Iowa Department of Natural Resources

Leading Iowans in caring for our natural resources

How Dams Fail and Proper Dam Maintenance

Meeting Logistics

- All lines are muted
- We will have several Q&A breaks
- Can ask a question at any time using the Question box.
- Meeting is being recorded and can be watched at a later time.
- Meeting slides and other resources are available for download in handout section.
  - Handout with links to other resources
  - When a permit is needed
  - How to apply for a permit
  - Dam Maintenance Manual
  - Copy of today's PowerPoint slides

Webinar Series

- **May 6: Dams 101 and DNR Dam Safety Program**
  - Learn about how dams work, what are the critical parts and features, and how they are regulated in Iowa.
- **May 13: How Dams Fail and How to Properly Maintain Your Dam.**
  - Learn about common ways that dams fail and how proper maintenance can reduce the risk of failure.
- **May 20: Dam Ownership, When and How to Hire an Engineer**
  - When do you need to call in an expert? We'll discuss when and how to find and hire qualified engineers to help with repairs and design of dams.
- **May 27: Dam Design and Permitting**
  - This webinar will go into technical engineering design requirements and what's needed to obtain a permit. We will also discuss upcoming changes to Iowa's dam safety administrative rules.

Introductions

Jonathan Garton, P.E.

- Jonathan.Garton@dnr.iowa.gov
- 515-725-8360

Casey Welty, P.E.

- Casey.Welty@dnr.iowa.gov
- 515-725-8330

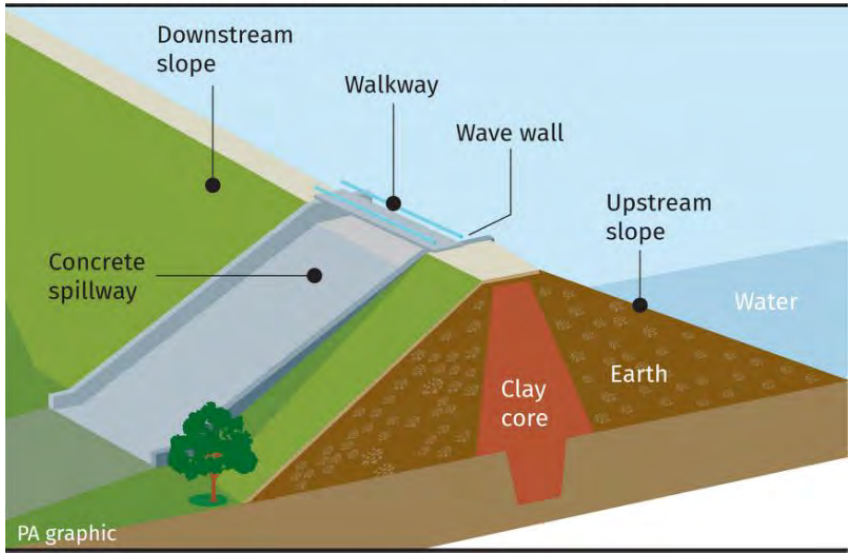
Presentation Outline

- Recap of Dams 101
- Primary causes of dam failures
- Examples of dam failures
- Inspection by owners
- Proper dam maintenance
- Required dam repairs
- Dam emergencies

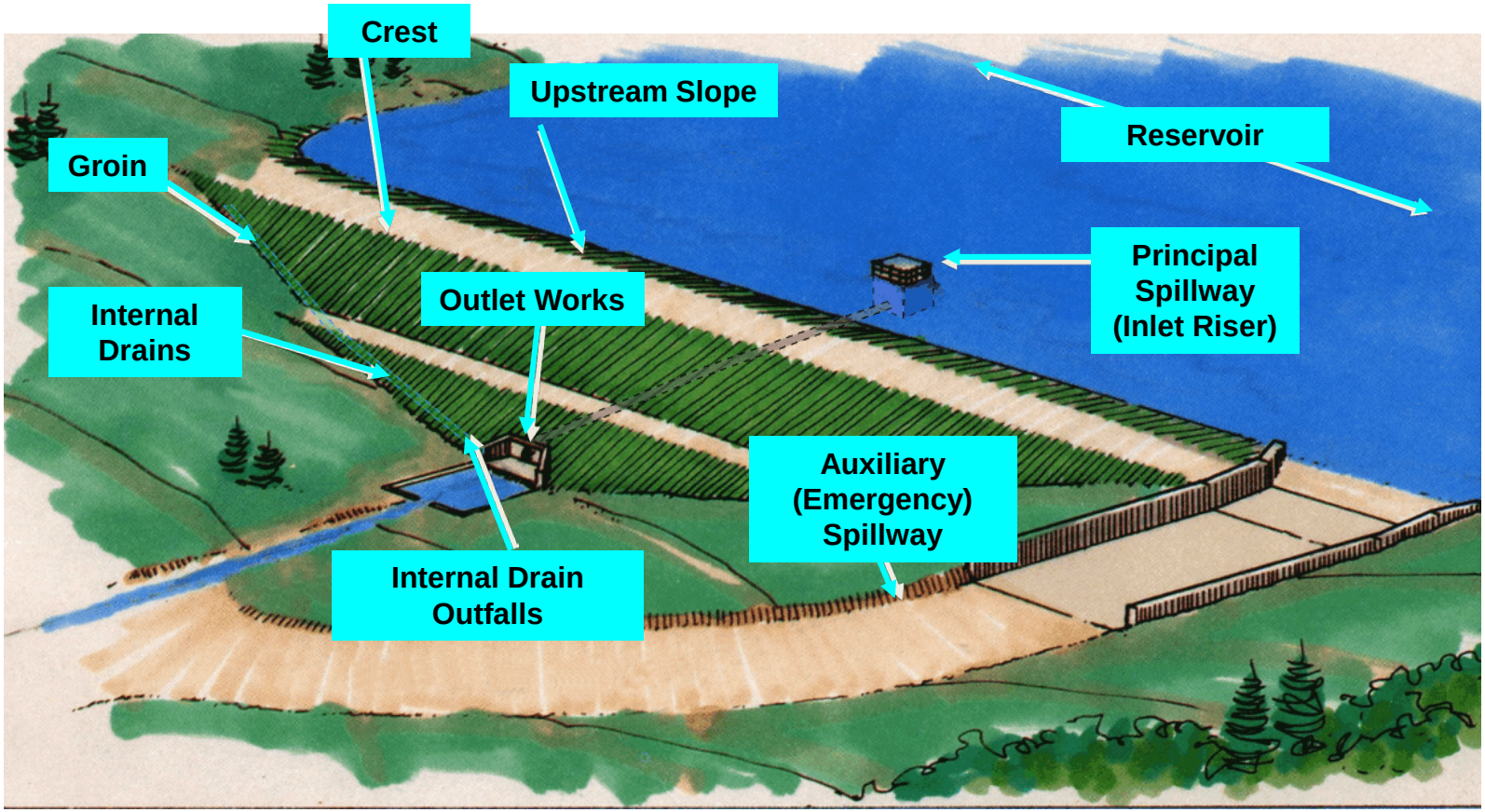
How do dams work?

- Safely Hold Water
  - Clay soil embankments or concrete structures
  - Good foundation and abutment conditions or cutoffs
  - Internal drainage for embankment stability
- Safely Pass Extra Water
  - Spillways
  - Outlet works

Earth embankment dam: key features

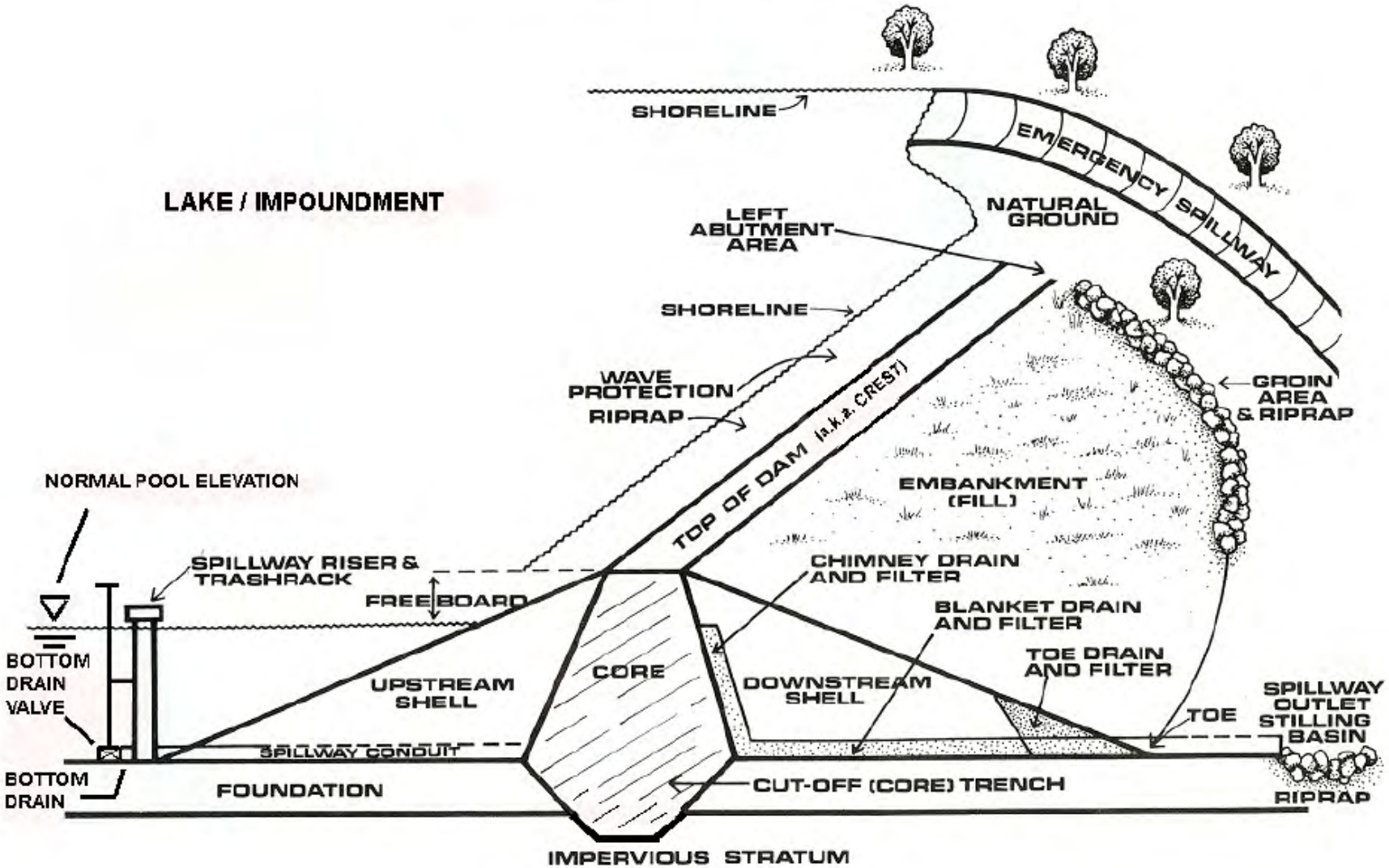


Parts of an Embankment Dam



PARTS OF AN EARTH DAM

(SEE GLOSSARY FOR TERM DEFINITIONS)



How do Dams Fail?

- Inadequate Spillway Capacity/Overtopping
- Spillway scour
- Internal erosion along conduits
- Piping from rodent burrows
- Structural Failure of Inlet or Outlet Works
- Erosion from Uprooting of Trees and Woody Vegetation
- Wave Erosion
- Liquefaction

Why are Dam Failures of Concern?

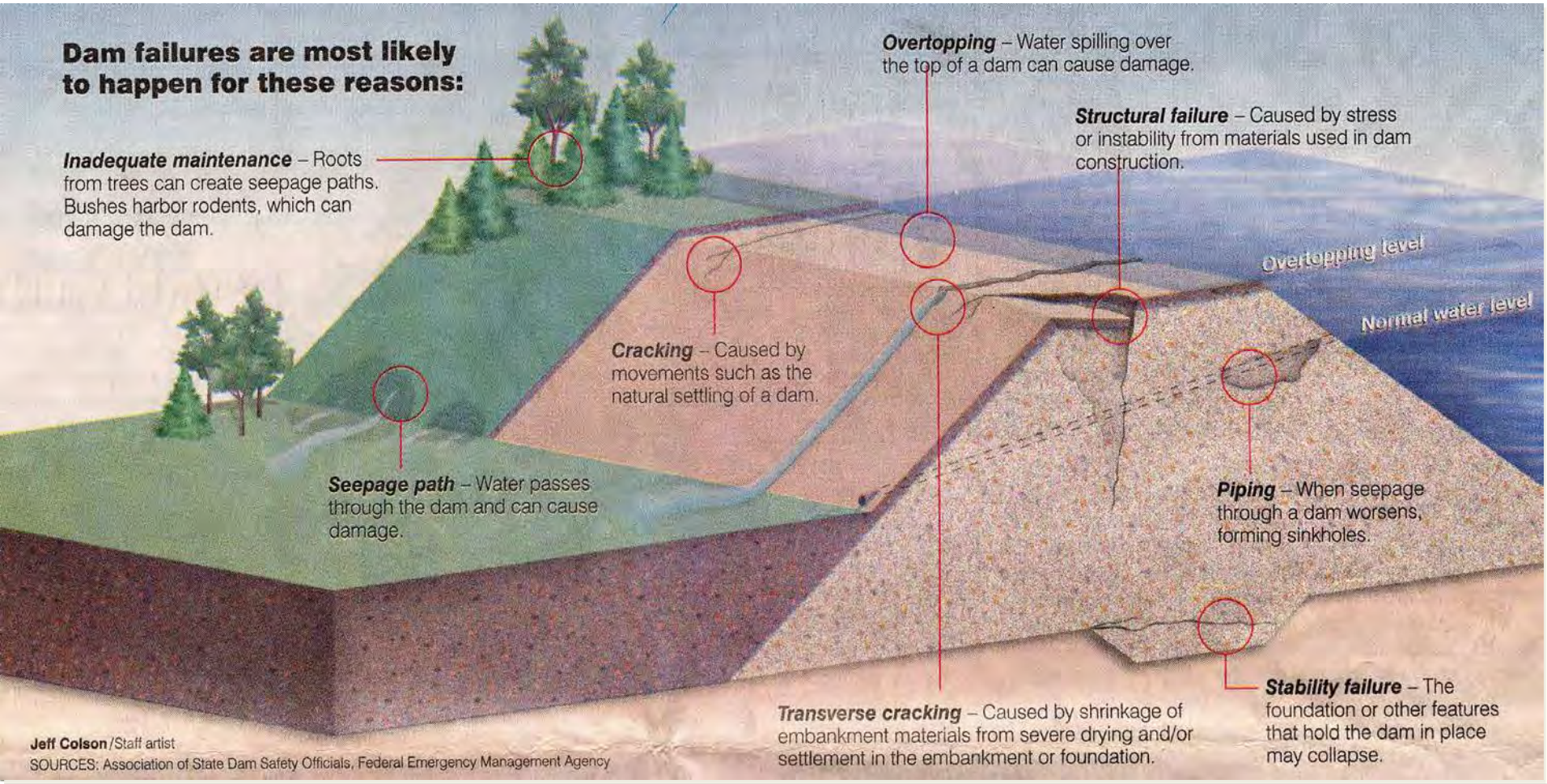
- Loss of Life
- Property Damage
- Environmental Impact
- Loss of Use
- Repair Costs

Potential Loss of Life

Property Damage

Loss of Reservoir Use

Anatomy of a Dam Failure:
The most common causes of dam failures



Causes of Failure

- Dam Overtopping
  - Clogged spillway
  - Inadequate capacity for rainfall event
    - Low hazard dams typically designed for 50 year flood
  - Overtopping causes downstream embankment to erode leading to a potential breach of the dam.

Embankment Failure by Overtopping

Damage Caused by Embankment Overtopping

Overtopping Dam Failure Animation

Causes of Failure

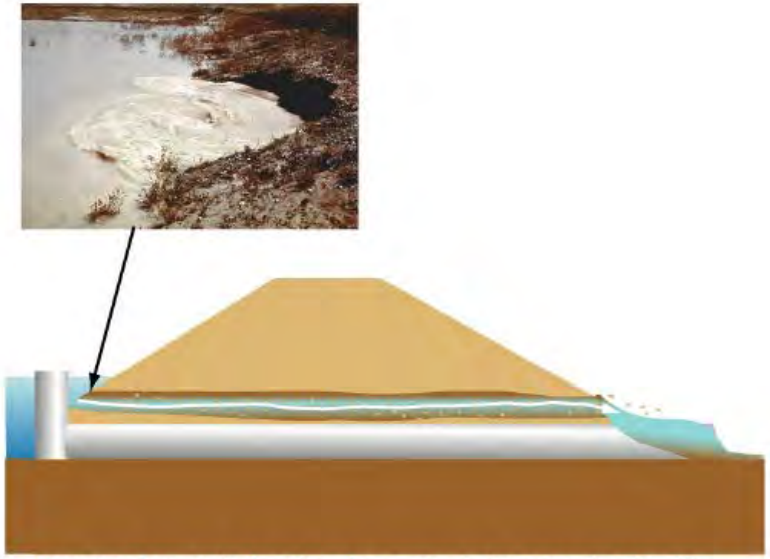
- Seepage through the dam
  - Also called “Piping” or “Internal Erosion”
  - Water finds a weak point, begins to transport soil, flow increases
    - Poor compaction
    - Poor foundation conditions and cutoff
    - Improperly designed penetrations through the dam (conduits or utilities)

Seepage

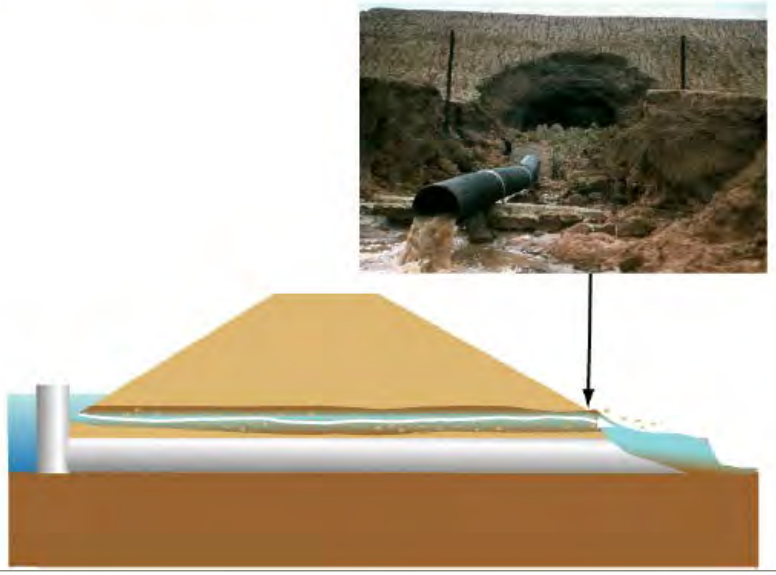
Internal Erosion

Water from the reservoir penetrates the hydraulic fracture, initiating internal erosion of the side walls of the fracture.

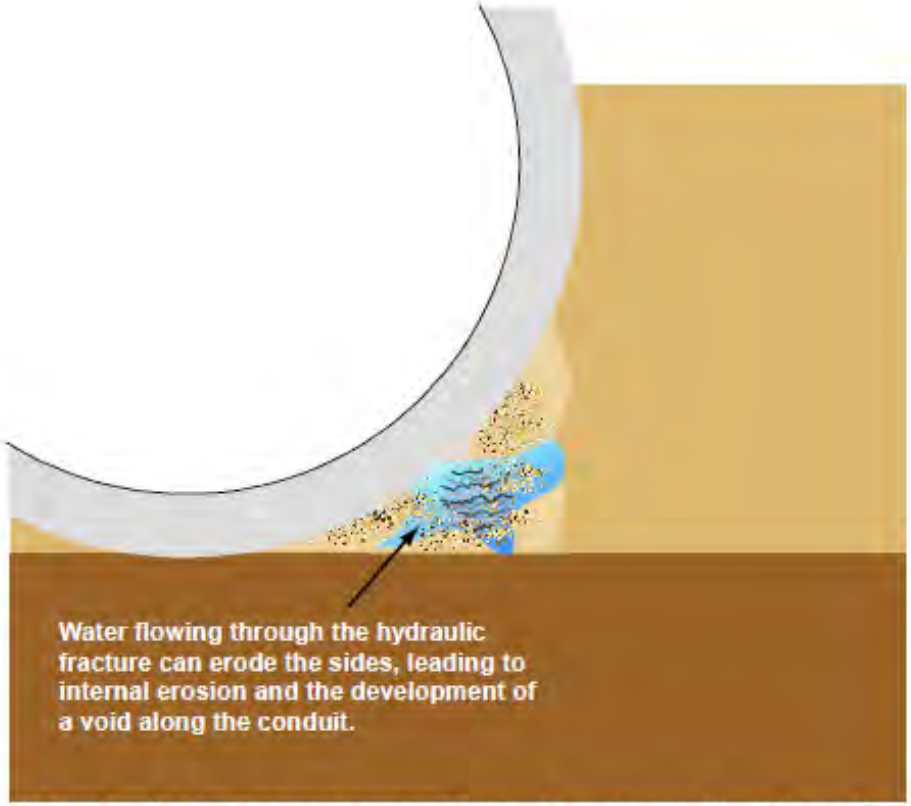
The internal erosion process continues as water flowing in the hydraulic fracture widens the walls of the fracture. Intergranular seepage is not involved in the process, and the soils surrounding the fracture are unsaturated. Intergranular seepage rarely has time to develop, since this type of failure occurs most frequently on first filling of the reservoir.



A vortex may form at the location where water in the reservoir enters the upstream end of the hydraulic fracture.



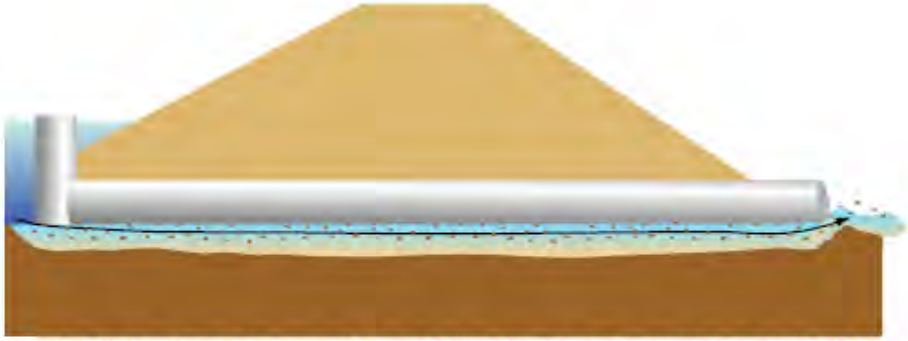
Internal Erosion along a pipe



The hydraulic fracture can propagate in a downstream direction and initiate flowing water from the reservoir.

Internal Erosion along a pipe

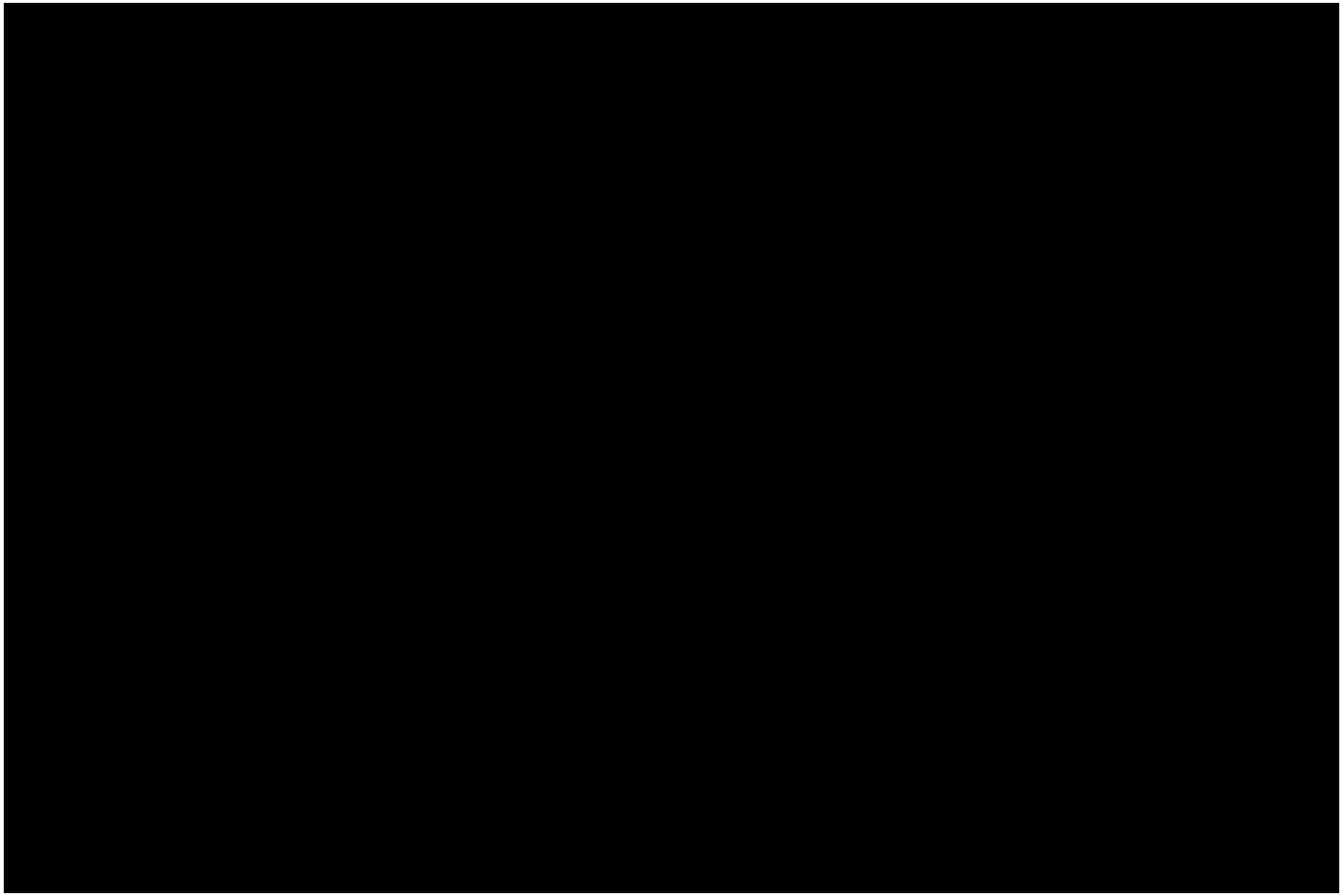
Water from the reservoir penetrates the hydraulic fracture, initiating internal erosion of the side walls.



Flowing water from the reservoir continues the internal erosion process within the hydraulic fracture. Intergranular seepage is not necessarily involved in this process, and the embankment materials surrounding the void may be unsaturated.

Internal Erosion

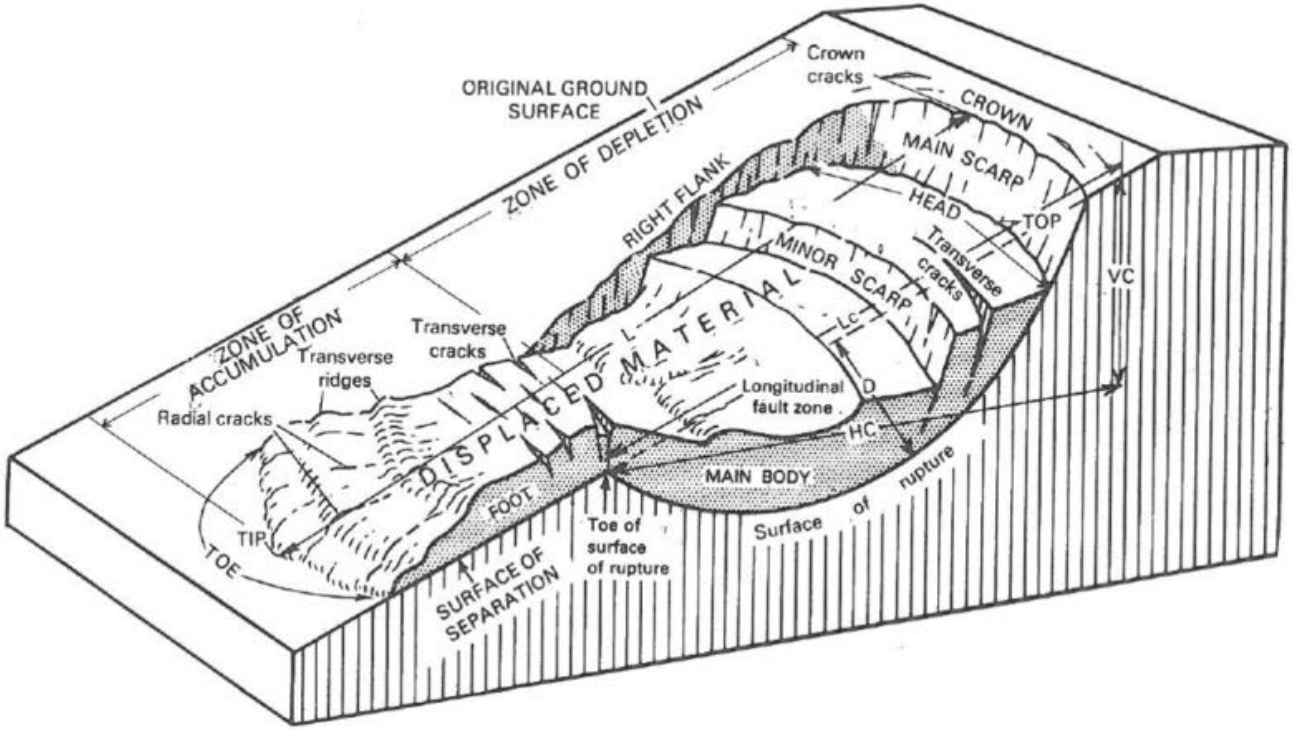
Piping Failure Animation



Causes of Failure

- Embankment slides
  - Soils loose strength as they become saturated
    - Saturation of slope due to excessive rainfall
    - Saturation of slope due to excessive seepage
  - Steepness of slope beyond stable design
  - Large trees blowing over opening voids

Embankment Slide



Embankment Slide

Embankment Slide

Causes of Failure

- Structural Failure
  - Spillway deterioration
    - Pipe rusting through
    - Concrete cracking and deterioration
    - Concrete spillway chute undermining
  - Concrete dam deterioration

Spillway Deterioration

Spillway Deterioration

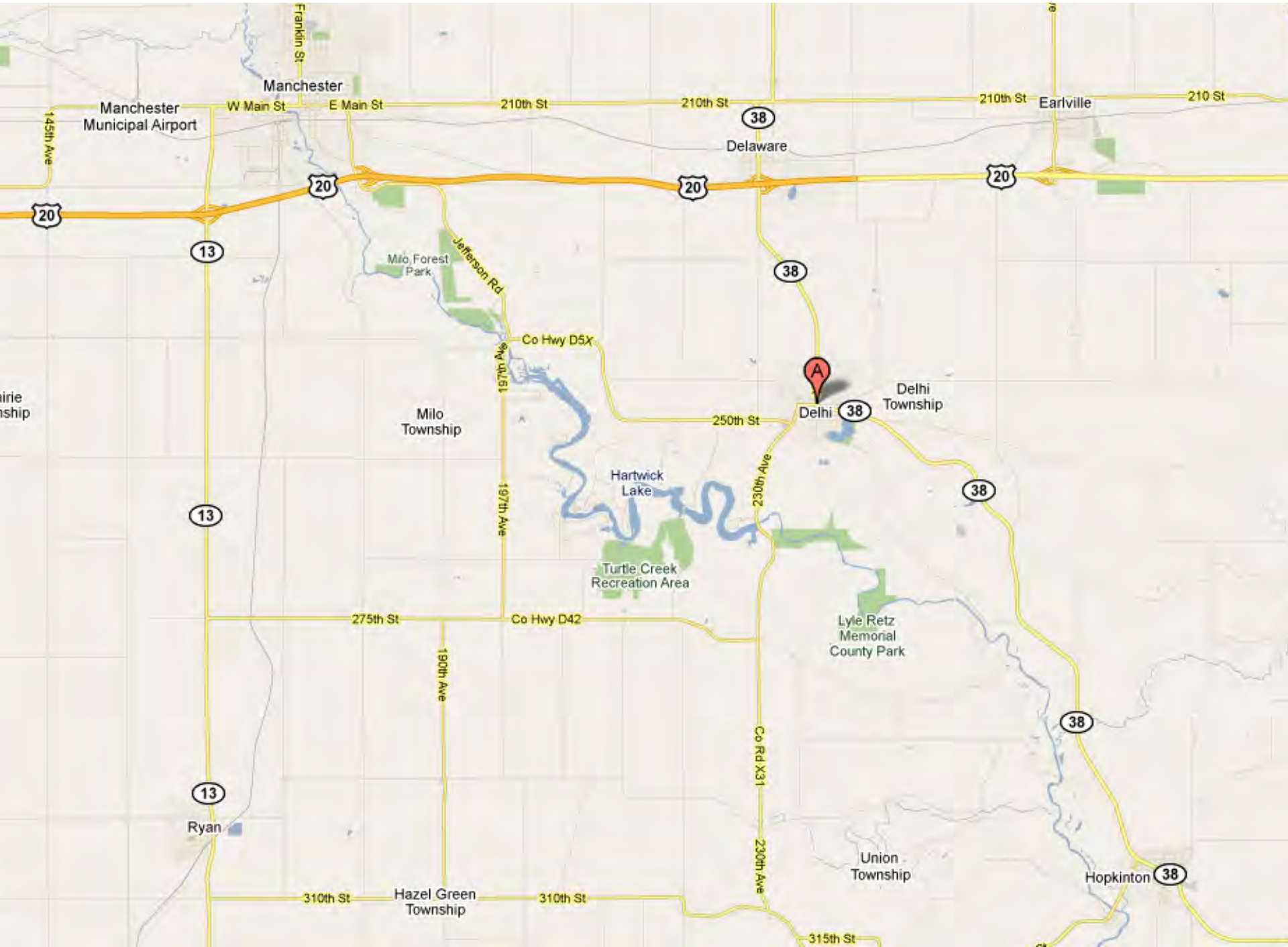
Spillway Deterioration

Question Break

Case Studies

Lake Delhi: 2010

Lake Delhi


Franklin St
Manchester
Manchester Municipal Airport
W Main St
E Main St
210th St
210th St
210th St
Earlville
210 St
145th Ave
38
Delaware
20
20
20
20
13
Milo Forest Park
Jefferson Rd
38
Co Hwy D5X
197th Ave
A
Delhi Township
Milo Township
250th St
Delhi
38
Hartwick Lake
230th Ave
38
13
197th Ave
Turtle Creek Recreation Area
275th St
Co Hwy D42
Lyle Retz Memorial County Park
190th Ave
38
Co Rd X31
13
Ryan
230th Ave
Union Township
Hopkinton
38
310th St
Hazel Green Township
310th St
315th St

Lake Delhi

- Originally constructed in 1927 by Interstate Power Company for Hydroelectric purposes.
- At normal stage the dam held an estimated 3790 acre-feet of water. An estimated 9920 acre-feet of water was stored when the water began to overtop the dam.
- 58 feet high.
- 9 mile long impoundment
- Hydro production ceased in 1973 and dam was sold to Lake Delhi Recreation Association.

Lake Delhi Regulatory History

- Permitted by Iowa Natural Resources Council in 1973
- Required to submit inspection performed by professional engineer every 5 years.
- DNR inspected every 5 years.

2009 Lake Delhi DNR Inspection

- Erosion on upstream water line
  - Being repaired at time of inspection with new riprap
- Left gate could not be opened beyond 8 feet due to concrete deterioration
  - Repair plans were underway
- Trees and brush on downstream slope
  - Never addressed

Upstream Slope

Downstream Slope

Leak through concrete around gate

Concrete damage

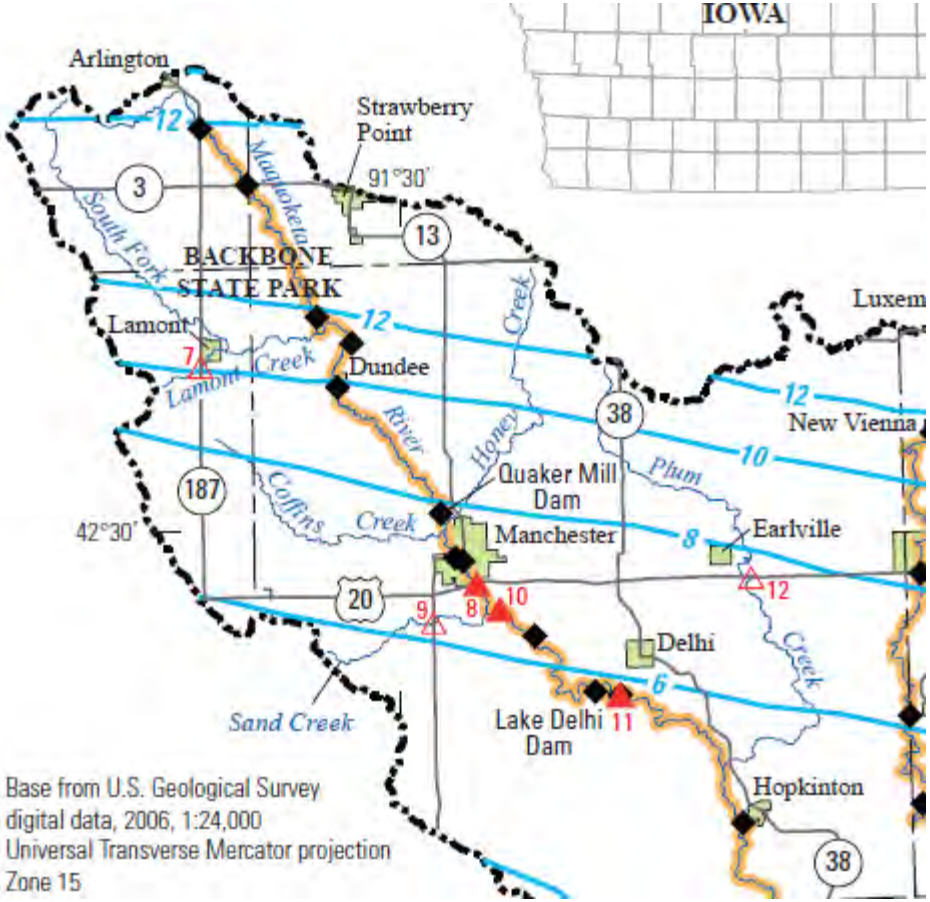
General Timeline of Failure July 23-25, 2010

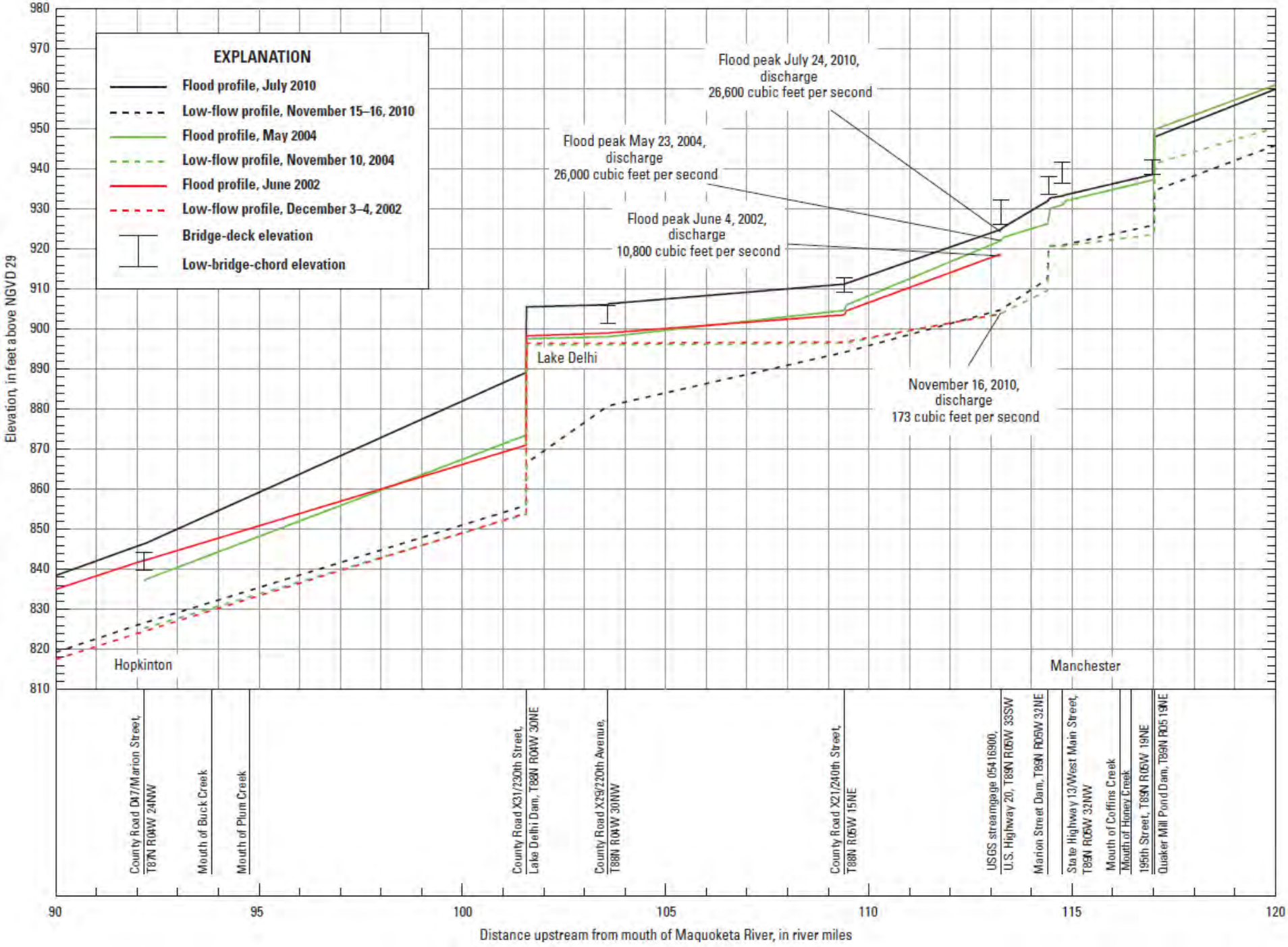
- Heavy Rains in the watershed causes increase in river flows.
- Thursday night: First flood gate needed to be opened partially.
- Throughout Friday: Gates were increasingly opened to maintain normal pool.
- Friday evening: Gates were raised as far as they could go.
- 08:00pm Mike Ryan receives new notice from the Weather Service 11-14 inches predicted over next 48 hours
- Saturday about 3:00 am: Whirlpool and roadway settlement discovered on south end of dam.
- 5:30 am: 6 foot x 2 foot sinkhole on upstream slope
- Saturday 6:00 am: Boil discovered on downstream side. Piping and internal erosion confirmed.

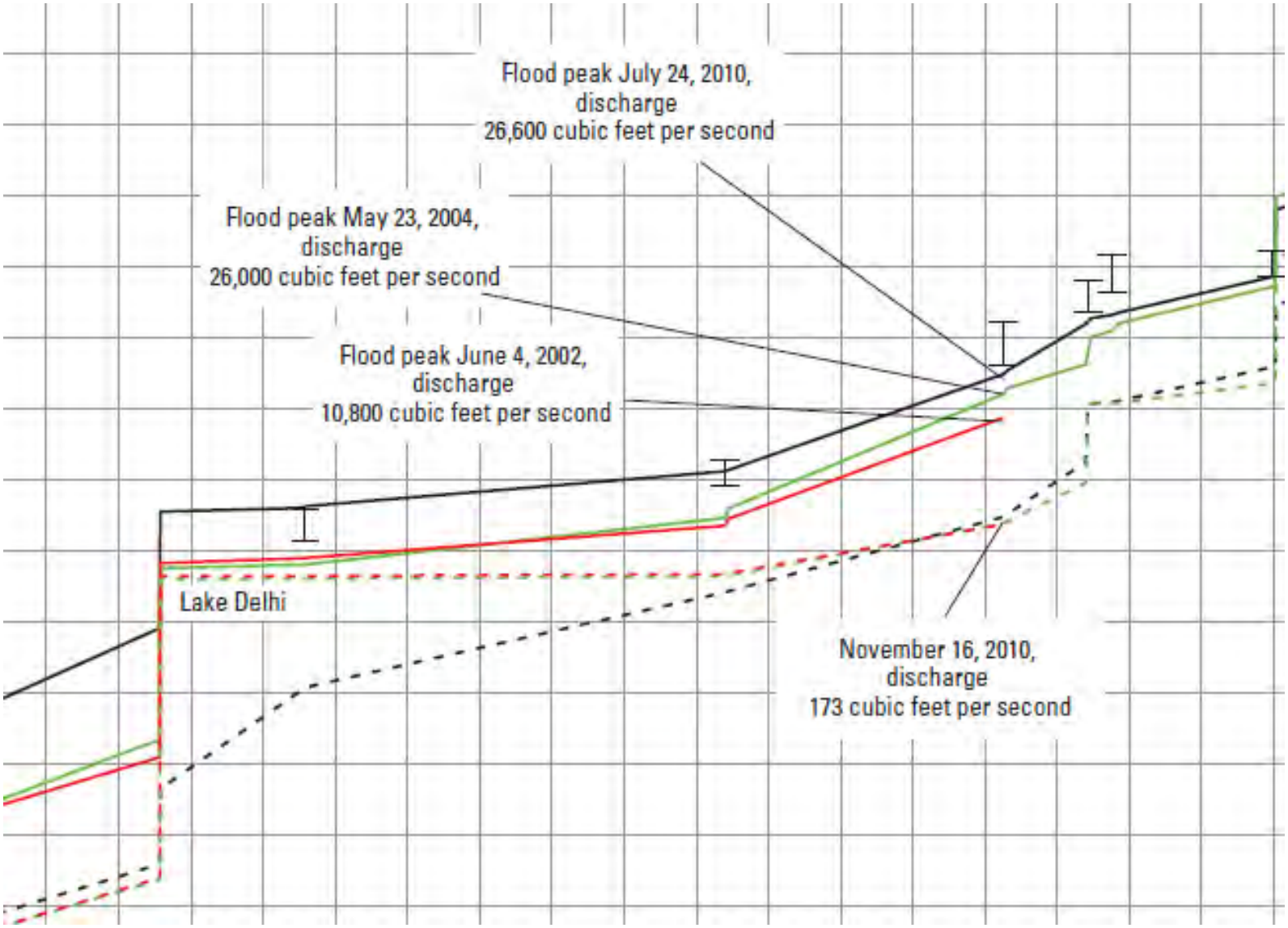
General Timeline of Failure July 23-25, 2010

- Saturday 8:00 am: Dam evacuated, no further work to open gate or mitigate internal erosion.
- Saturday 10:30 am: Dam begins to overtop.
- Saturday 1:00 pm: Dam fully breached.

Rainfall


IOWA
Arlington
Strawberry Point
91°30'
Maquoketa
South Fork
BACKBONE STATE PARK
Lamont
Lamont Creek
Dundee
River
Honey Creek
Luxem
New Vienna
Plum
Quaker Mill Dam
Coffins Creek
Manchester
Earlville
42°30'
Delhi
Creek
Sand Creek
Lake Delhi Dam
Hopkinton
12
10
8
6
3
13
38
187
20
7
8
9
10
11
12
Base from U.S. Geological Survey
digital data, 2006, 1:24,000
Universal Transverse Mercator projection
Zone 15


EXPLANATION
Flood profile, July 2010
Low-flow profile, November 15–16, 2010
Flood profile, May 2004
Low-flow profile, November 10, 2004
Flood profile, June 2002
Low-flow profile, December 3–4, 2002
Bridge-deck elevation
Low-bridge-chord elevation
Flood peak July 24, 2010, discharge 26,600 cubic feet per second
Flood peak May 23, 2004, discharge 26,000 cubic feet per second
Flood peak June 4, 2002, discharge 10,800 cubic feet per second
November 16, 2010, discharge 173 cubic feet per second
Lake Delhi
Hopkinton
Manchester
Elevation, in feet above NGVD 29
980
970
960
950
940
930
920
910
900
890
880
870
860
850
840
830
820
810
County Road D17/Marion Street, T87N R04W 24NW
Mouth of Buck Creek
Mouth of Plum Creek
County Road X31/230th Street, Lake Delhi Dam, T88N R04W 30NE
County Road X29/220th Avenue, T88N R04W 30NW
County Road X21/240th Street, T88N R05W 15NE
USGS streamgage 05416900, U.S. Highway 20, T89N R05W 33SW
Marion Street Dam, T89N R05W 32NE
State Highway 13/West Main Street, T89N R05W 32NW
Mouth of Coffins Creek
Mouth of Honey Creek
195th Street, T89N R05W 19NE
Quaker Mill Pond Dam, T89N R05 19NE
90
95
100
105
110
115
120
Distance upstream from mouth of Maquoketa River, in river miles


Flood peak July 24, 2010,
discharge
26,600 cubic feet per second
Flood peak May 23, 2004,
discharge
26,000 cubic feet per second
Flood peak June 4, 2002,
discharge
10,800 cubic feet per second
Lake Delhi
November 16, 2010,
discharge
173 cubic feet per second

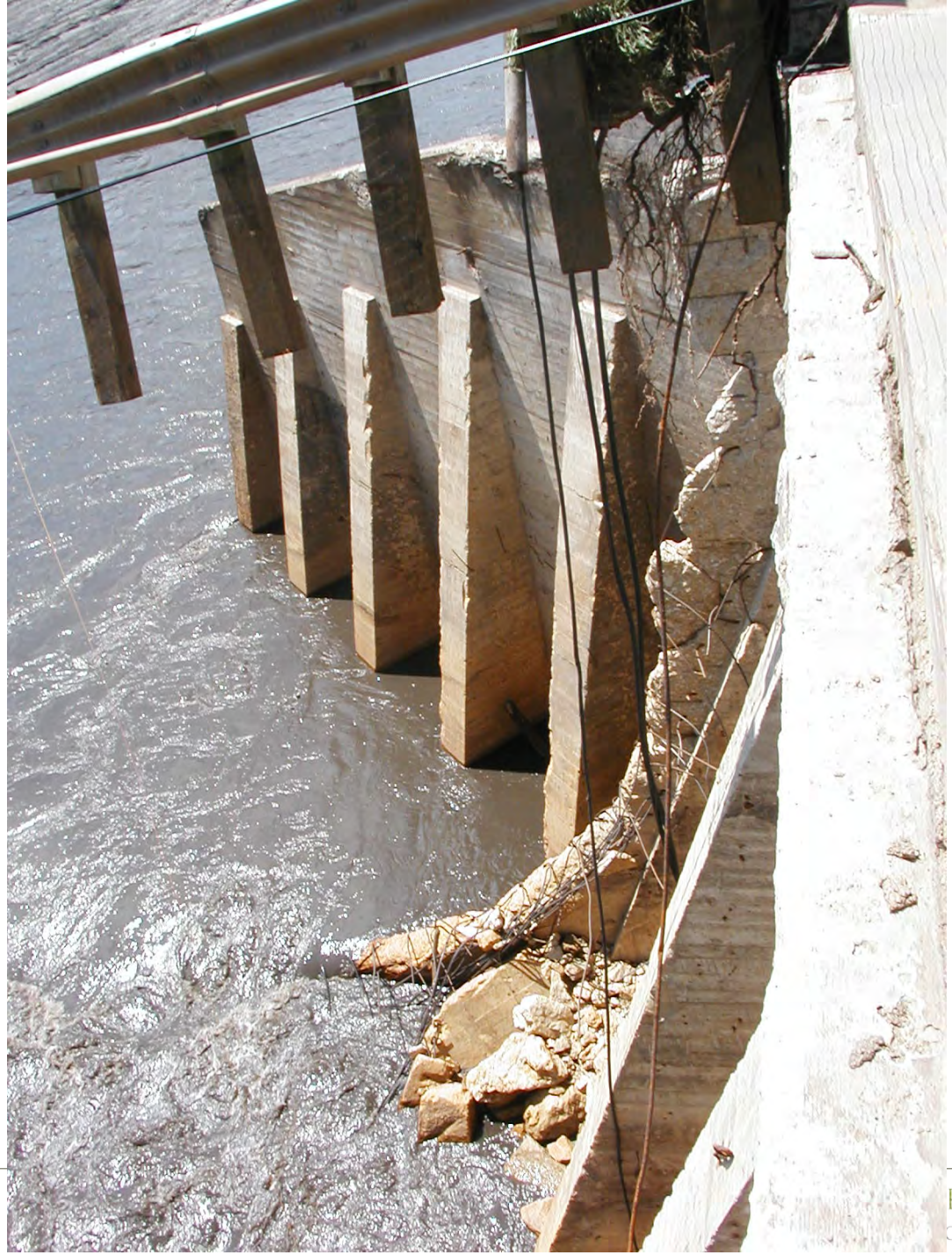
Manchester Flooding

Flooding at Lake Delhi

THIS DAM IS THE
PROPERTY OF
LAKE DELSI
RECREATION
ASSOCIATION

THE DAM IS THE
PROPERTY OF
LAKE DELHI
RECREATION
ASSOCIATION

Photo II-3



Dam Failure Investigation Setup

- Dam Safety Community reached out to Iowa
- Scope
  - Review the operational characteristics of the project leading up to the breach of the upper reservoir.
  - Perform an evaluation of the breach of the dam to determine the specific failure mode.
  - Submit a final report documenting the results of their findings on the cause of the breach of the upper reservoir and the important lessons learned.

Team

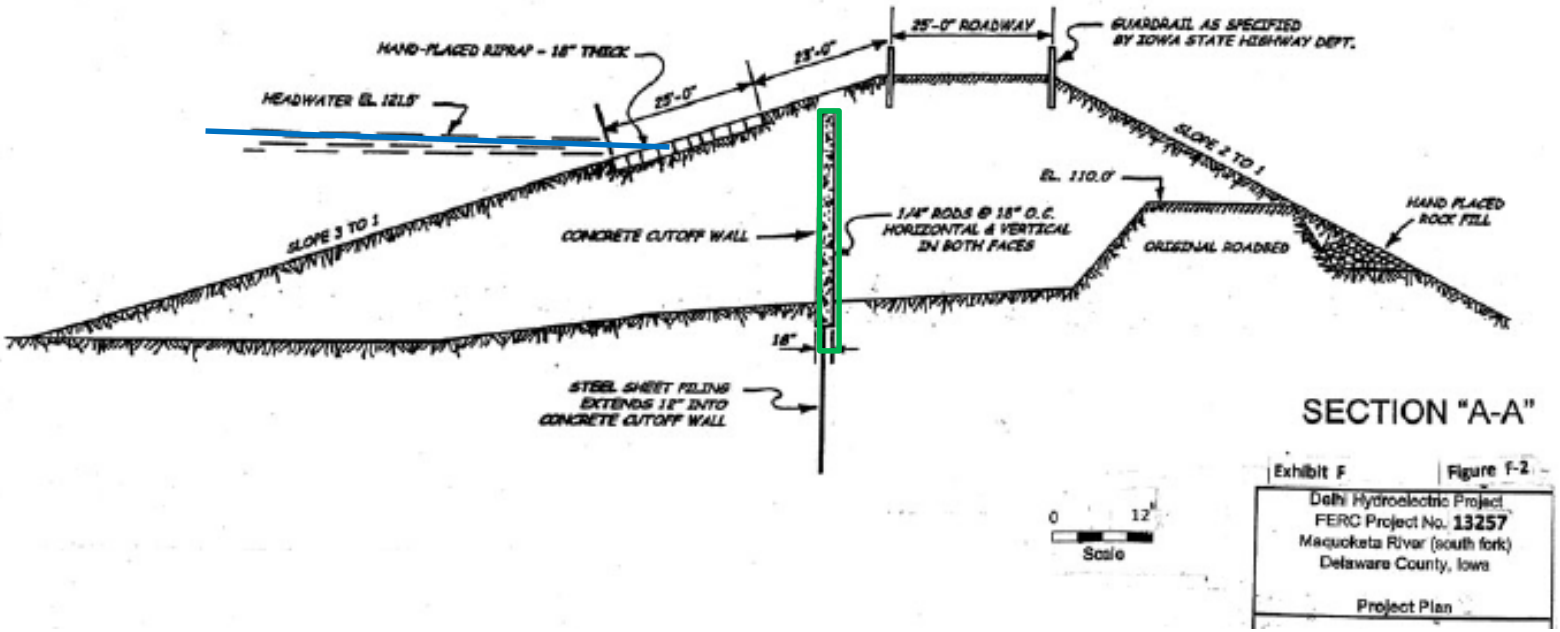
- William Fiedler,
  - Bureau of Reclamation
- Wayne King,
  - Federal Energy Regulatory Commission
- Neil Schwanz,
  - U.S. Army Corps of Engineers

Investigation

- Independent Panel of Engineers
  - Inspected dam and conducted interviews.
  - Established timeline of events
  - Pieced together facts including hydrology, spillway capacity and failure mode.
  - Published report.

Core Wall

- Elevation was 6 feet below top of dam
- Relatively rigid element within the earthen embankment



Estimated 17 hours of time above core wall

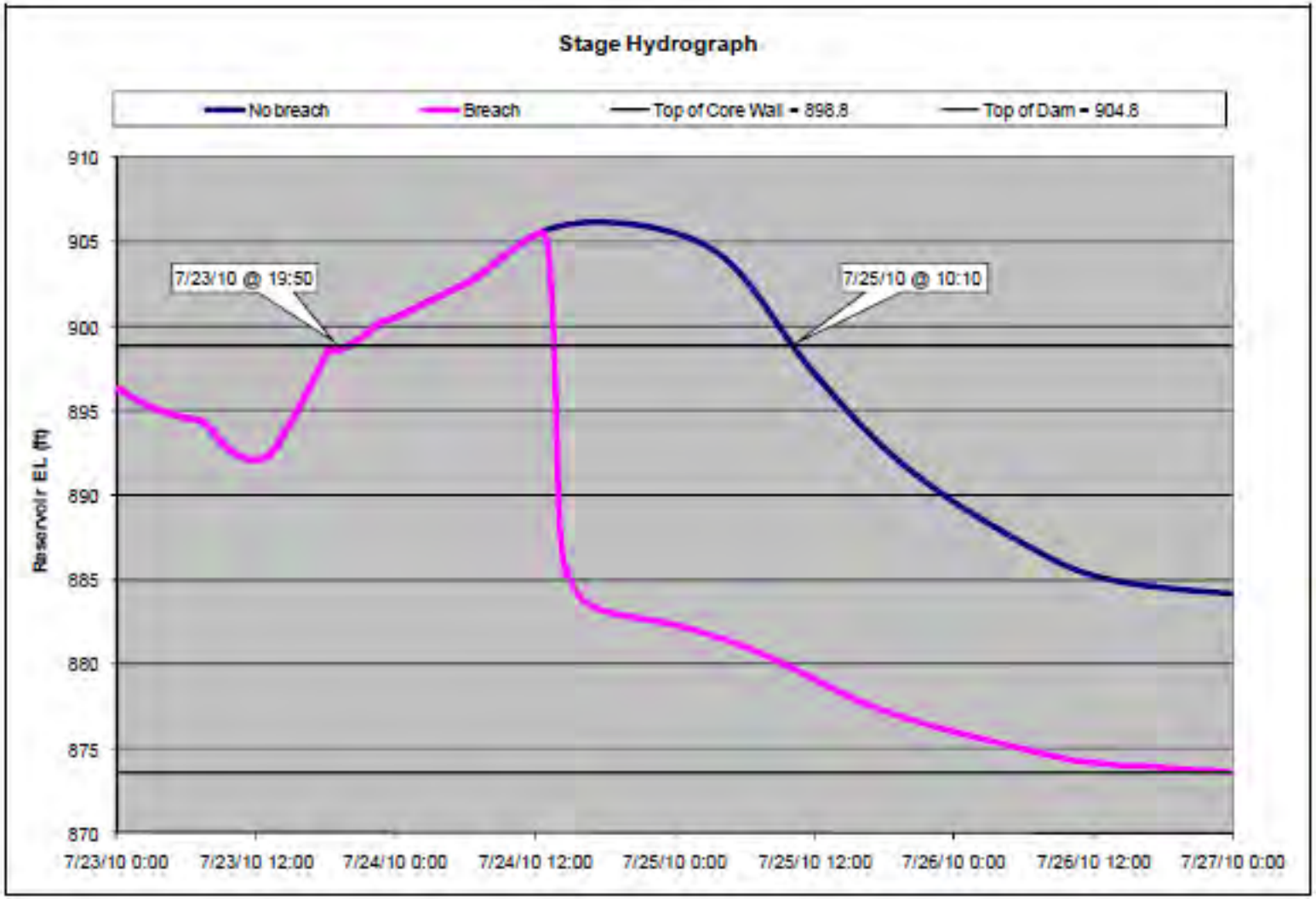


Photo IV-12
Approximate whirlpool/vortex locations by Mr David Fink. Approximate developing sinkhole location from post breach inspection shown by red star.

Photo IV-8
Overtopping flow and discolored discharge from beneath geotextile (still photo captured from amateur video).

Photo IV-9
Discolored discharge emerging near toe (DesMoinesregister.com).

Investigation Conclusion

Cause of Dam Breach

From the eyewitness descriptions, photographic and video evidence and limited excavation investigation, the cause of the dam breach was internal erosion in the embankment coupled with overtopping flow. The internal erosion was most likely caused by a seepage path initiated along differential settlement of the embankment material adjacent to the core wall. The failure mode was triggered by reservoir levels that exceeded the top elevation of the concrete core wall which was exacerbated by the inability to open the third gate beyond the 4.25 ft measured in the post breach investigation.

Internal erosion likely caused by seepage path along core wall

Lessons Learned

- Association of State Dam Safety Officials formed a dam failure investigation committee.
  - Developed guidelines for dam failure investigations.
- Record water levels on any dam should put owner on alert.
  - Many dams have not been fully tested.
- Trees and brush on dams impede inspection and inhibit early detection.
- Be diligent about reviewing existing dams for lack of compliance with existing design best practices.

Case Studies

Oroville Dam: 2017

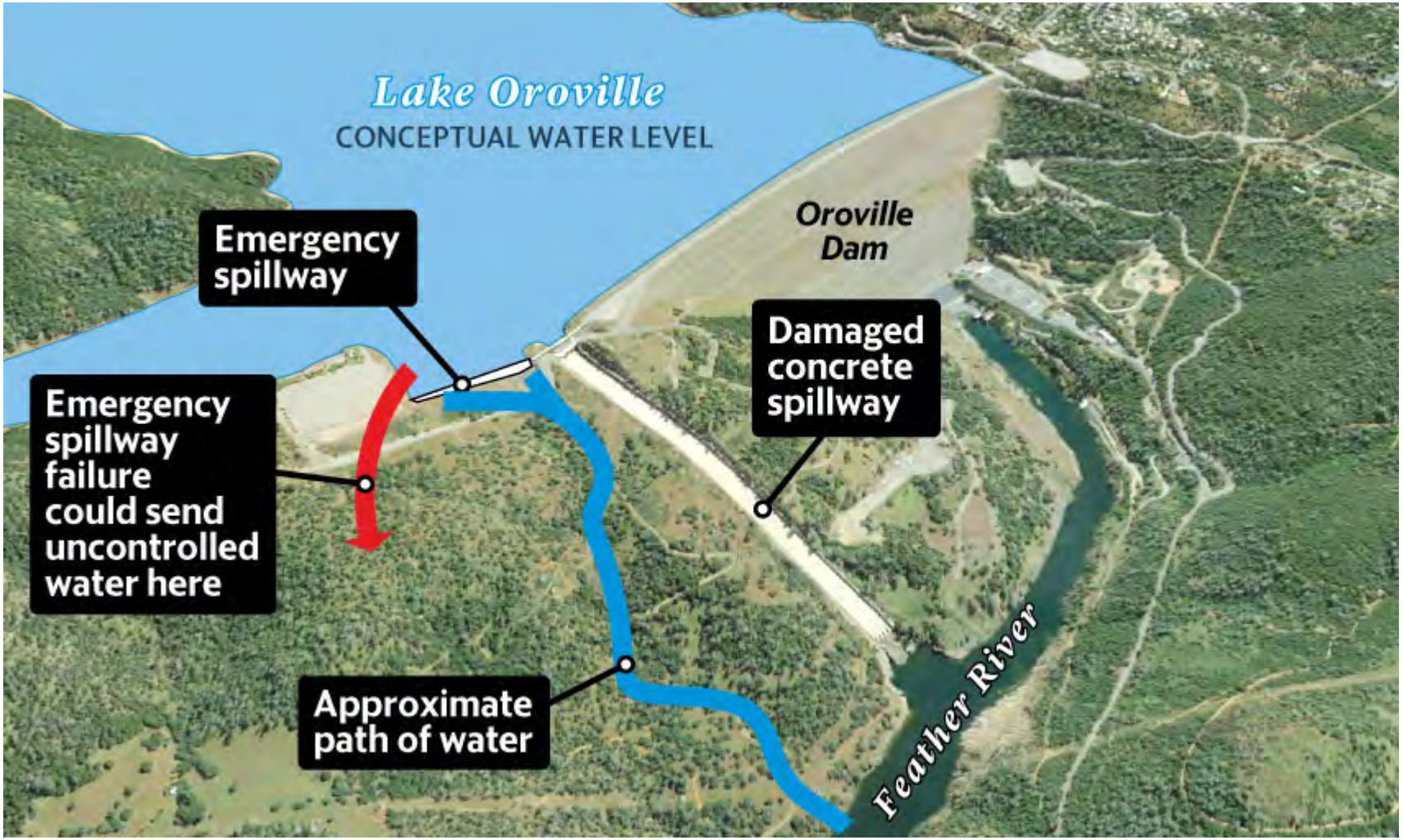
Oroville Dam

- 770 feet high zoned earth fill dam (tallest dam in US)
- Owned and Operated by California Department of Water Resources
- Serves mainly for water supply, hydroelectricity generation and flood control
- Drainage area: 3907 mi^2

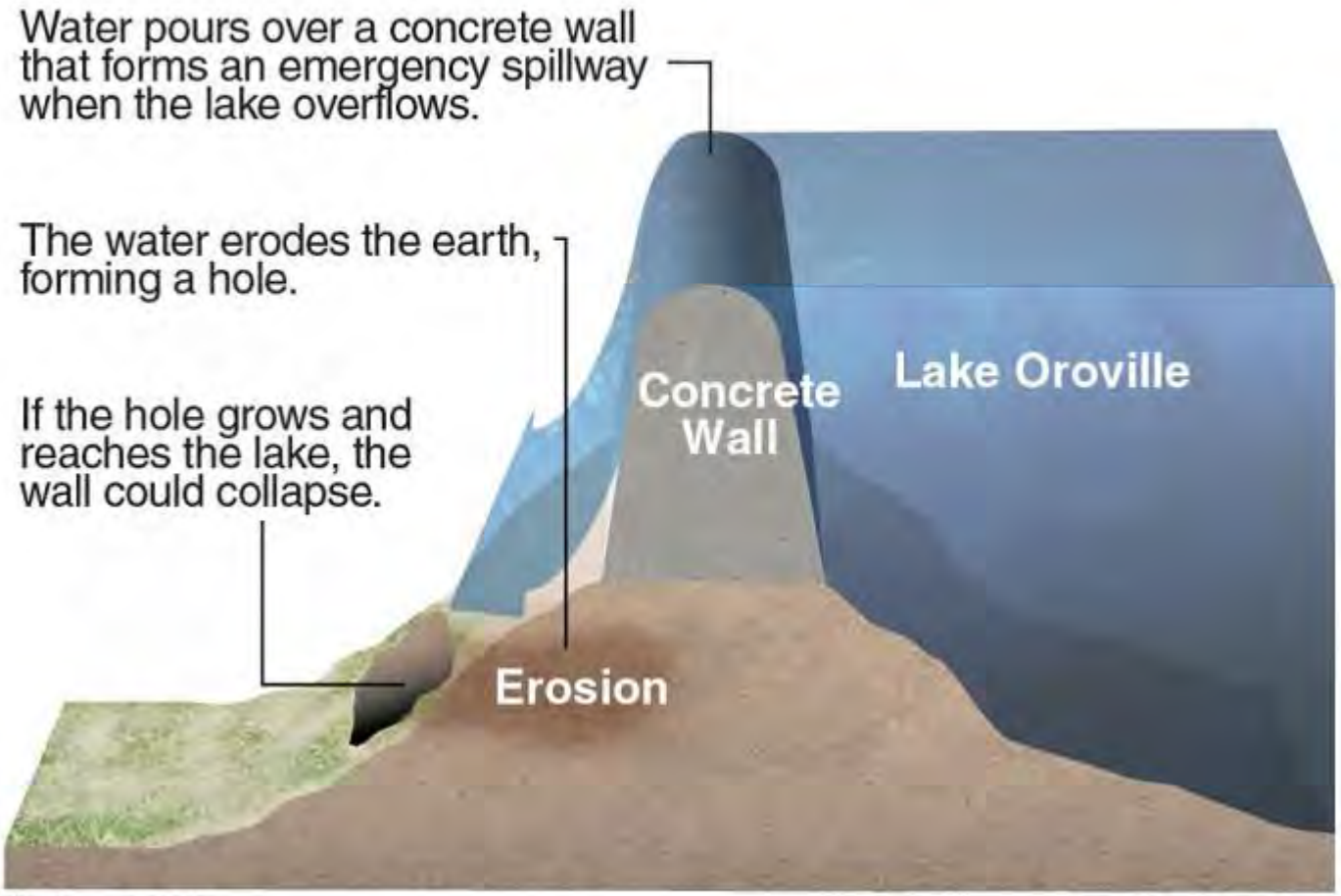
Crescent City
Klamath National Forest
Yreka
Weed
Modoc National Forest
Sheldon National Antelope Refuge
Six Rivers National Forest
McKinleyville
Shasta-Trinity National Forest
Eureka
Redding
Black Rock Desert - High Rock Canyon Emigrant...
Winnemucca
Battle Mountain
Carlin
Elko
Lassen National Forest
Chico
Plumas National Forest
Mendocino National Forest
Oroville Dam
Reno
NEVADA
Carson City
South Lake Tahoe
Humboldt-Toiyabe National Forest
Sacramento
Santa Rosa
Stanislaus National Forest
Yosemite National Park
San Francisco
San Jose
Sierra National Forest
Fresno
Salinas
Monterey
CALIFORNIA
Death Valley National Park
Visalia
Sequoia National Forest

Oroville Timeline (2017)

- Tuesday, Feb 7, releases of 50,000 cfs, spillway slab starts to break up.
- Can’t stop release of water, but reduced flows through spillway to try to minimize spillway damages.
- Friday, Feb 10, begin prepping for use of auxiliary spillway
- Saturday , Feb 11, 8:00am water begins flowing over auxiliary spillway
- Sunday, Feb 12, evacuation order due to dangerous erosion progressing to base of auxiliary spillway.
- Increased flow over primary spillway to 100,000 cfs
- Sunday, Feb 12, 8:00pm flows ceased over auxiliary spillway.


Lake Oroville
CONCEPTUAL WATER LEVEL
Emergency spillway
Oroville Dam
Damaged concrete spillway
Emergency spillway failure could send uncontrolled water here
Approximate path of water
Feather River

The erosion that could lead to a collapse at Lake Oroville



Source: DWR

Graphic: Los Angeles Times/TNS

NO ENTER

CAT

36~

Independent Investigation

- Association of State Dam Safety Officials and United States Society on Dams was request to create joint volunteer task force (forensic team):
  - Selected dam engineering experts
  - Independent from dam owner and state and federal regulators
  - Determine cause of failure
  - Look at human factors as well
    - The “why did this happen” and “how was this missed” factors

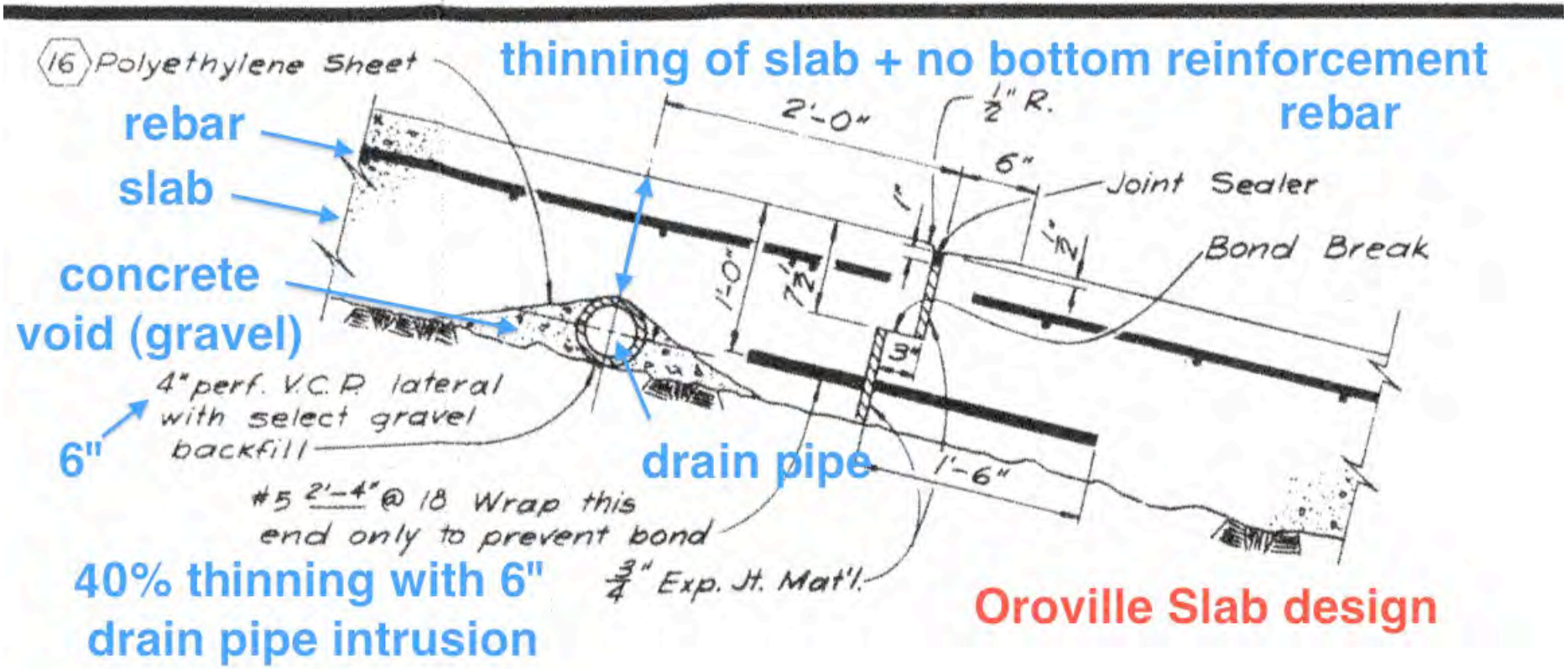
September Interim Memo: Physical Factors Determined

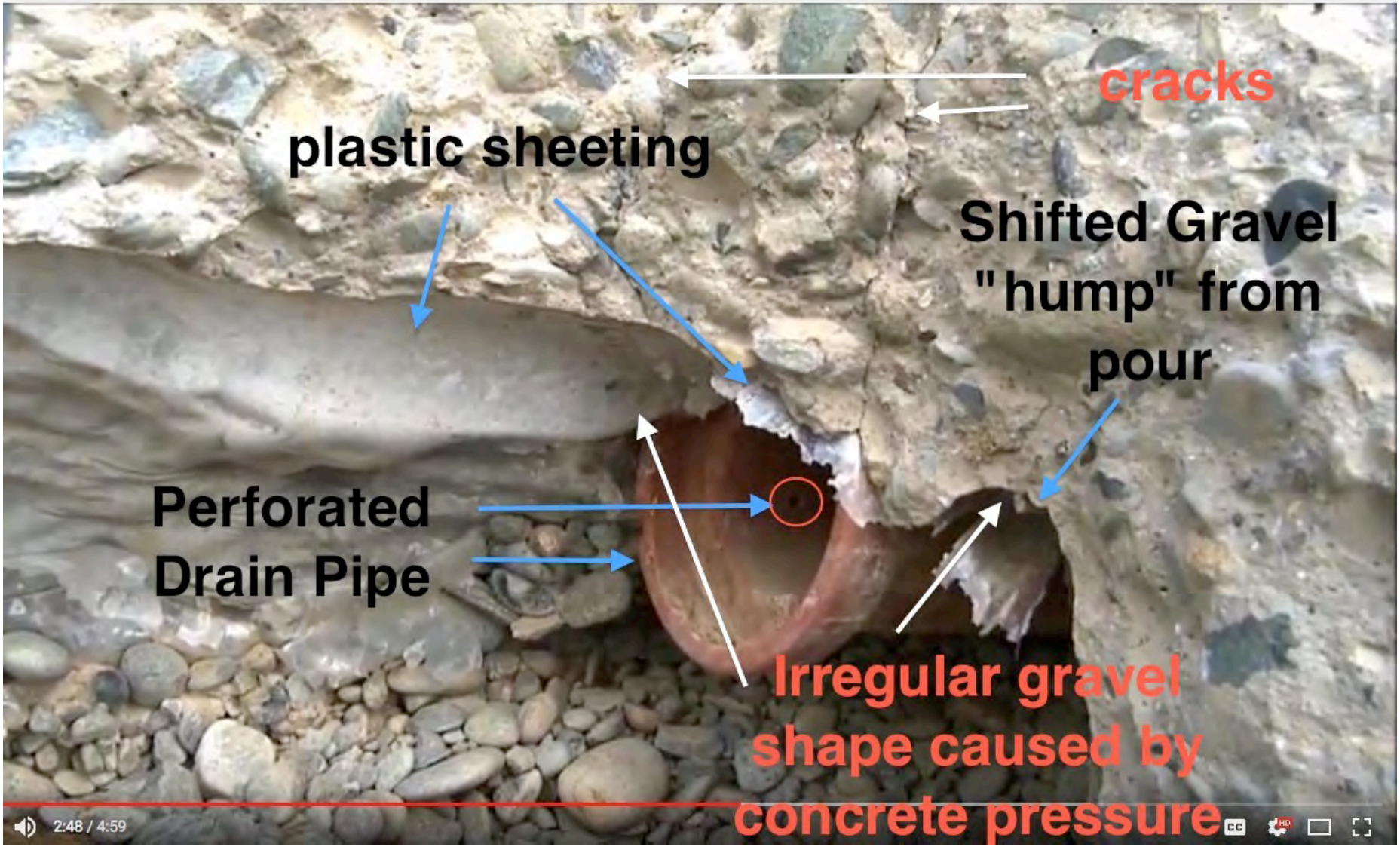
- Failure initiated by uplift and removal of section of slab downstream of station 33+50.
  - Timeline of events from maintenance workers on site.
- Allowed underlying moderately to highly weathered rock beneath the slab to erode with high velocity flows.
- Uplift caused by flow into cracks exceeding capacity of underlying drains.

UPSTREAM
33+00
33+50
34+00
35+00
DOWNSTREAM

Contributing Factors

- Underdrains intruded into the chute slab, reduced thickness from 7” from design of 15” causing cracks.
- Absence of waterstops at construction joints
- Relaxed foundation treatment during construction
- Shallow rock anchorage of 5 foot embedment, in placed into weather rock
- Drainage system deficiencies (no filtering, broken pipes, inadequate capacity)
- Single top layer of nominal reinforcement bars
- Large concrete aggregate size, resulting in propensity for cracking and spalling.


thinning of slab + no bottom reinforcement
rebar
rebar
slab
concrete
void (gravel)
6"
drain pipe
40% thinning with 6"
drain pipe intrusion
16 Polyethylene Sheet
2'-0"
1/2" R.
6"
Joint Sealer
Bond Break
1'-0"
7 1/2"
3"
1'-6"
4" perf. V.C.P. lateral
with select gravel
backfill
#5 2'-4" @ 18 Wrap this
end only to prevent bond
3/4" Exp. Jt. Mat'l.
Oroville Slab design


cracks
plastic sheeting
Shifted Gravel "hump" from pour
Perforated Drain Pipe
Irregular gravel shape caused by concrete pressure
2:48 / 4:59

2017 First Construction Season Repairs

Oroville Dam 2018

Case Studies

Spencer Dam: 2019

Spencer Dam

Spencer Dam

- Located on Niabrara River near Spencer, NE
- Hydroelectric dam

Spencer Dam

- Built in 1927
- Consists of a powerhouse, 400 foot long concrete spillway and a long earth embankment.
- Failed on March 14, 2019.
- 1 fatality

Timeline of events

- Wet autumn and colder than normal winter produced frozen ground and substantial thickness of river ice and snowpack
- Winter storm (bomb cyclone) beginning on March 12 produced heavy rain on the frozen watershed.
- Major ice run began on the Niabrara River.
- Ice jam temporary clogged on upstream bridge, then let loose.
- Ice clogged the spillway gates and water overtopped and washed out the dam.
- One home and occupant washed away.
- Findings concluded that is dam had not been there flooding alone would have caused damaged the home as well.

Spencer Dam

Spencer Dam

Spencer Dam

Spencer Dam

Investigation

- Association of State Dam Safety Officials setup a team
- Published report in April of 2020
- Available at https://www.damsafety.org/

- Flooding and Ice overwhelmed capacity of the spillway system
- Downstream flooding would have been severe even without the dam failure.

Case Study

Bedford Reservoir: 2018

Bedford Dam

- Built in 1969
- Located in Bedford, IA
- Original use was water supply
- October 2018, spillway pipe failure

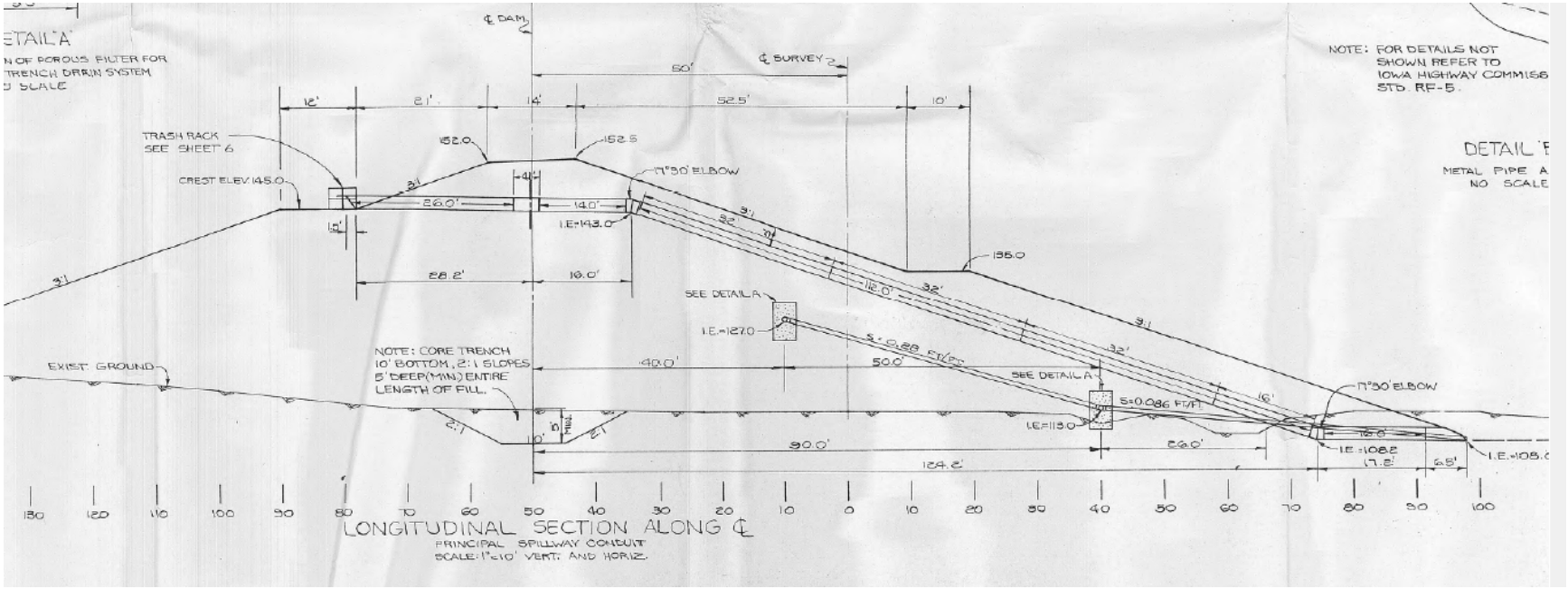
Bedford Dam

Bedford Dam

Bedford Dam

Bedford Dam

Bedford Dam


℄ DAM
℄ SURVEY
NOTE: FOR DETAILS NOT SHOWN REFER TO IOWA HIGHWAY COMMISS STD. RF-5.
TRASH RACK SEE SHEET 6
CREST ELEV 145.0
152.0
152.5
11°30' ELBOW
I.E.=143.0
135.0
SEE DETAIL A
I.E.=127.0
S=0.28 FT/FT
NOTE: CORE TRENCH 10' BOTTOM, 2:1 SLOPES 5' DEEP(MIN) ENTIRE LENGTH OF FILL.
EXIST. GROUND
S=0.086 FT/FT
I.E.=113.0
I.E.=108.8
LONGITUDINAL SECTION ALONG ℄
PRINCIPAL SPILLWAY CONDUIT
SCALE: 1"=10' VERT. AND HORIZ.

Bedford Dam

Case Study

Waterford: 2019

Waterford Dam

- Located in Johnston, IA
- Originally built in 1969
- Recreational lake
- Pipe Failure in May, 2019

Waterford Dam

Waterford Dam

Waterford Dam

Waterford Dam

- Spillway pipe reached it’s useful life of about 50 years
- Pipe collapsed leading to large sinkhole as embankment fell into pipe and was carried into the downstream channel.
- Failure was isolated and rest of embankment remained stable.
- Pipe replaced in December of 2019.

Questions on case studies?

The responsibility for proper operation, maintenance, and inspection of dams falls upon dam owners.

Liability

- **Common law holds that the storage of water is a hazardous activity.**
- Dams are owned and operated by individuals, private and public organizations, and the government. The responsibility for maintaining a safe dam rests with the owner.
- Safely maintaining a dam is a key element in preventing a failure and limiting the liability that an owner could face.

- *"In today's litigious society it is safe to assume that in the case of catastrophic dam failure, extensive litigation will ensue. Any competent lawyer, representing the victims, will sue all possible wrong doers in seeking redress…including…the owners and operators of the facility, and…architects, engineers, contractors, sub-contractors, and consultants involved in the original construction and any subsequent modifications…"*

  – Denis Binder, Professor of Law, Chapman University

O&M Pays Off

- Proper operation, maintenance, and inspection of a dam is like that of an older vehicle in need of extensive repair:
  - If left un-maintained, repair is expensive.
  - If maintenance and repair are performed as needed, costs are minimized.

Proper Dam Operations

Dam Operations

- Follow formal O&M manual, if available
- Recordkeeping
  - Design plans and calculations
  - Inspection reports
  - Documentation of repairs
  - Monitoring of seepage and structural cracks
- Periodic Inspection
- Emergency action plan (EAP)
  - EAP must be updated on an annual basis
  - Downstream development is typically a potential concern that can drastically affect EAP contents
- Operation of bottom drain, siphon systems, and gates/flashboards
  - Bottom drains, siphon systems, pool control gates, flashboards, and other outlet control works must be operated at least annually.
  - If systems are deteriorated and have not been operated in many years, they must be inspected by a qualified engineer.

Dam Operations (cont.)

- Monitoring fluctuation of pool elevation
- Removal of floating debris
- Monitoring instrumentation systems
- Monitoring alarm/warning systems

Inspections

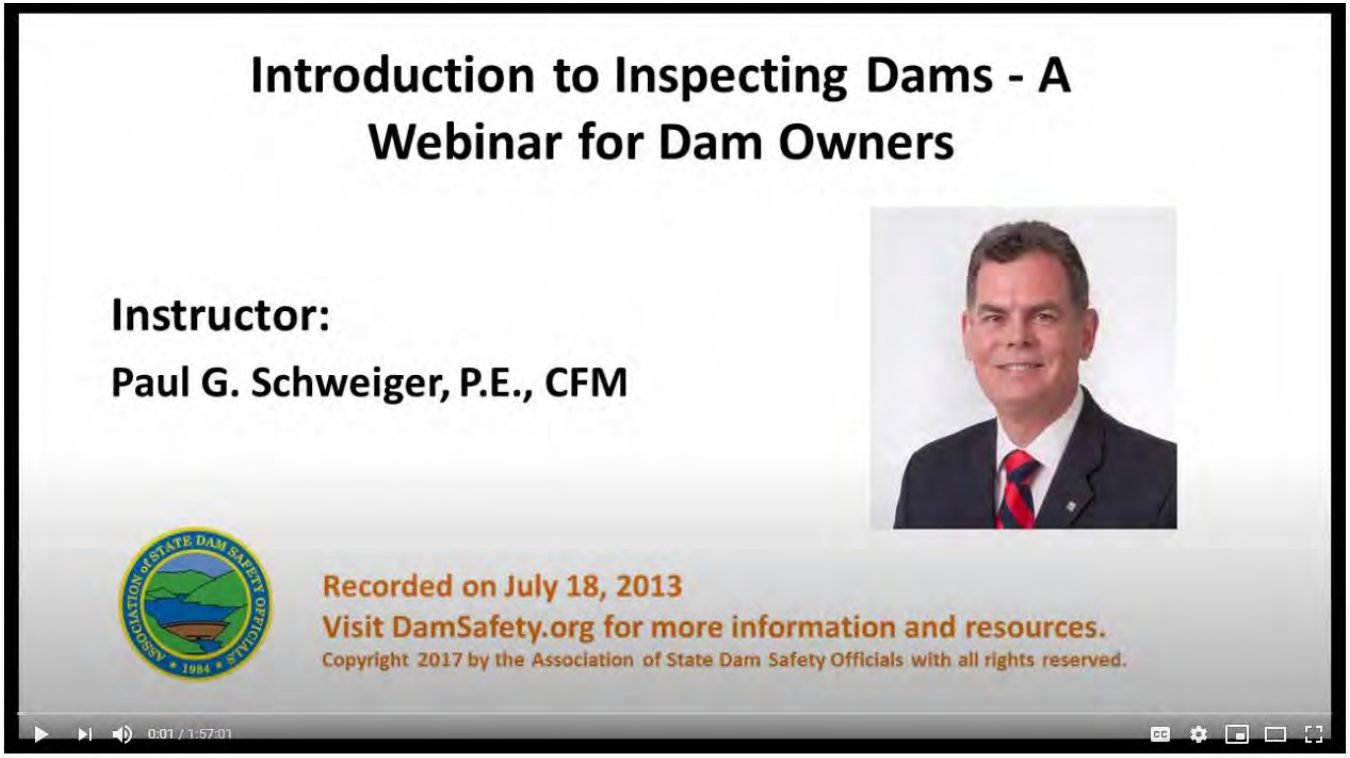
- When:
  - Periodically, generally weekly if no issues
    - High hazard dams with permanent pools, daily visit, weekly full walk through.
  - After large rainfall events
  - Especially during “first filling” and high water levels
- Purpose:
  - Identify early warning signs of potential problems or failure
  - Identify O & M needs
  - Monitor instrumentation

Inspections: What to Look For

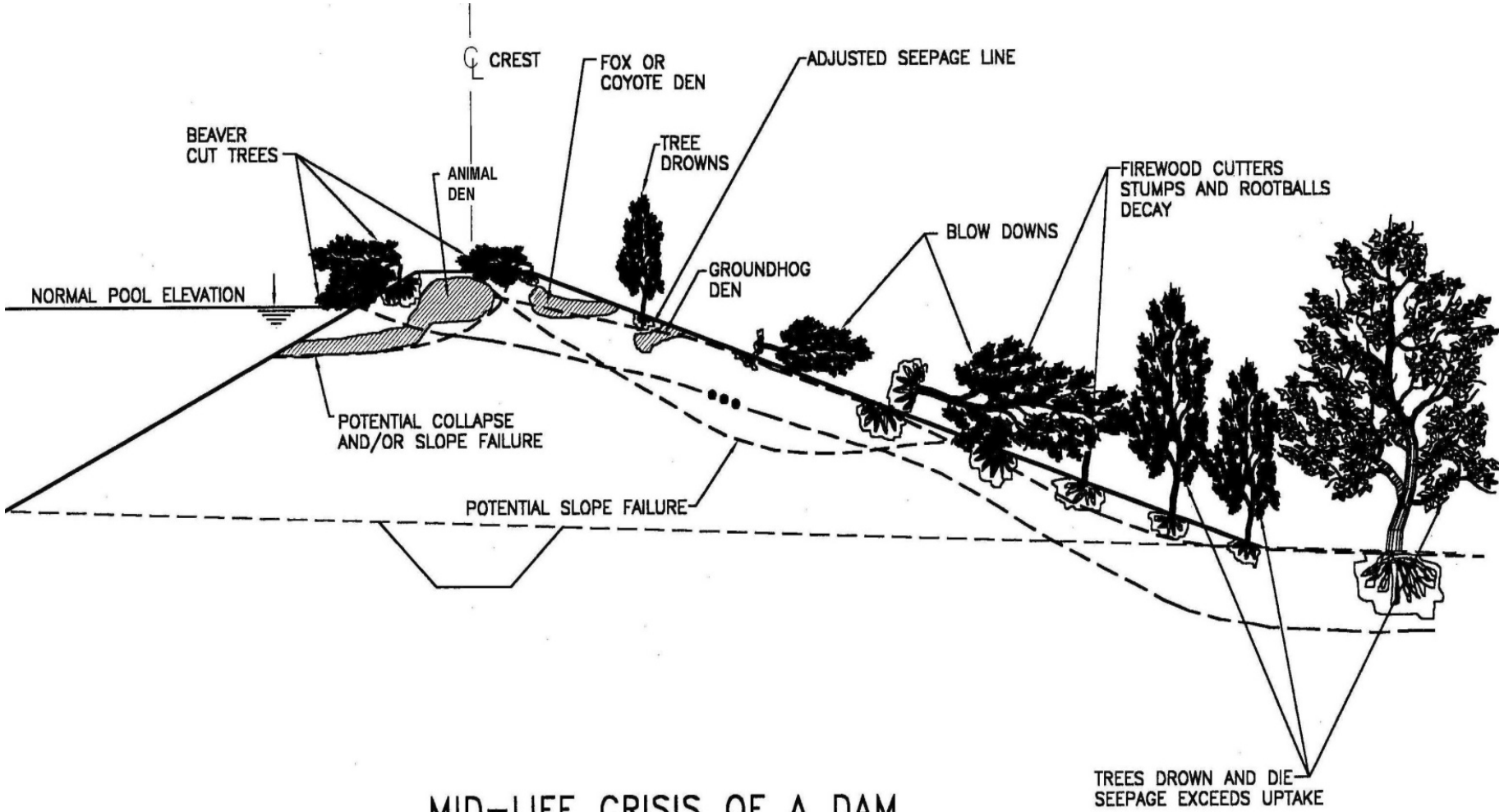
- Stability of Embankment & Structures
- Erosion - Embankment Upstream & Downstream Slopes, Abutment Juncture, Spillways & Outlets
- Seepage - Through Dam, Abutment, Foundation, Around Structures
- Vegetal Cover - Type & Condition
- Wildlife Damage
- Deterioration/Cracking of Concrete Surfaces & Structures

Additional Resource: Dam Inspections

https://www.youtube.com/watch?v=xCz58JFeqpg&t=1s



Dam Maintenance



MID-LIFE CRISIS OF A DAM

PLANT (TREE) AND ANIMAL PENETRATION PROBLEMS

Dam Maintenance Activities: Embankment

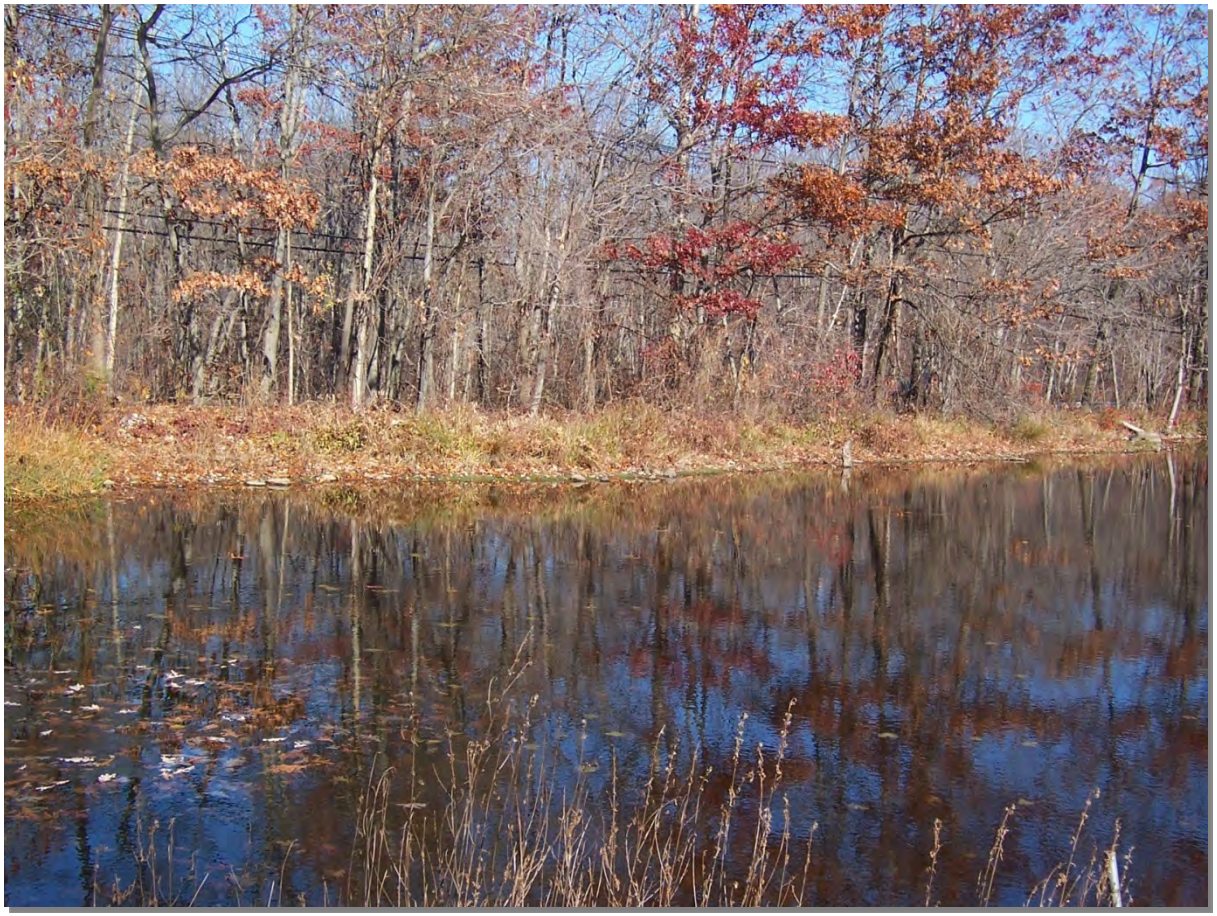
- Nurturing and mowing/burning grassed areas
- Removal of trees and brush
- Removal of floating debris from outlet works
- Repair of eroded/scoured areas
- Mainatain upstream slope wave protection
- Control and repair of damage caused by wildlife

Why no trees and brush?

- Tall grass and brush make inspections more difficult
- Tall grass provides a haven for borrowing animals
- Trees can blow over in high winds and severely damage the embankment.
- Tree roots penetrate the embankment and alter its structural integrity.
- Tree roots can become pathways for seepage.

Nurturing and Mowing Grass Areas

Removal of Trees and Woody Vegetation

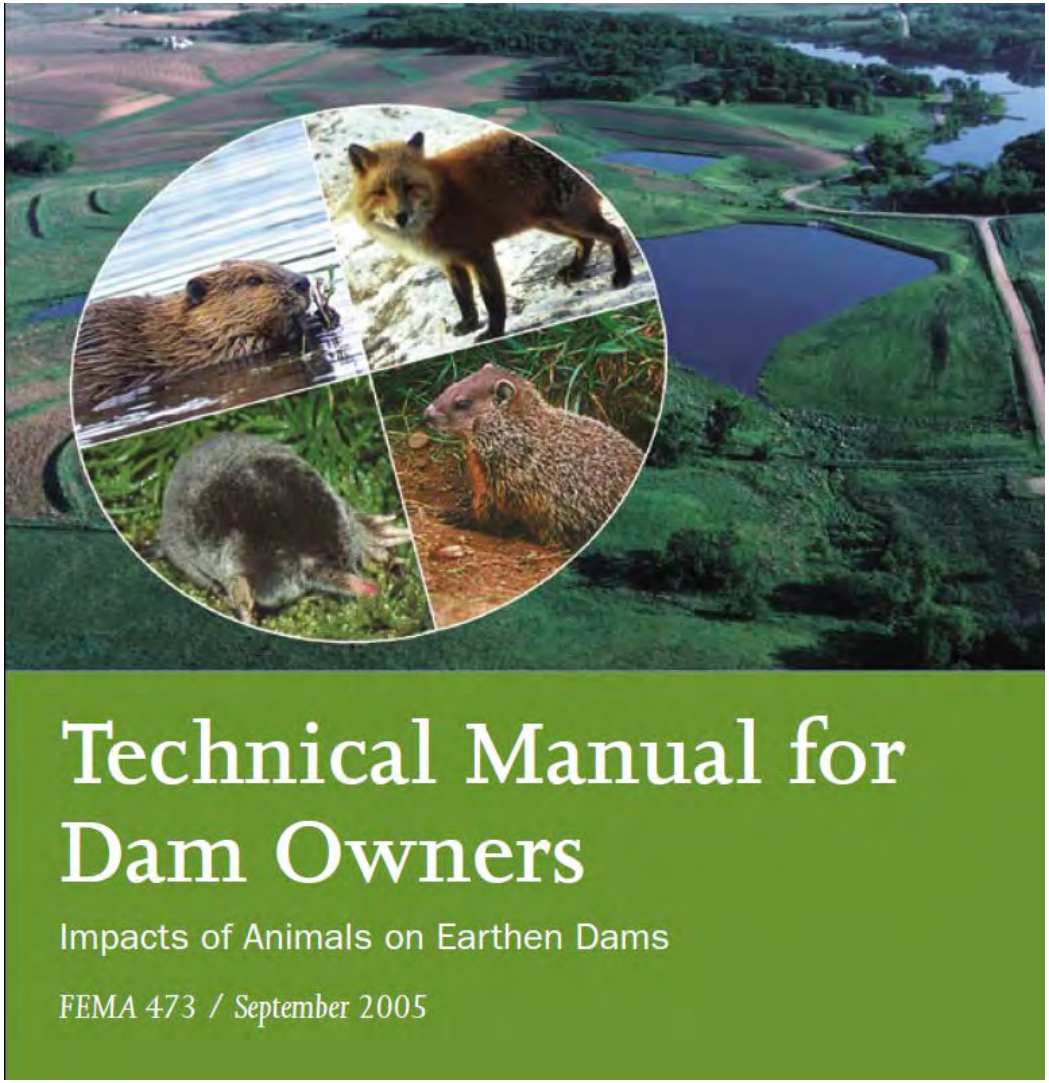


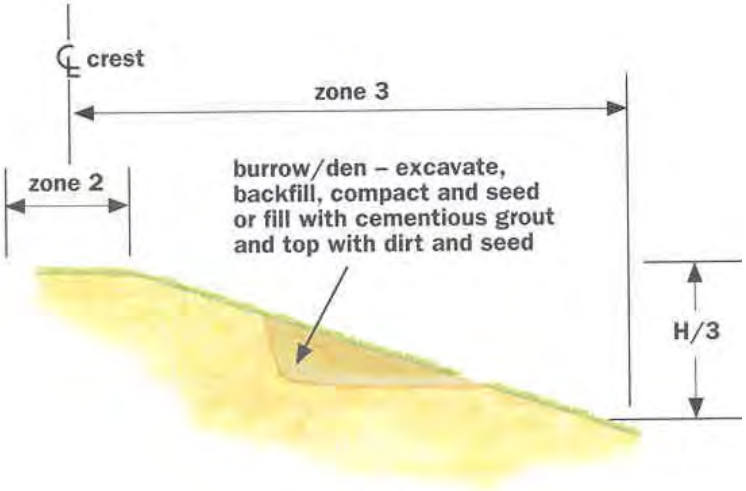
Repair Embankment Surface Erosion

Maintenance of Upstream Slope Wave Erosion Protection

Identify Wildlife Activity

Control and Repair of Damage Caused by Wildlife





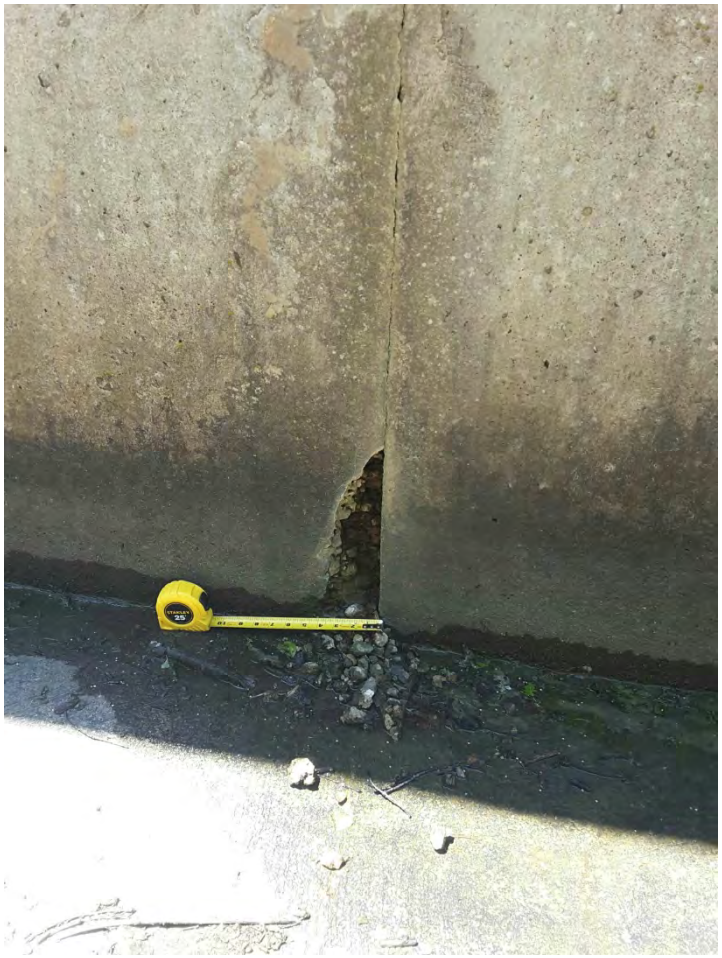
Dam Maintenance Activities: Spillways

- Keep spillway free of debris to ensure full capacity
- Opening and closing of outlet & spillway gates to ensure operability
- Painting and repair of metal components
- Grouting and sealing concrete joints/cracks
- Removal and protection of spalling concrete

Debris at Inlet

Opening and Closing of Lake Drains to Ensure Operability

Grouting/Sealing of Concrete Joints/Cracks



Repair Spalling Concrete

Replace or line CMP spillways

Dam Maintenance Activities: Other

- Maintenance and stabilization of outlet channels
- Maintenance or repair and replacement of warning signs
- Maintenance of instrumentation/ monitoring systems
- Maintenance of upstream slope wave erosion protection

Public Safety at Dams

- Public safety
  - Public access should be controlled
  - Includes proper warning signs, fencing, etc.

(Photo source: Mary Chind, The Des Moines Register)

Control access where possible

Public Safety: Signage for boats

SCENARIOS POSSIBLE FOR RIVER USERS TO AVOID A DROWNING ZONE AND DAM	Water Trail Includes Portage Around Dam	Water Trail Launch Available Upstream of Dam to Exit River	Water Trail Launch Available Upstream of Dam to Exit River; Water Trail Ends Here
1 EARLY WARNING SIGN To alert river users to the upcoming dam and cue them to watch for instructions about exiting safely. Required only if landing or egress is located 300 feet or less upstream of a dam, although it may be used optionally to be conservative IPI Part Number: FDNR408EA	Warning Dam Ahead 1,500 Feet	Warning Dam Ahead 1,500 Feet	Warning Dam Ahead 1,500 Feet
2 LAST LANDING ABOVE SIGN To alert river users of the last landing above the dam IPI Part Number: FDNR410EA	Warning Dam Ahead 1.4 Miles Last Landing Portage Ahead Left Bank	Warning Dam Ahead 1.4 Miles Last Boat Landing	Warning Dam Ahead 1.4 Miles Last Landing Water Trail Ends Here
3 LAND-BASED LAST LANDING ABOVE SIGN To alert those staging watercraft or putting in at the launch IPI Part Number: FDNR411EA	Warning Dam Ahead 1.4 Miles Last Landing Portage Ahead Left Bank	Warning Dam Ahead 1.4 Miles Last Boat Landing	Warning Dam Ahead 1.4 Miles Last Boat Landing
4 MOVE LEFT OR RIGHT SIGN To cue river users to move over for last safe exit and/or portage (20/20 vision) IPI Part Number: FDNR414EA	Warning Dam Ahead Move Left For Portage	Warning Dam Ahead Move Left For Safe Exit	Warning Dam Ahead Move Left For Safe Exit
5 LAST SAFE EXIT SIGN To mark the last safe exit and/or portage (20/20 vision) IPI Part Number: FDNR421EA	Danger Dam Ahead Last Safe Portage Here Exit Now! →	Danger Dam Ahead Exit Now! →	Danger Dam Ahead Exit Now! →
6 DROWNING ZONE, UP/DOWNSTREAM LIMITS SIGN To mark the area beyond which no one should enter because of dangerous currents. Exact placement based on field conditions (20/40 Vision) IPI Part Number: FDNR422EA	Dam	Dam	Dam
7 PEDESTRIAN DROWNING ZONE WARNING SIGN Placed at pedestrian approaches to drowning zone areas. Exact placement based on field conditions IPI Part Number: FDNR40918X24EA	Danger Recirculating Currents Below Dam Trap And Drown Victims	Danger Recirculating Currents Below Dam Trap And Drown Victims	Danger Recirculating Currents Below Dam Trap And Drown Victims
8 OTHER HAZARDS SIGN Placed on-land or on-water to alert river users to an upcomming non-dam hazards IPI Part Number:	Warning Rapids Ahead	Warning Rapids Ahead	Warning Rapids Ahead

Summary – Take Aways

- Dams of all sizes can and do fail.
- Proper Inspection and O&M can help prevent failure
- Resources are available

Additional Resources

- Association of State Dam Safety Officials
  - Membership open to all dam owners, consultants, and dam safety officials
  - Many available resources both for members and general public
    - http://damowner.org/
    - http://damfailures.org/
    - http://damsafety.org/

- Low Head Dam Safety
  - Concrete or rock dams across a river or stream channel.
  - DNR Water Trails staff works with low head dam owners to improve safety around dams.
  - https://www.iowadnr.gov/Things-to-Do/Canoeing-Kayaking/Low-Head-Dams
- Iowa Ponds Website
  - DNR fisheries biologist recommendations
  - https://www.iowadnr.gov/Fishing/About-Fishing-in-Iowa/Iowa-Ponds

Questions

Upcoming Webinars

- **May 20: Dam Ownership, When and How to Hire an Engineer**
  - When do you need to call in an expert? We'll discuss when and how to find and hire qualified engineers to help with repairs and design of dams.
- **May 27: Dam Design and Permitting**
  - This webinar will go into technical engineering design requirements and what's needed to obtain a permit. We will also discuss upcoming changes to Iowa's dam safety administrative rules.

https://www.iowadnr.gov/dams