c. Earthquakes

2. **Inadequate Design**

3. **Poor Operation or Maintenance**

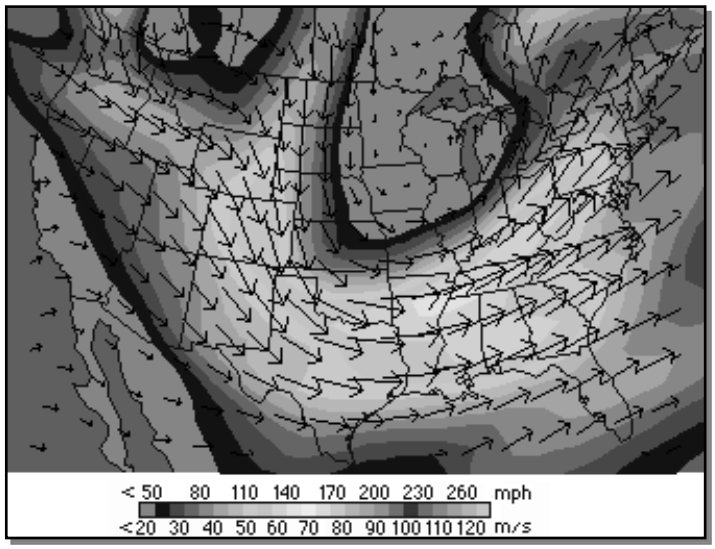
4. **Vandalism**

1. Extreme Events: Rainfall and Wind

Jet Stream Configurations

A. Troughs – or bending – in the *jet stream* originating from low barometric pressure systems extending from the north produce storms.

- The normal or undisturbed jet stream is the high altitude flow of air from west to east near the U.S. - Canadian border.
- Deep troughs in the normal jet stream are caused by low barometric pressure systems extending down from the Arctic or northern Canada.



Typical Jet Stream Configuration

- Troughs in the jet stream typically contain eastward-moving low-pressure systems that rotate counterclockwise, creating intense storms.

B. High-intensity storm cells embedded in major low pressure storm systems

- The most problematic condition for extreme storm events is associated with embedded storm cells within otherwise normal widespread storm systems.
- Embedded storm cells are often the cause of catastrophic tornadoes and localized extreme rainfall storm events.

Trough weather pattern

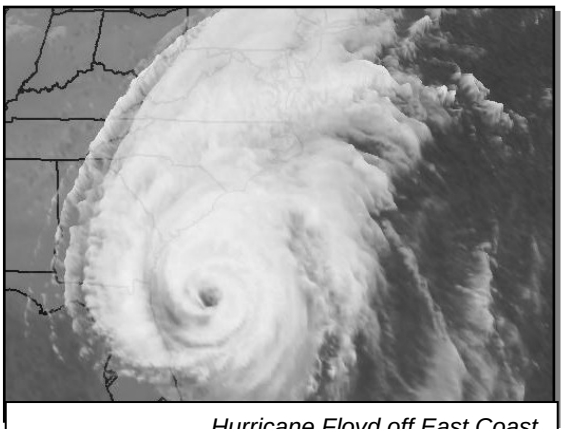
C. Topography can induce local storm events

- Topographic characteristics of the terrain that major storm systems travel across can cause extremely unusual precipitation.
- Wind currents from major storm systems can be disturbed in mountainous areas, producing extreme rainfall amounts.
- There are countless case histories of “Water Spout” in mountainous regions where embedded storm cells cause extraordinary amounts of rainfall in localized areas.

Tropical and Sub-tropical Storm Systems

Tropical depressions can create storm systems.

- Tropical and sub-tropical storm systems originate as low barometric pressure waves that typically travel from east to west across the Caribbean, south Atlantic Oceans and the Gulf of Mexico.
- Low-pressure waves gather strength and moisture in their typically westward movement across the warm waters of the tropical and sub-tropical seas.



Hurricane Floyd off East Coast

Hurricanes are fast moving.

- Hurricanes are relatively short-lived as a result of the typical fast moving center of the storm.
- Hurricanes typically produce more wind damage with extreme short-term rainfalls.

Tropical storms are slow moving.

- Once hurricanes and tropical storms have been downgraded to tropical depressions there is even more danger of extreme storm events because of the slow moving nature of these storm systems.
- These storm systems can produce extreme amounts of rainfall over broad areas in both short and long periods of time.

Embedded storm cells produce extreme localized rainfall.

- Tropical and sub-tropical storm systems typically contain embedded cells of even more severe or extreme storms.
- Embedded cells usually produce extreme rainfall amounts over relatively small or localized areas.
- Embedded cells can affect dams in relatively small watersheds while being totally unnoticed in adjacent watersheds.

Combined Weather Systems

A deep low pressure trough in the jet stream coupled with a tropical storm or a tropical depression equals the “Perfect Storm.”

- The possibility of this condition is real as evidenced by recent climatological records.
- A movie made about this very phenomenon that occurred along the northeast coast of the United States.
- An extreme storm system within a deep trough of the jet stream collides head-on with an extreme tropical storm system churning off the northeast coast creating the most extreme storm known in recent climatological history.

This situation could occur almost anywhere within the eastern United States, particularly during the hurricane season (June through October).

Precipitation Data and Flood Forecasting Resources for Dam Owners

Go to the National Oceanic and Atmospheric Agency (NOAA) website for Extreme Storm Event Data and Flood Forecast data via the internet.

National Weather Service and NOAA web sites:

https://hdsc.nws.noaa.gov/pfds/

This site:

- Provides precipitation frequency data for selected areas of the United States
- Provides partial duration and annual maximum rainfall data for selected locations
- Provides frequency based data for selected durations

At this site dam owners can:

- View the rainfall data for the location of their dam based on latitude and longitude.
- Look at the five-day outlook, which should be sufficient to allow owners to operate their dams most efficiently to reduce the potential for downstream flooding, overtopping of dams, and possible dam failure.

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This site:

- Provides Probable Maximum Precipitation (PMP) information for the United States

At this site dam owners can:

- Download PMP Studies for the New Mexico (HMR 49 and HMR 55A)

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This site:

- Provides a five-day forecast
- Asseses risk of significant flooding
- Covers 13 river systems in the United States

At this site dam owners can:

- View the web data to determine if major storm systems are likely to produce a risk of significant river flooding in their area.
- Look at the five-day outlook, which should be sufficient to allow owners to operate their dams most efficiently to reduce the potential for downstream flooding, overtopping of dams, and possible dam failure.

1. Extreme Events: Earthquakes

Earthquakes occur frequently and extreme earthquakes are catastrophic and can result in failure by:

- large slides in earthen or rock fill structures
- liquefaction
- structural failure of appurtenances.

Top Earthquake States

2. Inadequate Design

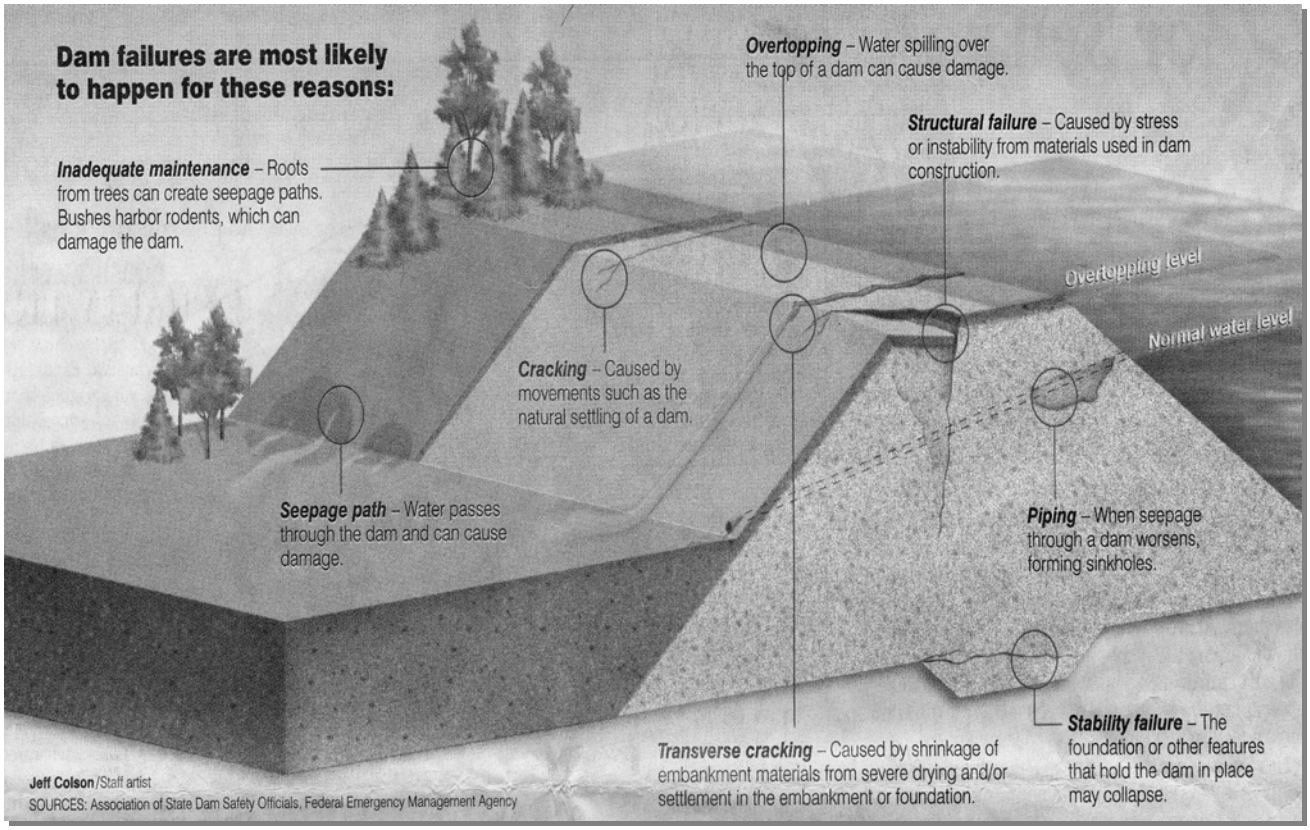
- Sizing of spillways and or appurtenances
- Stability of slopes and appurtenances
- Control of seepage and pore pressures

3. Poor Operation or Maintenance

- Inoperable gates unusable in emergency
- Bad maintenance of embankment surfaces cause erosion or uprooting of trees
- Blocked spillways
- Plugged drains

4. Vandalism

The Many Ways a Dam Can Failure



The Many Ways a Dam Can Fail

1. Inadequate Design: Spillway Capacity that results in Embankment and/or Structural Overtopping

   - Overtopping of earthen dams is likely the greatest cause of earthen dam failure during extreme storm events.
   - Earthen dam embankments typically cannot resist erosion created by high velocity flows during significant overtopping.

Overtopping

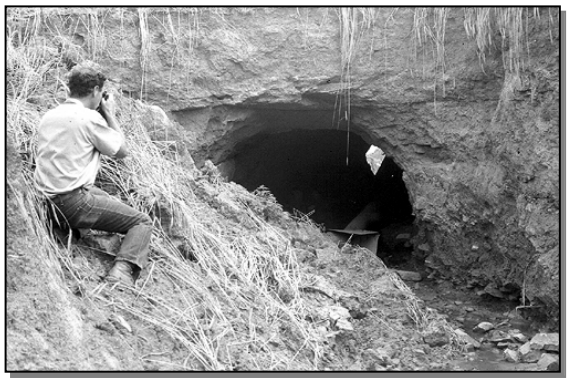
2. Spillway scour

   - Auxiliary and primary spillway systems are always subject to scour during sustained extreme discharge flows.
   - Scour and erosion of these structures can *back cut* upstream through the dam or abutment, resulting in a breach failure.

Spillway Scour

3. Internal erosion along conduits

   - Excess hydrostatic head can increase the seepage velocity along conduits through dams thus initiating and/or increasing internal erosion adjacent to dam conduit systems.



Internal erosion along conduit

4. Structural failure of inlet and outlet works

- Increased loading associated with higher water levels during extreme storm events can cause failure of inlet and outlet works that control the rate of floodwater release.
- Failure of appurtenant structures alters the controlled release of floodwater and can result in excessive scour and erosion of other portions of the dam.
- Only a few of the mechanisms of dam failure can occur during extreme storm events.

Structural Failure of Outlet Works

5. Erosion from uprooting of trees and woody vegetation

- Extreme storm events typically have associated high winds that can cause 'blow-down' and uprooting of large trees penetrating earthen dam embankments and abutments.
- Cavities left from *rootball extraction* can expose localized seepage through embankments that can result in internal erosion of the embankment.

Erosion from Uprooting of trees

6. Structural failure of embankment or abutment:

- Higher than normal pool levels and/or plugged embankment drains can increase seepage pressure and rates.
- Wave action from strong winds can cause severe upstream slope erosion.
- Earthquake loading and/or liquefaction caused by earthquake can cause failure of the embankment, appurtenant structures, foundations.

Structural failure of embankment

- Vandalism can cause extensive damage to structures and result in failure of the dam immediately or later during an extreme event

No Dam Owner is Exempt!

- Extreme storm events do occur!
- Dam failures do happen!
- No dam owner is exempt!