Emergency Management Insights from Dam Failures & Incidents

National Dam Safety Program Technical Seminar | 2024

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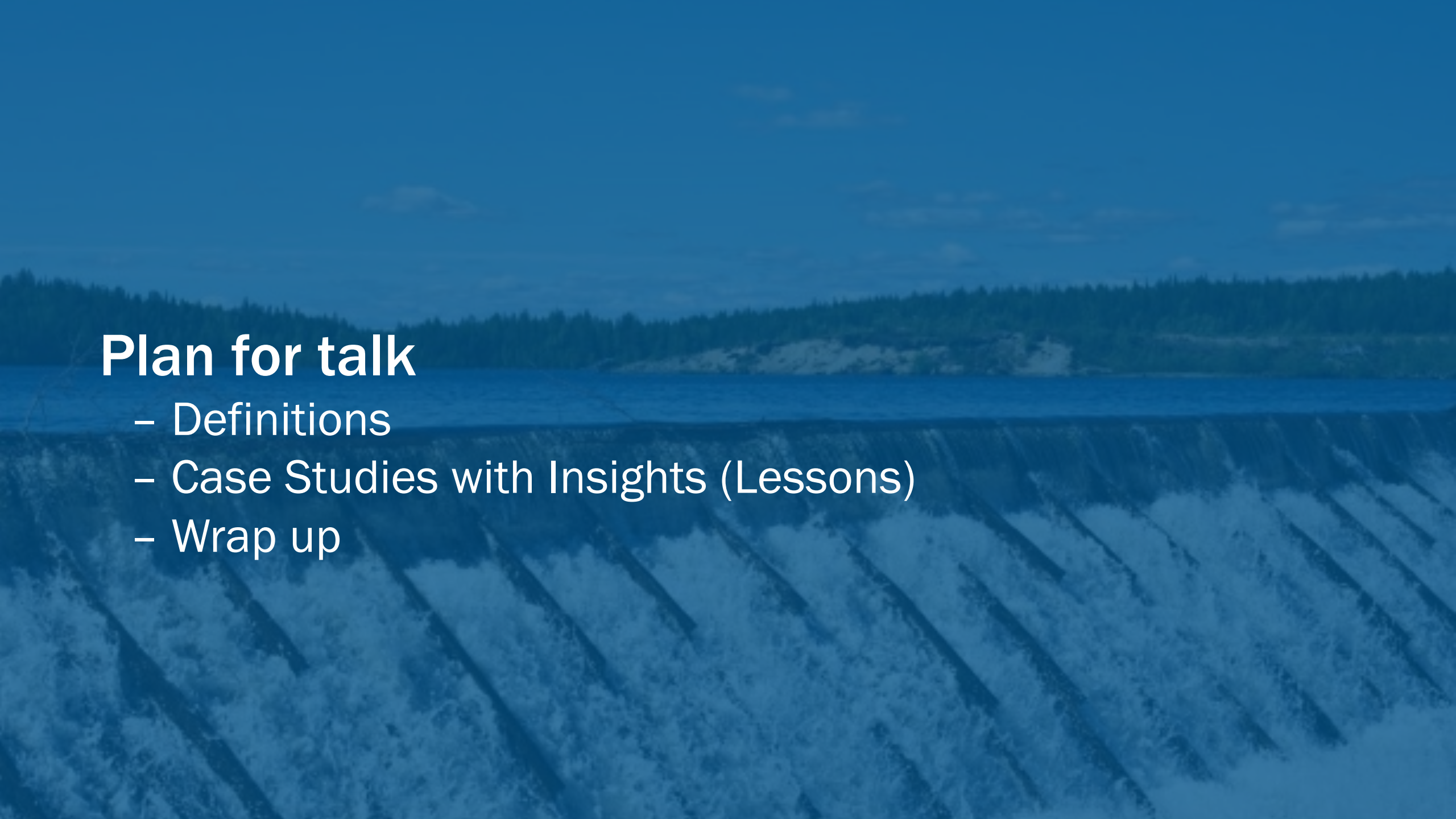
DamCrest CONSULTING



Plan for talk

- Definitions
- Case Studies with Insights (Lessons)
- Wrap up

Dam Failure Definition:

Catastrophic type of failure characterized by the sudden, rapid, and uncontrolled release of impounded water

Dam Incident Definition:

Dam Safety Incident: An incident where a failure mode initiates and progresses but does not progress to an uncontrolled release of the reservoir.

Operational Incident: Controlled release that results in property damage or loss of life.

Public Safety Incident: When an individual is seriously injured, killed or required rescue, due to presence or operations of a dam.

Security Incident: Not addressed.

Oroville Dam 2017

Pop Quiz: Failure or Incident 1

FEMA

Pop Quiz: Failure or Incident 2

Lake Delhi Dam, 2010

More on Incidents

Dam Safety Incident: An event where a failure mode initiates and progresses but does not progress to an uncontrolled release of the reservoir.

- More incidents happen than failures
- Can be minor or major
- May or may not be detected
- May lead to failure or may resolve on own or be stopped by intervention
- All failures start out as incidents

Examples: Slides, seeps, cracks, sinkholes, flood event

FEMA

More on Incidents and Failures

Dam Safety Incident: An inci
failure mode
not progress
reservoir.

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Insights:
Incidents are often a surprise (random)
but are more likely during:

- Floods/earthquakes
- High reservoir levels
- Major spillway flows
- First time the reservoir fills after construction or major modification

Examples: Slides, seeps, cracks, sinkholes, flood event

FEMA

The Worst Case – Undetected incident that progresses to failure – No intervention, warning and Evacuation

No EAP

Kaloko Hawaii, 2006

- A jungle/mountain Dam
- Dam failed before dawn from sliding, overtopping
- After heavy rain
- No detection, warning or evacuation
- 7 people killed including a pregnant woman

FEMA

The Worst Case – Undetected incident that progresses to failure – No Warning and Evacuation

No EAP

Insights:
- It is more challenging to operate, maintain, and monitor remote dams.
- Incidents and failures at these dams may go unnoticed until it is too late.

Kaloko Hawaii, 2006

ntain Dam

fore dawn

vertopping

n

No detection, warning or evacuation

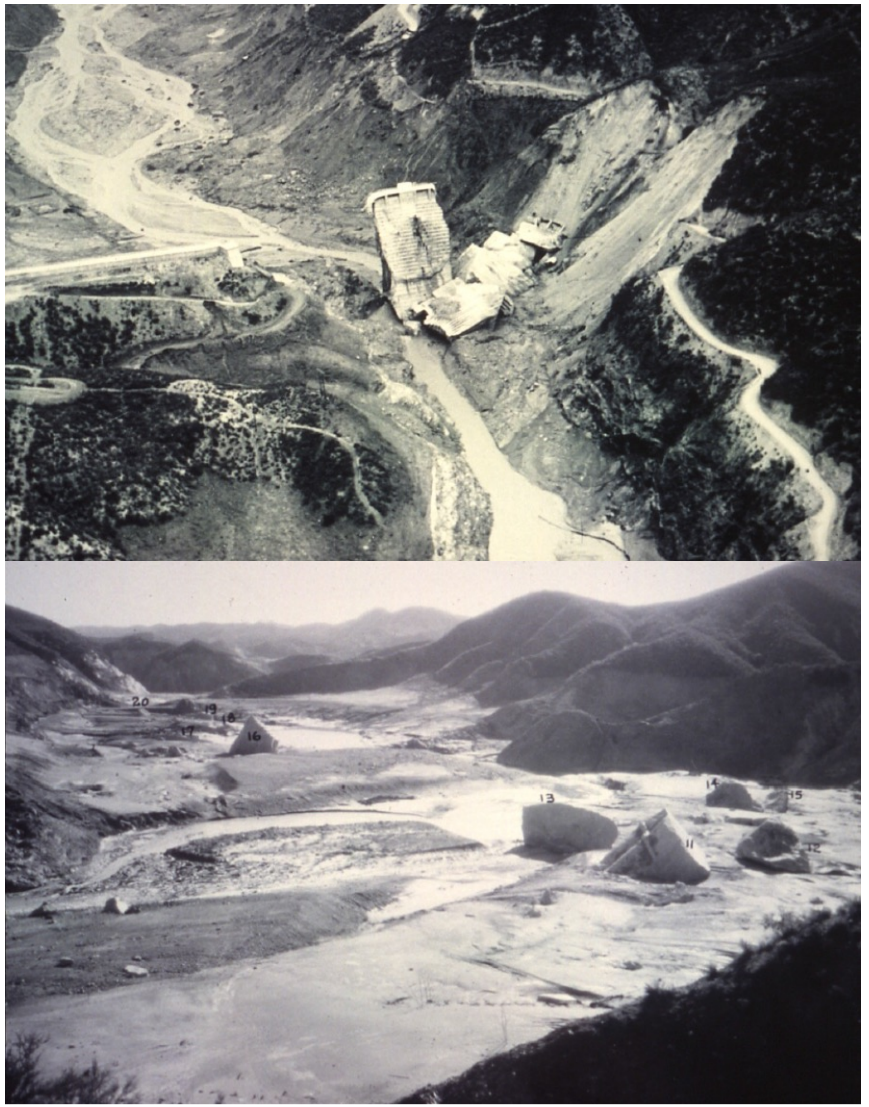
- 7 people killed including a pregnant woman

FEMA

The Worst Case – Undetected incident that progresses to failure – No Warning and Evacuation

- Failed suddenly around midnight
- New 205-ft-high dam
- Failed on first filling
- High velocity/deep flood
- ~450 lives lost
- Motorcyclist raced downstream warning

No EAP



St. Francis Dam, CA 1928

FEMA

The Worst Case – Undetected incident that progresses to failure – No Warning and Evacuation

- Failed suddenly ar
- New 20
- Failed or
- High velo
- ~450 live
- Motorcycl

Insights:

- New dams and dams that have had major repairs should be carefully monitored for first filling
- Have an EAP and exercise before first filling

St. Francis Dam, CA 1928

FEMA

The Worst Case – Undetected incident that progresses to failure – No Warning and Evacuation

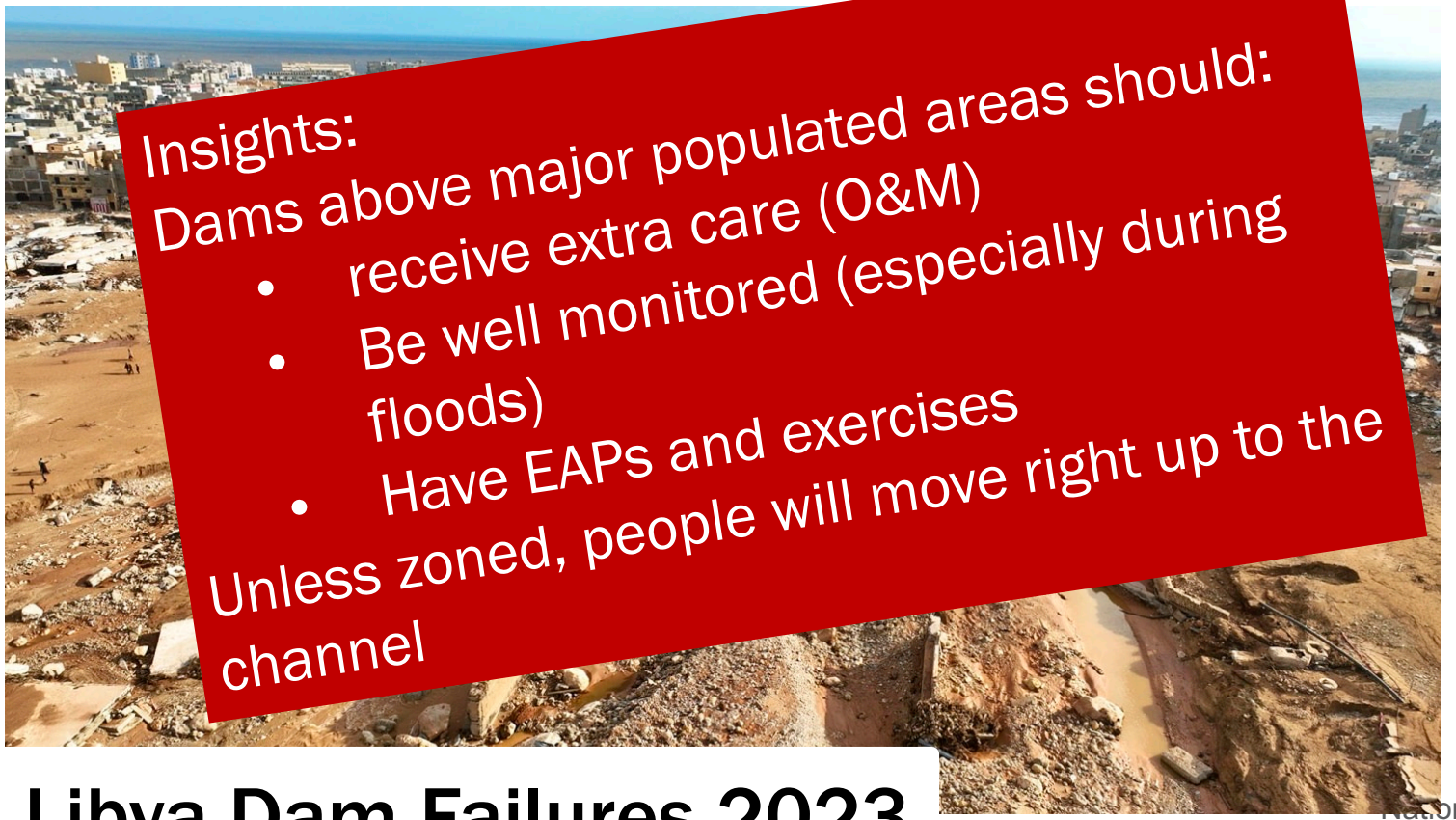
No EAP

Libya Dam Failures 2023

- 2 dams failed at night after Mediterranean storm Daniel
- City of Derna downstream
- 3:00AM
- 25% of the city "disappeared"
- No warning/Evacuation
- 5,300 -20,000 killed

The Worst Case – Undetected incident that progresses to failure – No Warning and Evacuation

No EAP



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Libya Dam Failures 2023

The Best Case – No incidents or failure.

- Dam designed and built well
- Properly maintained and operated.

FEMA

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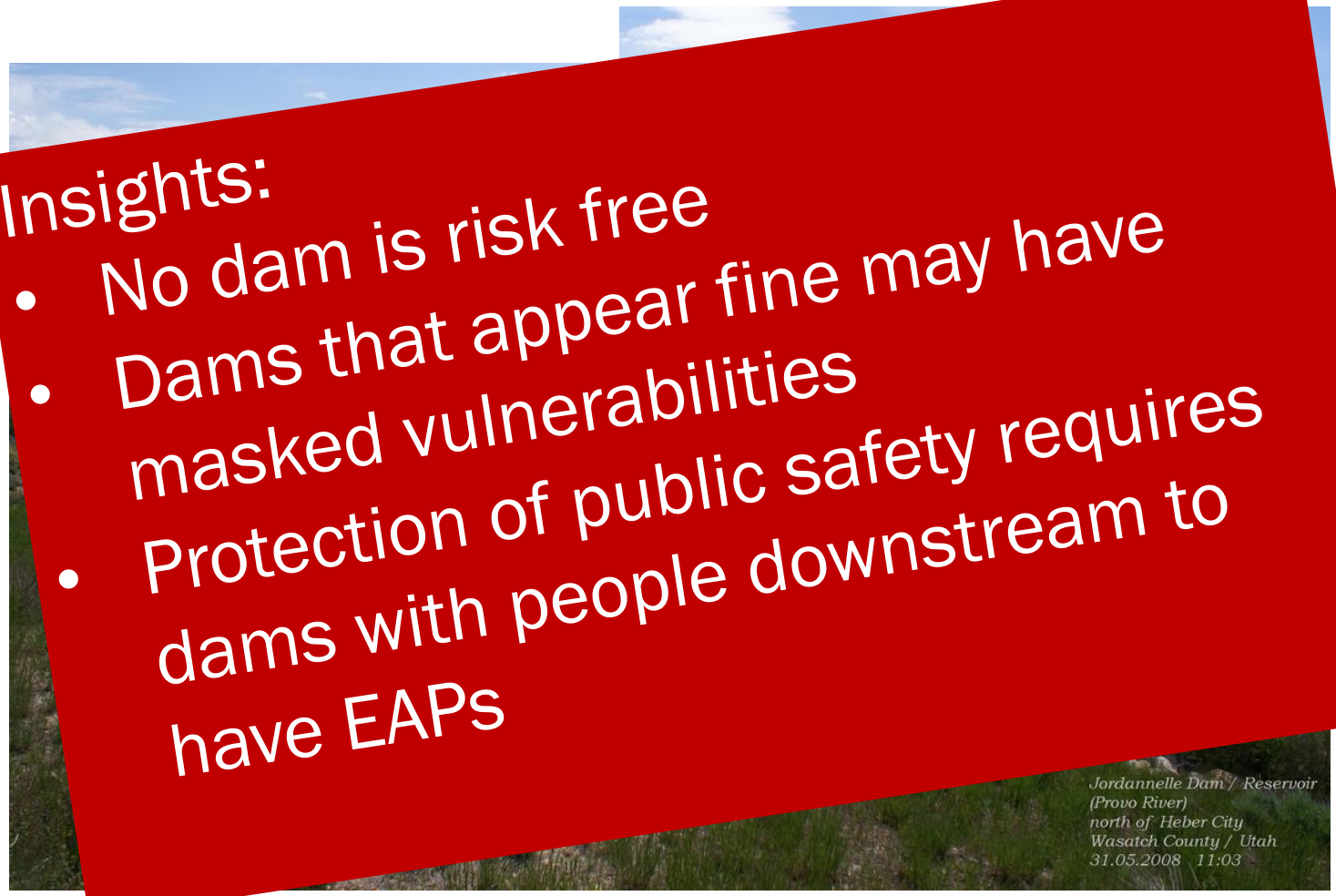
- Properly maintained and operated.



Insights:

- No dam is risk free
- Dams that appear fine may have masked vulnerabilities
- Protection of public safety requires dams with people downstream to have EAPs

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The Reality Case – Incidents may happen and if you are prepared, you can make a difference

Step 1: Make sure you detect incidents Detection is the discovery of an initiating event at a dam, examples:

- High water,
- Increased seepage
- Cloudy seepage,
- Concrete movement
- Slides, slumps, cracks

The Reality Case – Incidents may happen and if you are prepared, you can make a difference

Step 1: Detect by:

- Keeping vegetation down
- Make all parts of the dam accessible
- Training staff at dams what to look for
- Make them comfortable to report
- Eyes on dam frequently
- Earlier discovery the better

The Reality Case – Incidents may happen and if you are prepared, you can make a difference

Step 2: Notify

- Follow EAP
- Assess severity with help of engineers
- Notify

If severity is deemed **Minor**:

- Some call "Internal Alert"
- Continue to monitor
- Communicate regularly
- Prepare for if it gets worse

If severity is deemed **Major**

- Declare EAP response level 1 or greater
- Consider Intervention.

Intervention– Taking actions to slow or stop a failure mode (incident) in progress.

- Can be successful: dam does not fail
- Can be unsuccessful: dam fails

- Intervention (even unsuccessful intervention) can delay failure to allow more time for warning and evacuation)

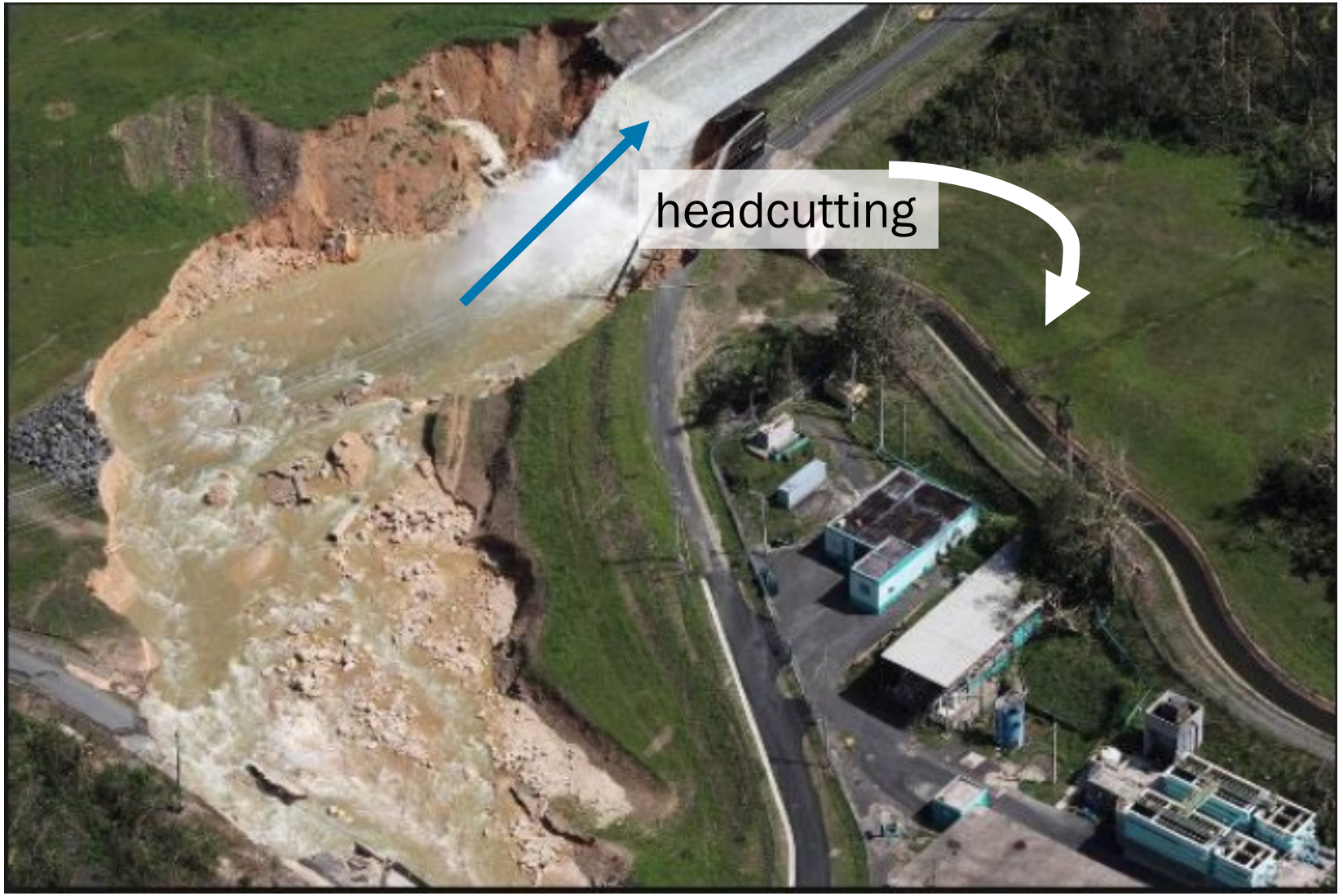
Successful Intervention Example

Guajataca Dam, PR – Pre-Incident

FEMA

Successful Intervention Example

Hurricane Irma, Guajataca Dam, PR Sep 2017



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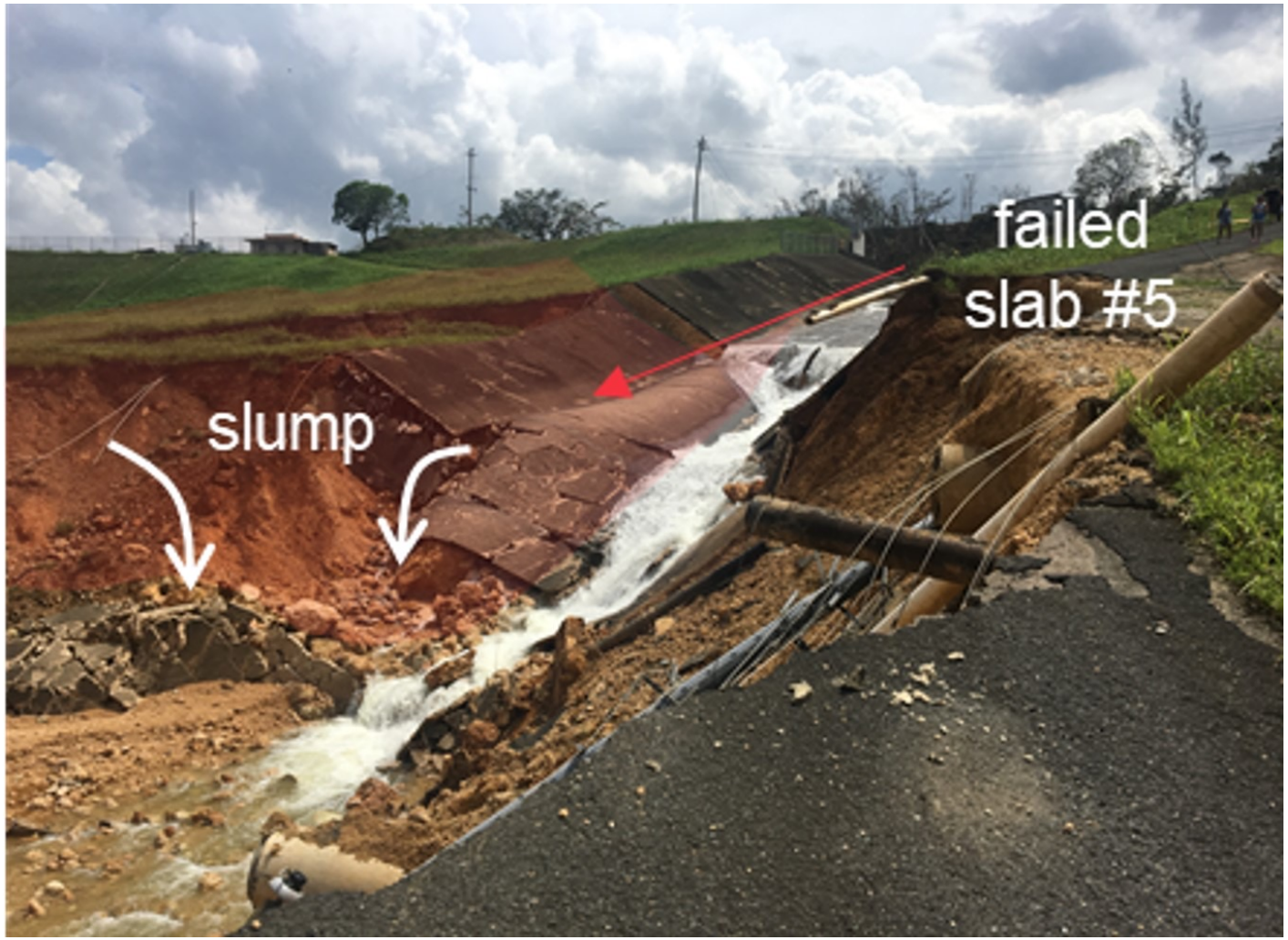
Successful Intervention Example

The National Weather Service warned Friday that the failure of Guajataca Dam in northwest Puerto Rico was "imminent" and could lead to flash flooding for some 70,000 people that could be affected if it collapsed.



Guajataca Dam, PR Sep 2017

FEMA

Successful Intervention Example

US Army Corps of Engineers®

Guajataca Dam, PR Sep 2017

Successful Intervention Example

US Army Corps of Engineers®

Insights:
Get help:

- Dam engineering expertise
- Equipment, materials, operators
- Plan for assistance in EAP

Guajataca Dam, PR Sep 2017

Successful Intervention Example

US Army Corps of Engineers®

Guajataca Dam, PR Sep 2017

Another Success Intervention Example

Fontenelle Dam, WY 1965

1 mile long, 126 ft high, 345,000 ac-ft
New dam, first filling in 1965

Day 1

Friday Sept 3, 1965

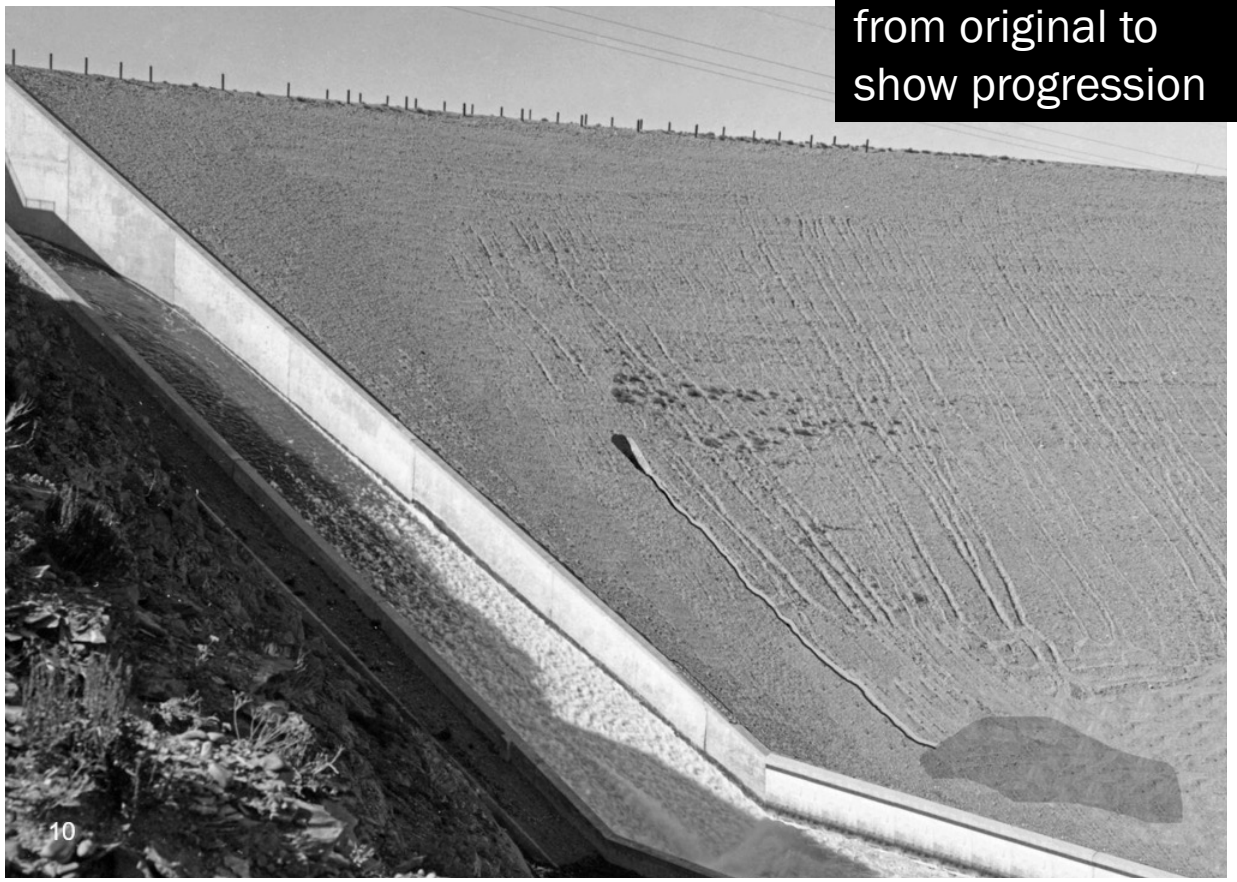


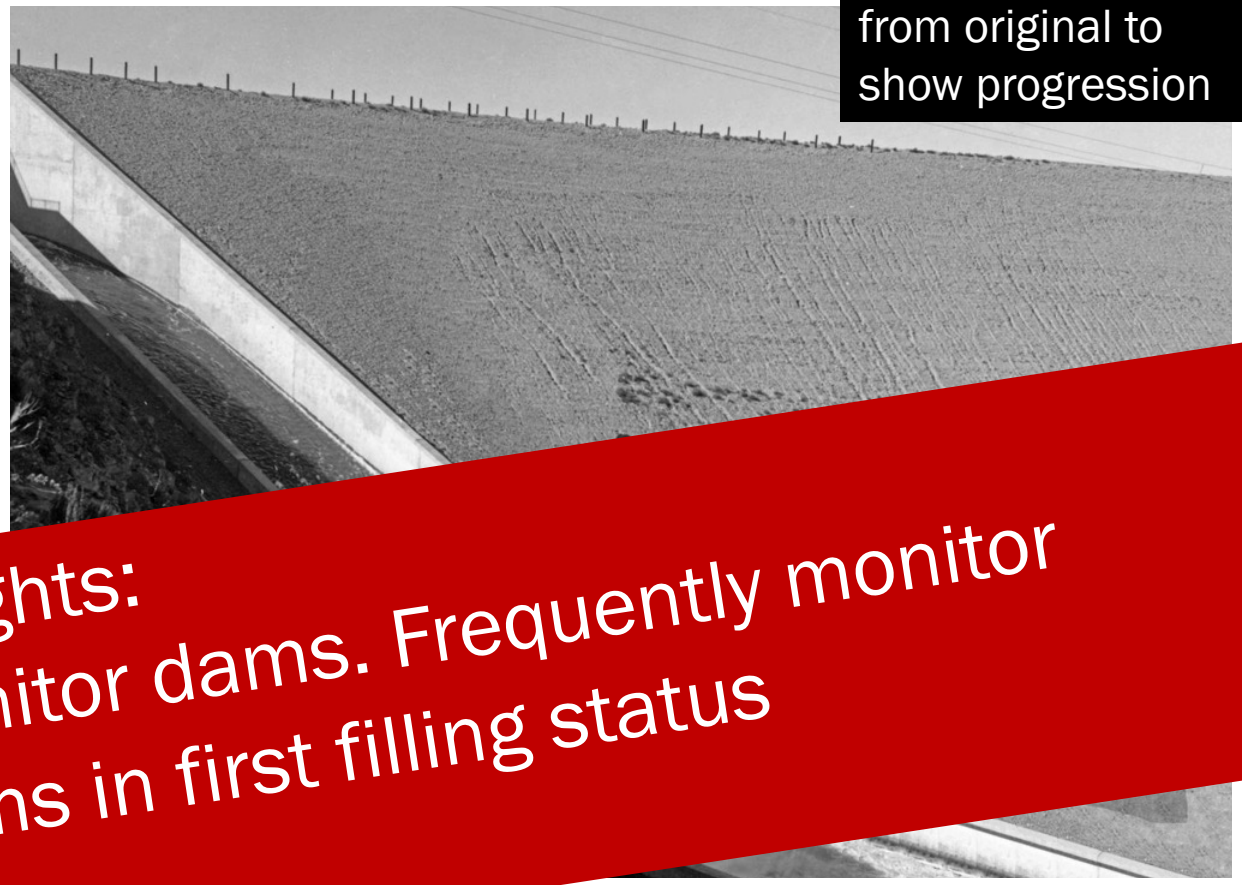
Photo changed from original to show progression

10:30 AM small trickle of water on downstream face of the dam

Fontenelle Dam, WY 1965

Day 1

Friday Sept 3, 1965



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Insights:
Monitor dams. Frequently monitor dams in first filling status

10:30 AM small trickle of water on downstream face of the dam

Fontenelle Dam, WY 1965

Day 1

Friday Sept 3, 1965

- Had his other staff monitor the seepage/leak

Fontenelle Dam, WY 1965

- Had his other staff monitor the seepage/leak

Day 1

Friday Sept 3, 1965

Insights:
Boost monitoring of problem areas
During dam incidents – especially long duration incidents - are highly demanding of staff time. Call people into help and relieve local staff

Fontenelle Dam, WY 19

Day 1

Friday Sept 3, 1965

Fontenelle Dam, WY 1965

4:00 PM 1 cubic-ft/sec (440 gal/min) leak

Day 1

Friday Sept 3, 1965

Fontenelle Dam, WY 1965

6:00 PM 5 cubic-ft/sec (2200 gal/min leak

Day 1

Friday Sept 3, 1965

Photo changed from original to show progression

Insight:
The situation can change rapidly and accelerate.

Fontenelle Dam, WY 1965

6:00 PM 5 cubic-ft/sec (2200 gal/min leak

Day 1

Friday Sept 3, 1965

- Called Denver Engineering center and the Salt Lake City Regional Office

Fontenelle Dam, WY 1965

6:00 PM 5 cubic-ft/sec (2200 gal/min leak

Intervention Example

- Called Denver Engineering center and the Salt Lake City Regional Office

Day 1

Friday Sept 3, 1965

Insight:

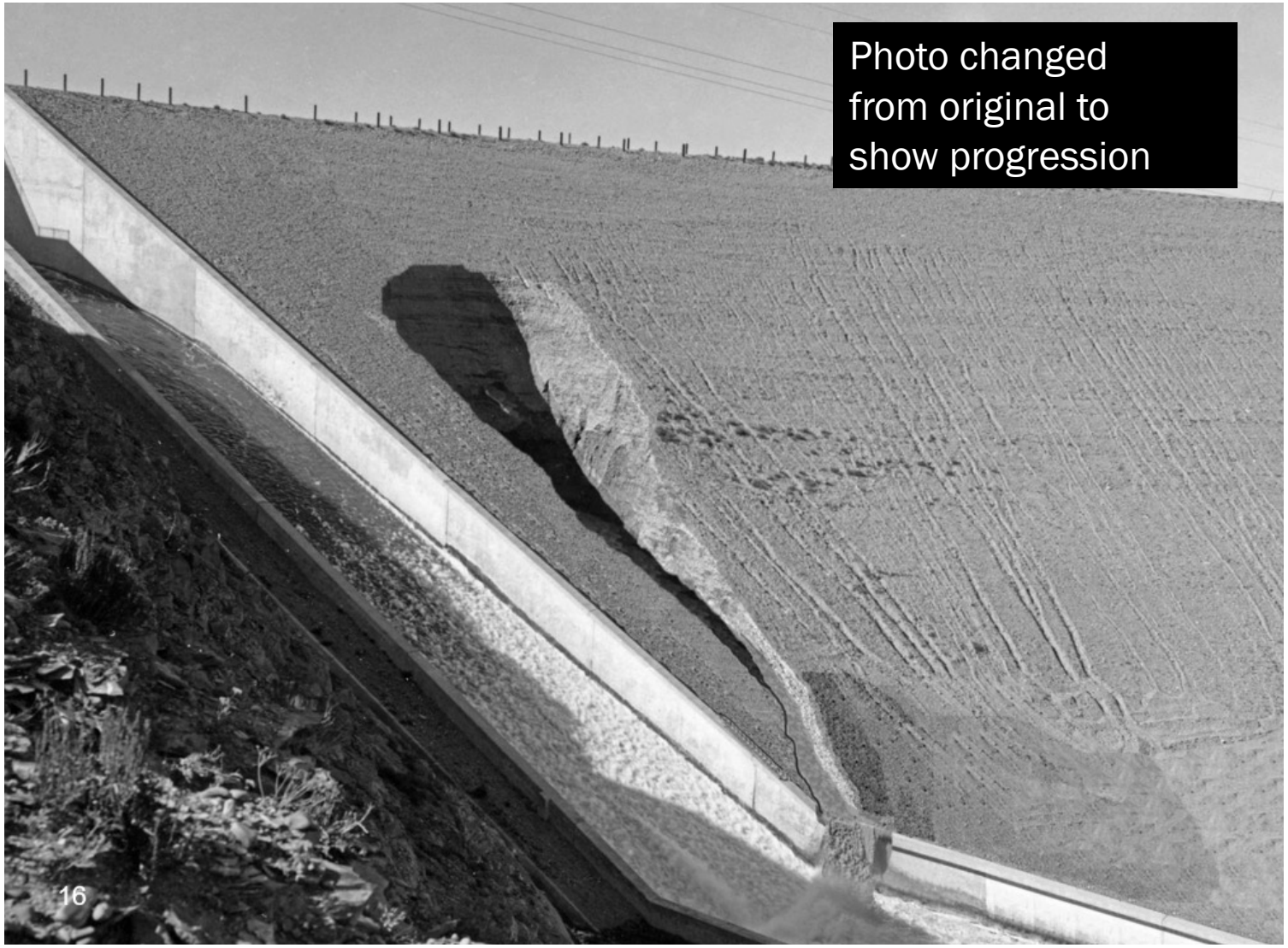
- EAPs should contain contacts for quickly getting technical expertise
- Don't go it alone in the field.

6:00 PM 5 cubic-ft/sec (2200 gal/min) leak

Fontenelle Dam, WY 1965

Day 1

Friday Sept 3, 1965

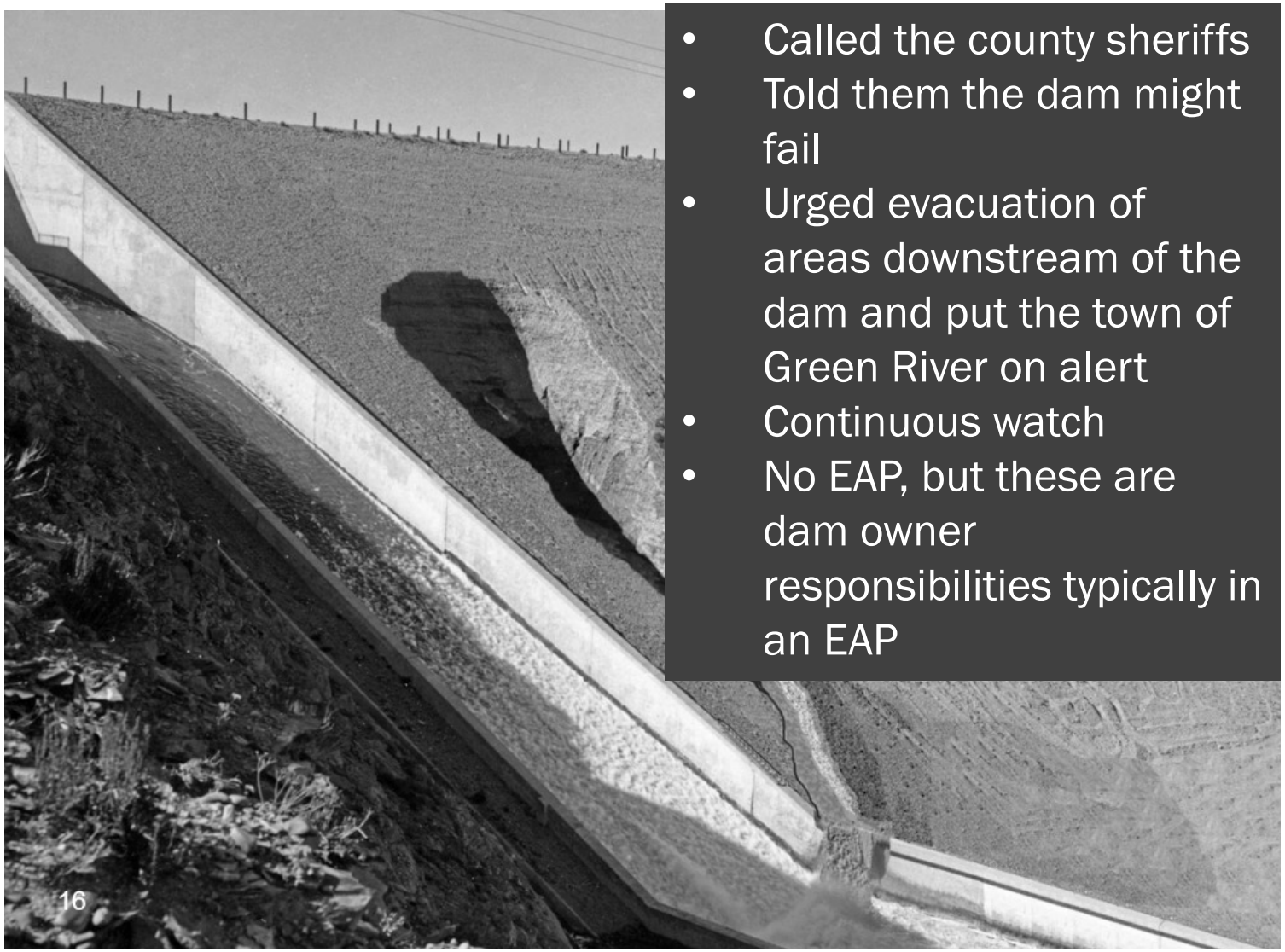


Fontenelle Dam, WY 1965

7:30 PM 10 cubic-ft/sec (4400 gal/min) leak

Day 1

Friday Sept 3, 1965



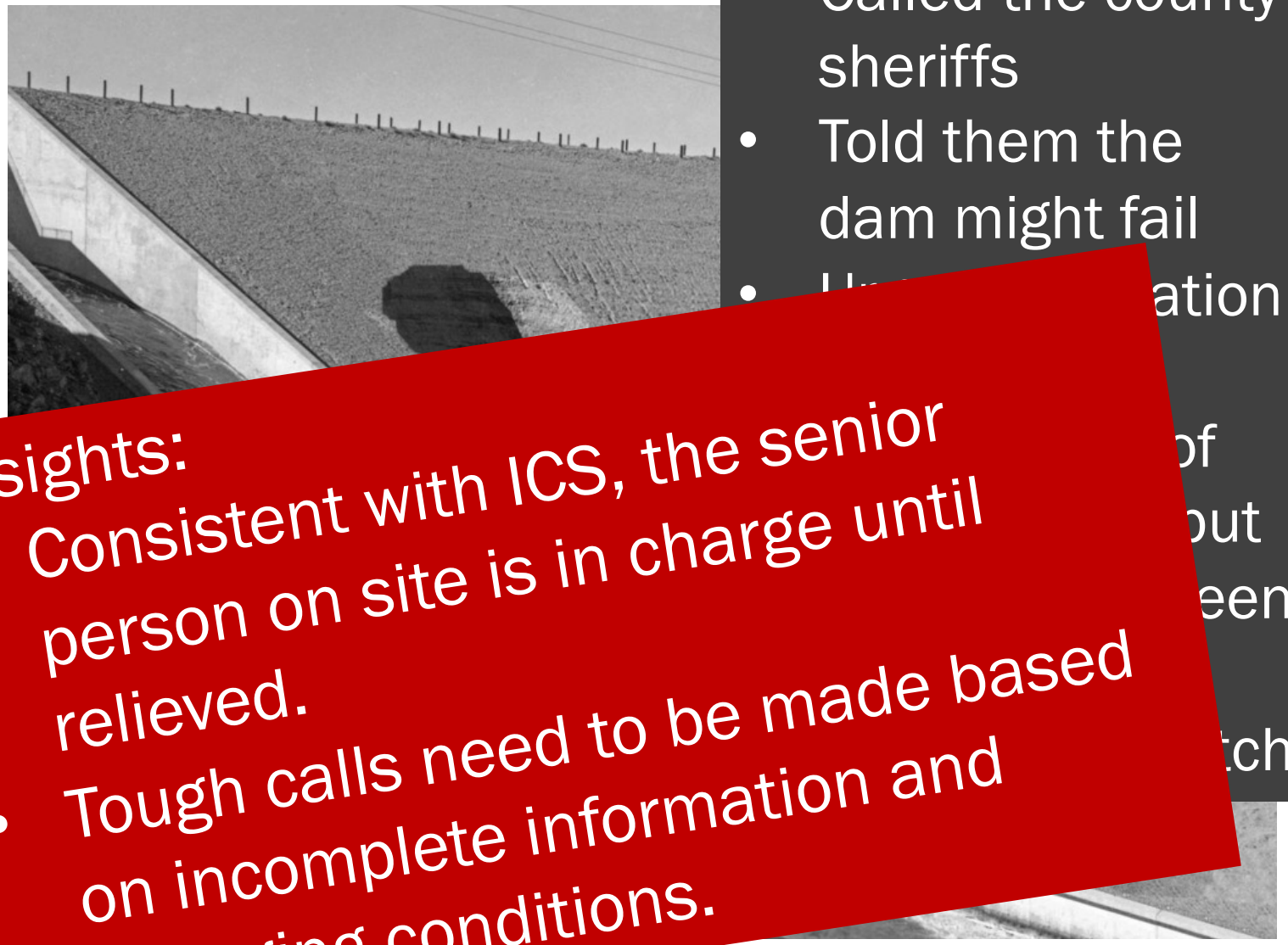
- Called the county sheriffs
- Told them the dam might fail
- Urged evacuation of areas downstream of the dam and put the town of Green River on alert
- Continuous watch
- No EAP, but these are dam owner responsibilities typically in an EAP

Fontenelle Dam, WY 1965

7:30 PM 10 cubic-ft/sec (4400 gal/min/min leak

Day 1

Friday Sept 3, 1965



- Called the county sheriffs
- Told them the dam might fail
- Un… ation

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Insights:

- Consistent with ICS, the senior person on site is in charge until relieved.
- Tough calls need to be made based on incomplete information and changing conditions.

Fontenelle Dam, WY 19…

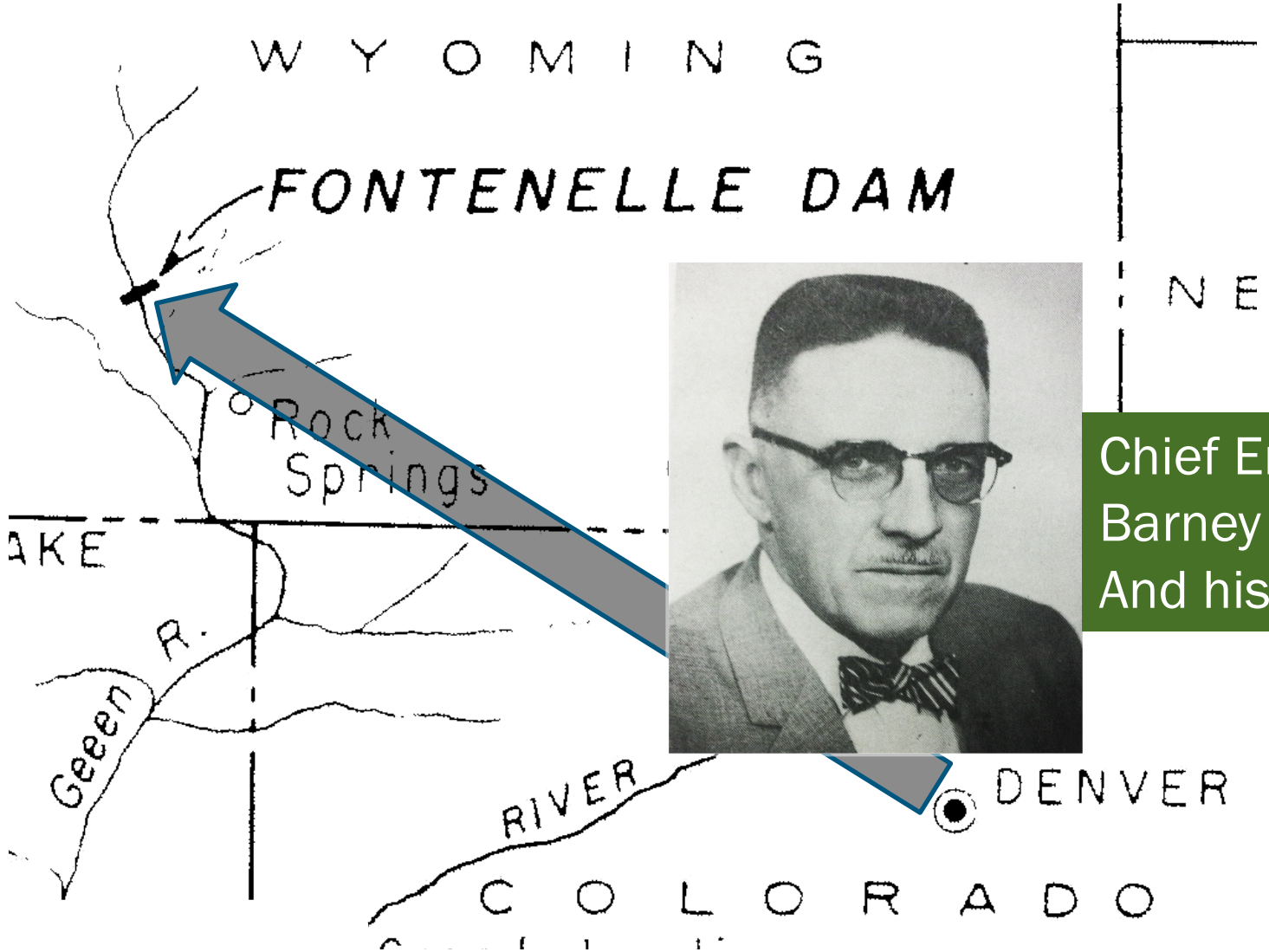
…:30 PM 10 cubic-ft/sec (4400 gal/min) leak

Town of Green River

FEMA

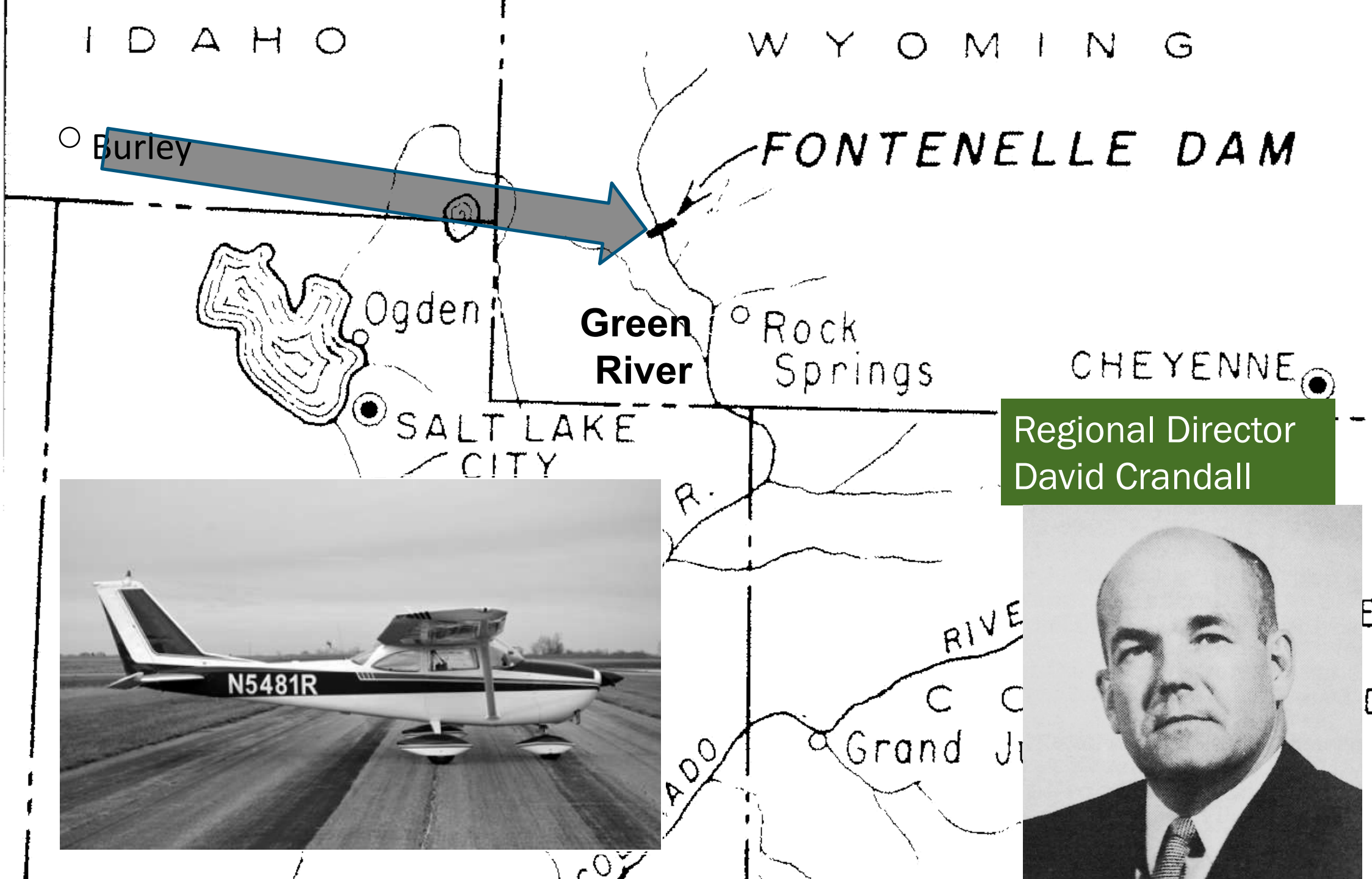
Day 2

Friday Sept 4, 1965



Chief Engineer
Barney Bellport
And his engineers

Fontenelle Dam, WY 1965



Regional Director David Crandall

IDAHO

WYOMING

Burley

FONTENELLE DAM

HEYENNE

DE

LORADO

Grand Junction

Insights:

- Information during incidents is sketchy, incomplete, and changes.
- "Over respond" (get to the site) to make sure you are in a good position to respond if it gets serious

Intervention Example

Day 2

Sat Sept 4, 1965

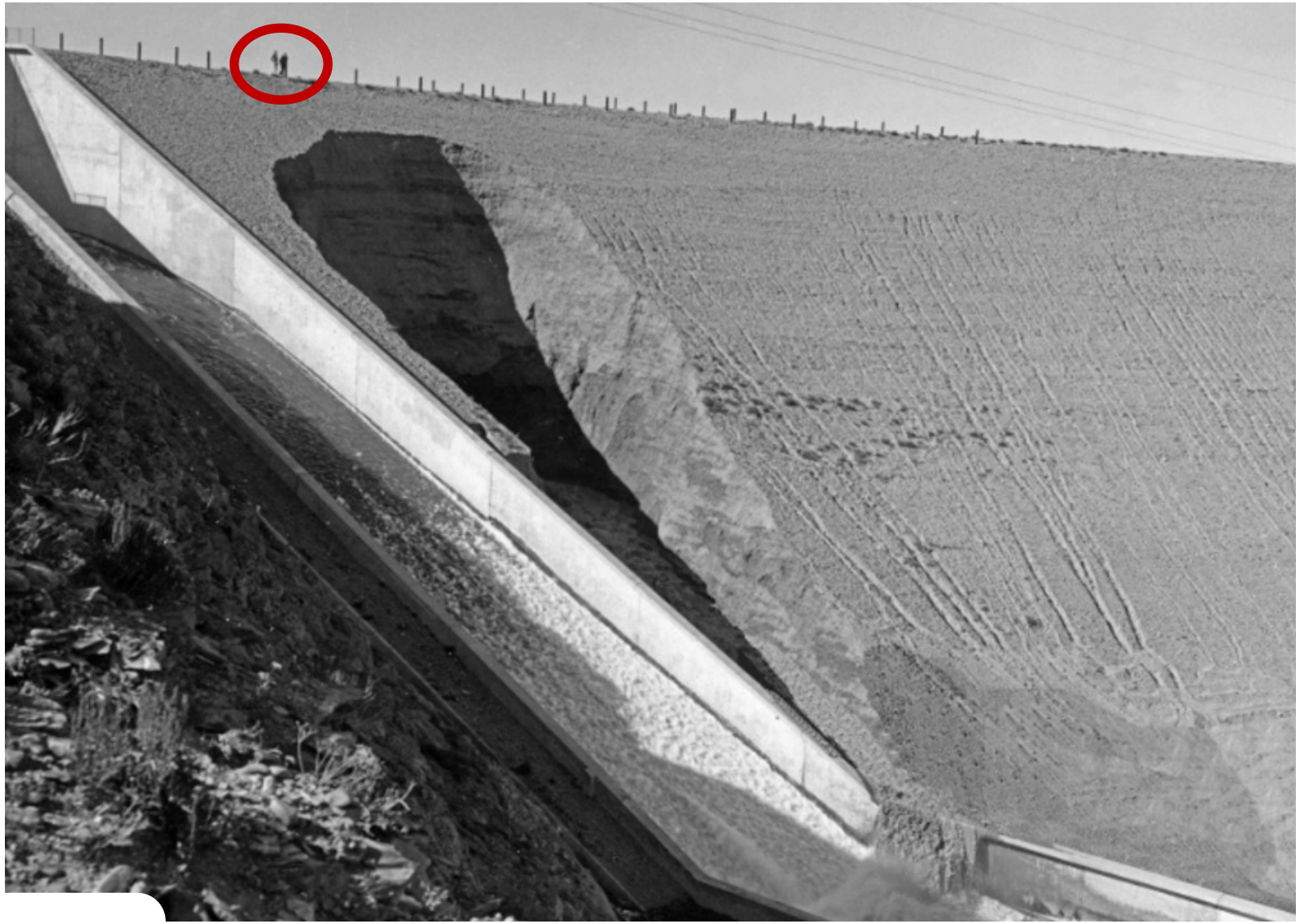
Cavity 170 ft-long, 65-ft wide, 50-ft deep

Fontenelle Dam, WY 1965

Intervention Example

Day 2

Sat, Sept 4, 1965

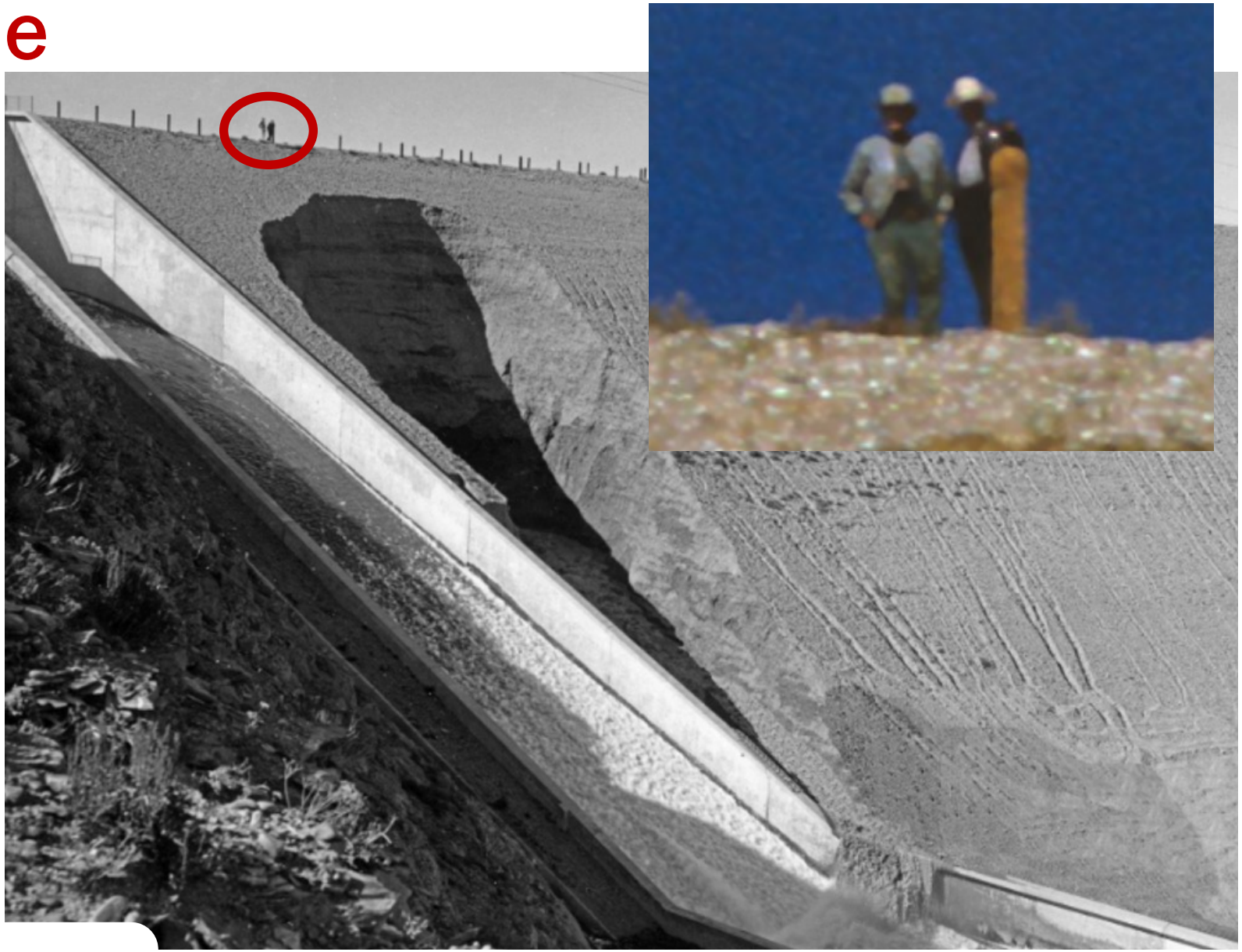


Fontenelle Dam, WY 1965

Intervention Example

Day 2

Friday Sept 3, 1965



Fontenelle Dam, WY 1965

Intervention Example

Day 2

Friday Sept 3, 1

Insights:

- Consider inviting public safety officials to come see a developing incident themselves

Fontenelle Dam, WY 1965

Intervention Example

Day 2

Friday Sept 3, 1965

Fontenelle Dam, WY 1965

Intervention Example

Day 2

Friday Sept 3,

Insight:

- Get the best technical, local and regional people together to evaluate the situation, come up with options and decide what to do.

Fontenelle Dam, WY 1965

Intervention Example

Day 2

Sat Sep 4, 1965

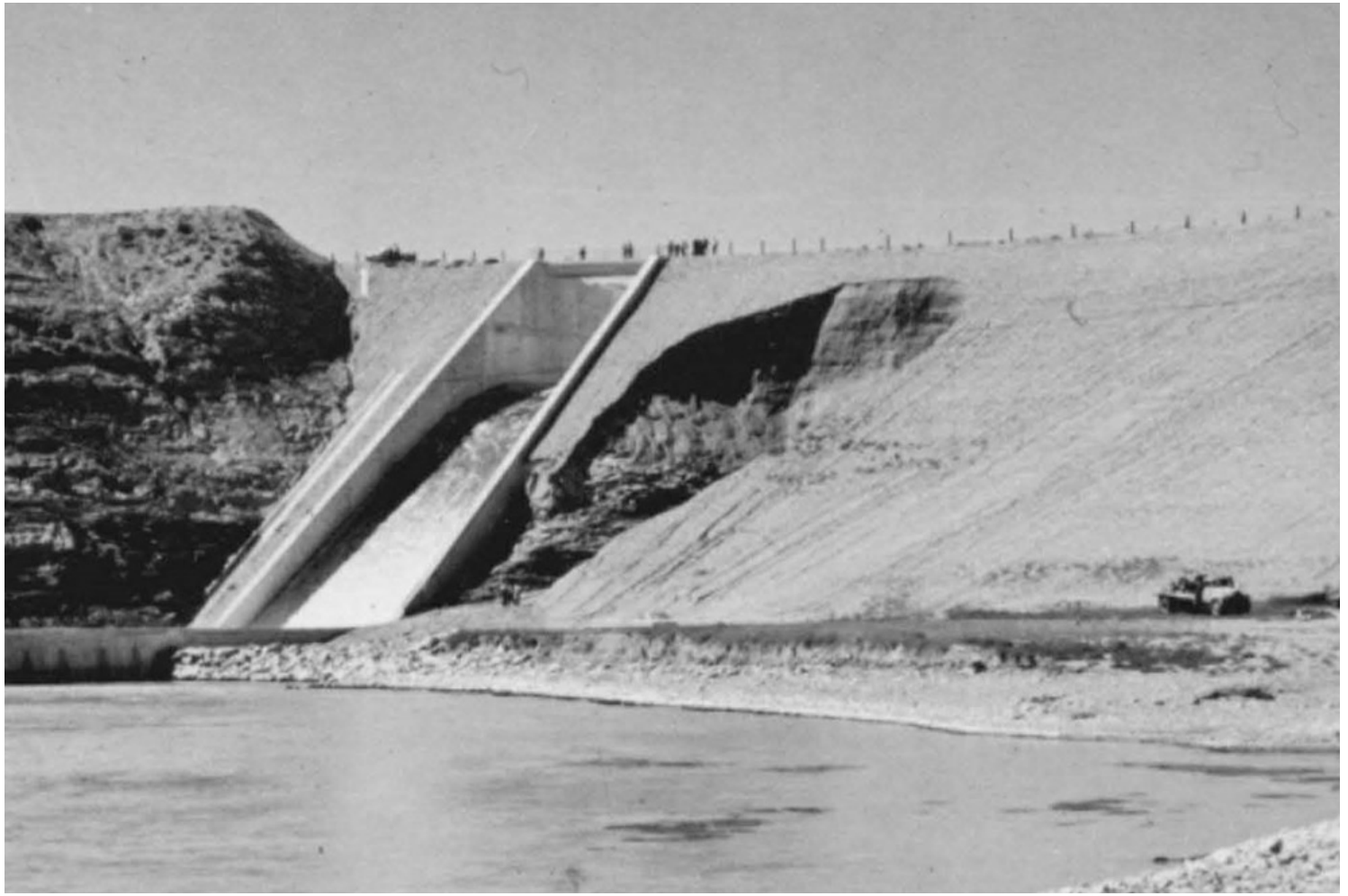
Decision: Lower the Reservoir

Fontenelle Dam, WY 1965

Intervention Example

Day 2

Sat Sep 4, 1965



Fontenelle Dam, WY 1965

Decision: fill the void to stop the cavity from getting bigger

End of Day 2

Sat Sep 4, 1965

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Regional Office - Region 4
Salt Lake City, Utah

September 4,1965

PRESS RELEASE

The small leak which developed Friday night near the right abutment of Fontenelle Dam is serious but not critical, B. P. Bellport, Chief Engineer for the Bureau of Reclamation said today. Immediate steps are being taken to eliminate all danger by lowering the Fontenelle Reservoir level and by filling the eroded area

FEMA

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Insights:

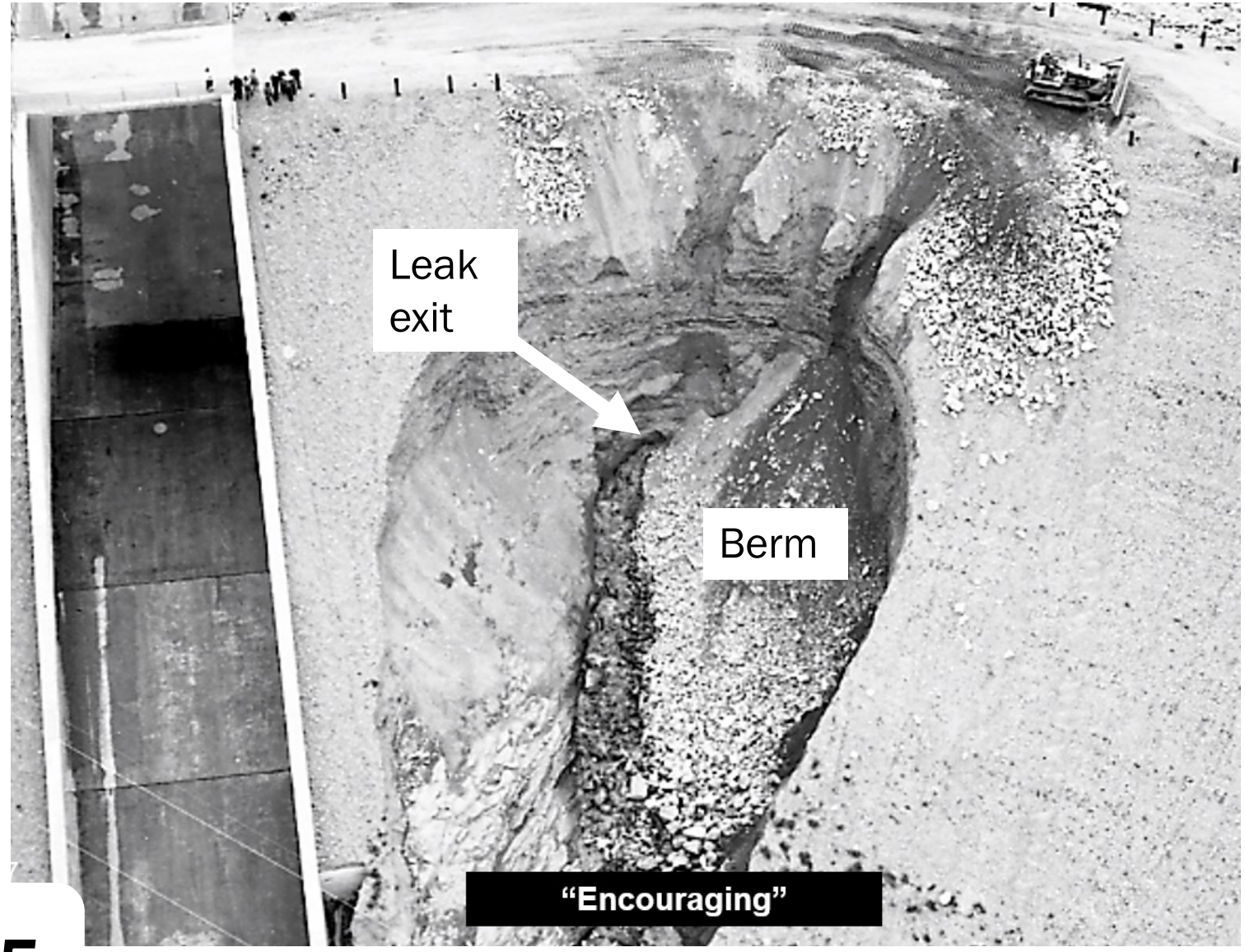
- For a major incident, get ahead of rumors – push out quality info with press releases – get your public affairs people involved.

FEMA

Intervention Example

Day 3

Sunday Sept 5, 1965

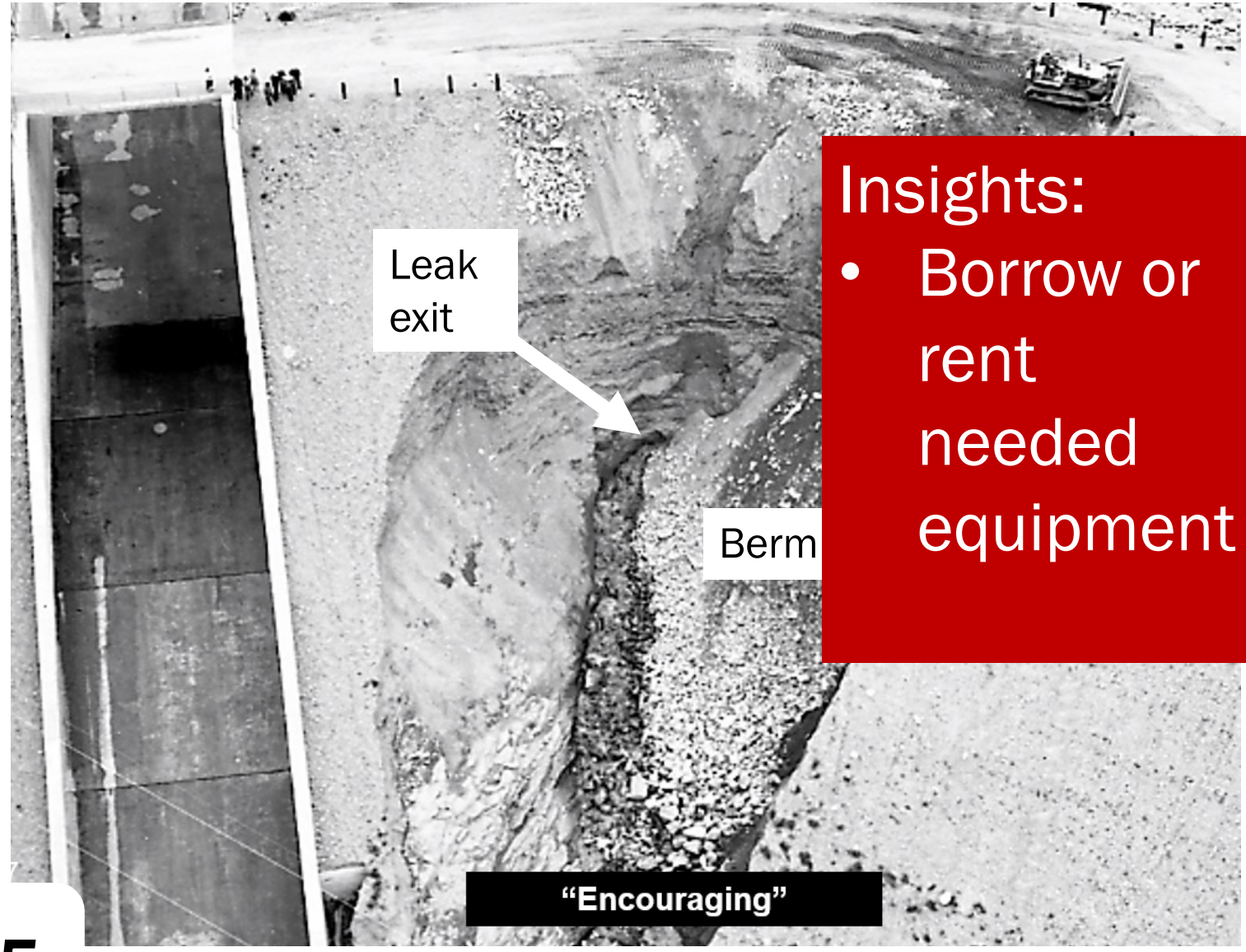


Fontenelle Dam, WY 1965

Intervention Example

Day 3

Sunday Sept 5, 1965



Insights:

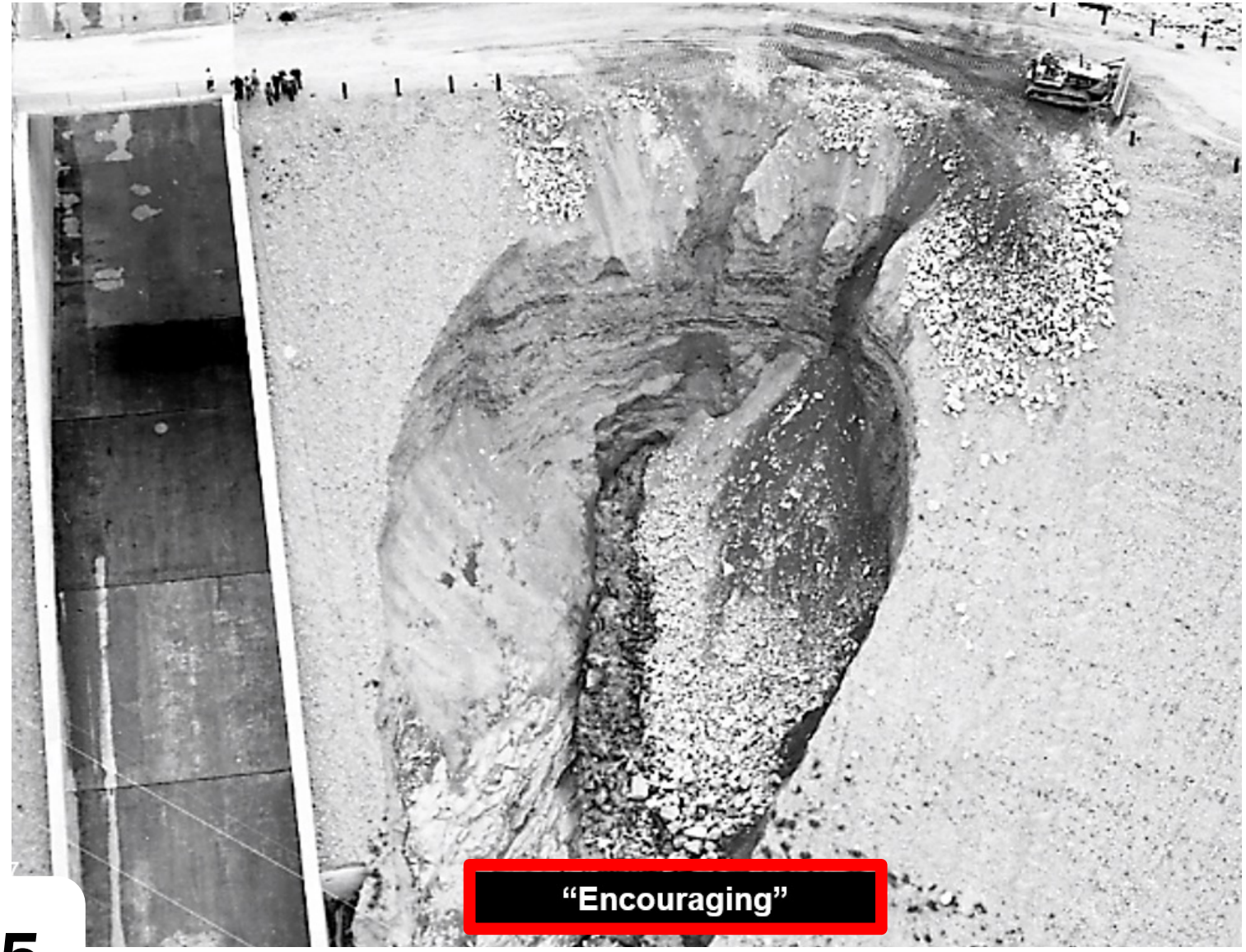
- Borrow or rent needed equipment

Fontenelle Dam, WY 1965

Intervention Example

Day 3

Sunday Sept 5, 1965



Fontenelle Dam, WY 1965

Intervention Example

Day 3

Sunday Sept 5

1965

Insights:

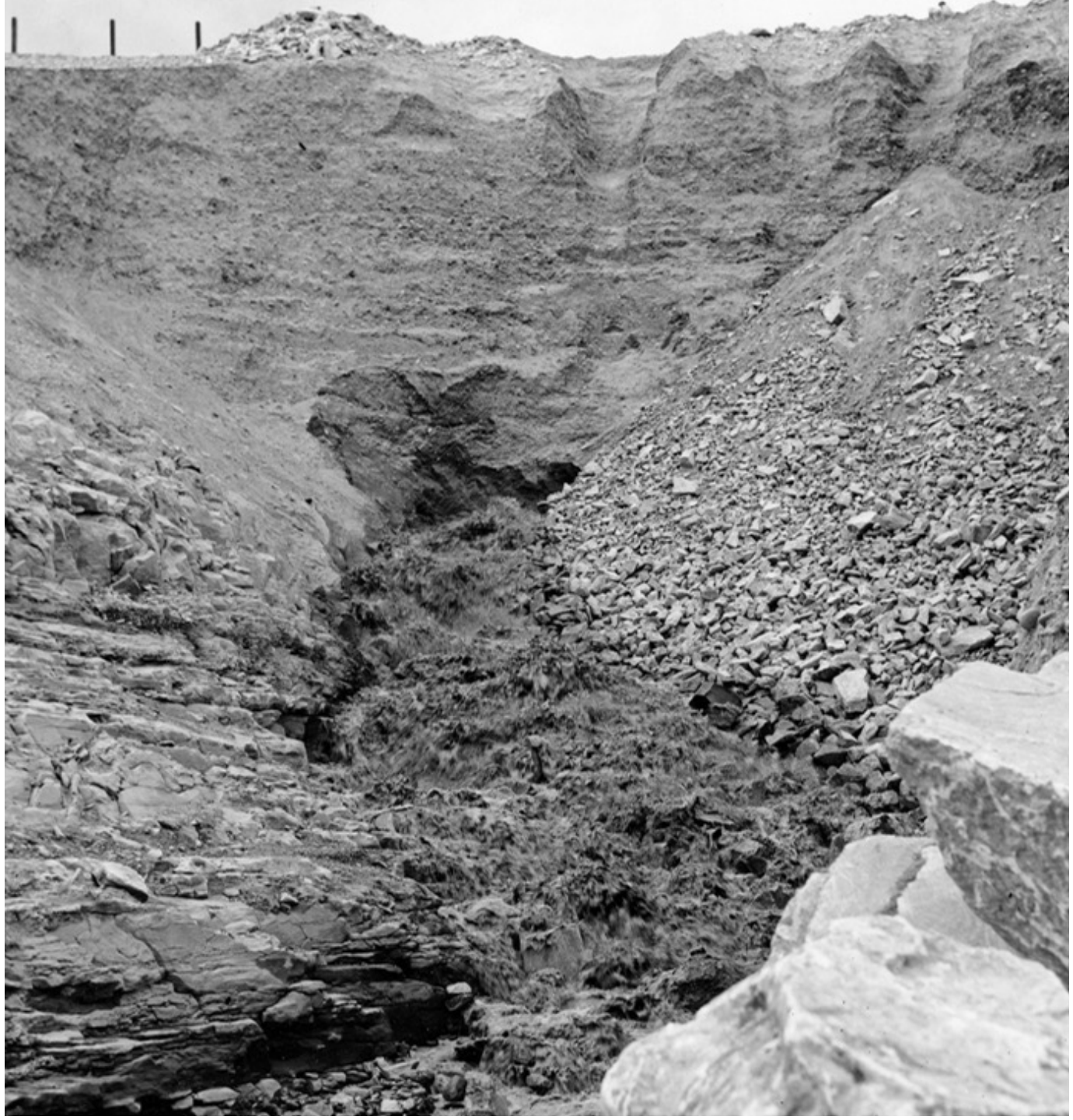
- Don't get cocky/overconfident
- The situation can change rapidly during an incident…
- As we will see . . . .

Fontenelle Dam, WY 1965

Intervention Example

Day 3

Sunday Sept 5, 1965



Fontenelle Dam, WY 1965

Day 4

Monday Sept 5, 1965

Fontenelle Dam, WY 1965

Day 4

Monday Sept 5, 1965

Fontenelle Dam, WY 1965

Day 4

Monday Sept 5, 1965

Fontenelle Dam, WY 1965

Day 4

Monday Sept 5, 1965

- 15 x 20-ft sinkhole appeared with a woosh and a cloud of dust
- One person raced down to the town of Green River and told people the dam was failing.
- The Sheriff said “I have Reclamation on the phone and the water is still in the reservoir”.

Fontenelle Dam, WY 1965

Day 4

Monday Sept 5, 1965

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- One person raced d to the town of Gree River and told peo the dam was failin
- The Sheriff said “I have Reclamation on the phone and the water is still in the reservoir”.

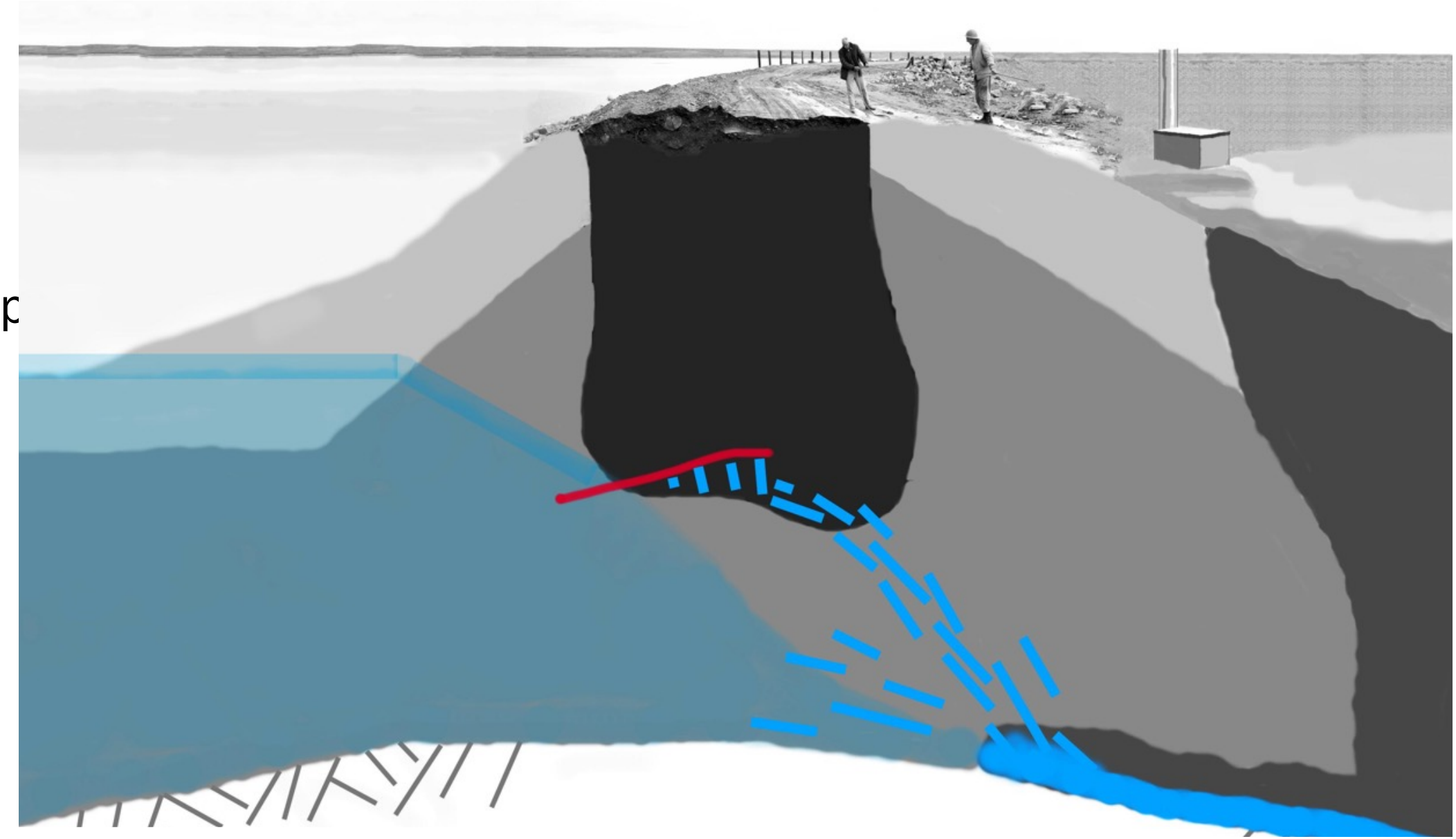
Insights:

- Remain in close communication with public safety officials during an incident.

Fontenelle Dam, WY 1965

Day 4

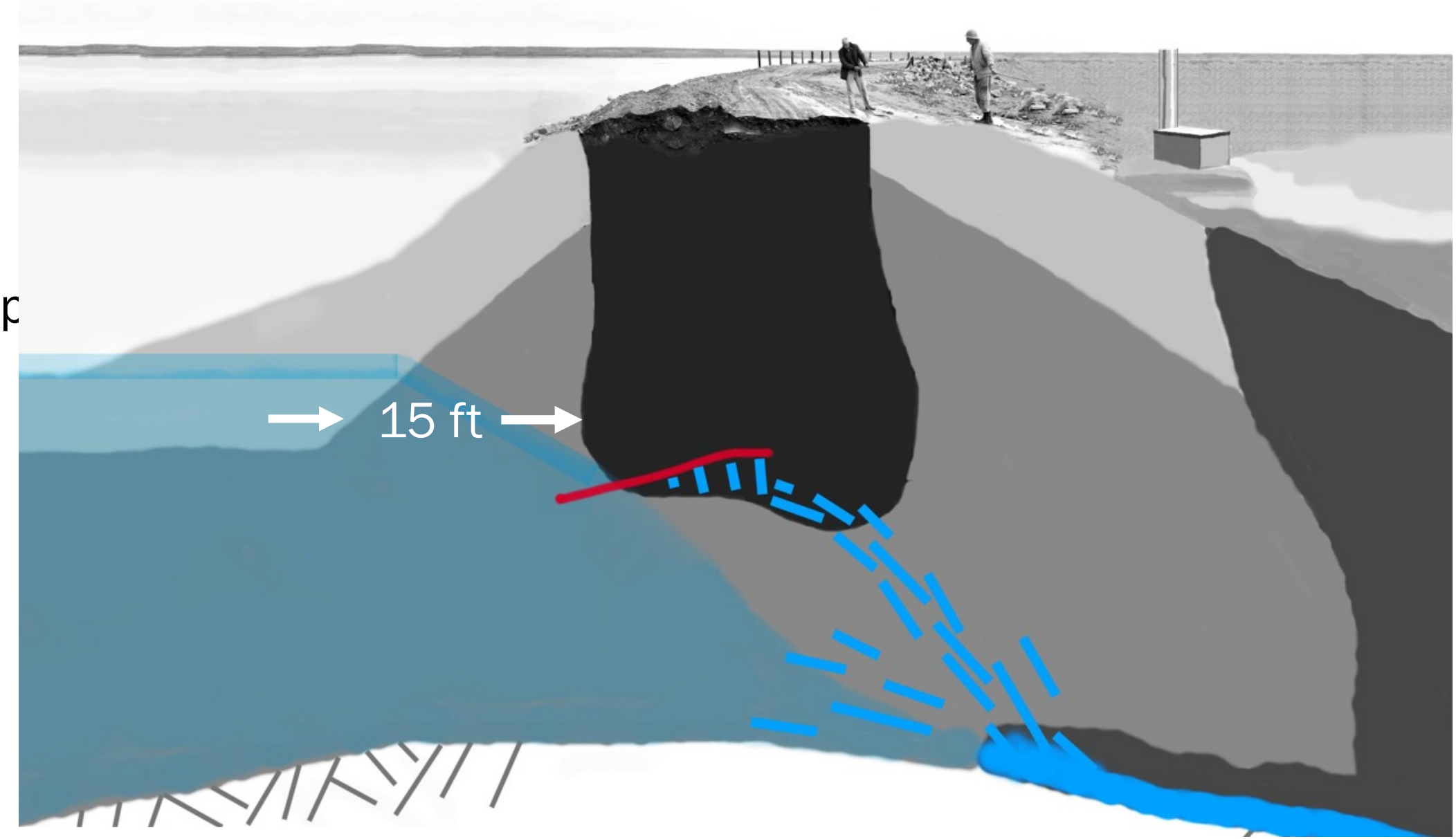
Monday Sep
1965



Fontenelle Dam, WY 1965

Day 4

Monday Sep
1965



Fontenelle Dam, WY 1965

Day 4

Monday Sept 5, 1965

Decided to immediately fill void

Fontenelle Dam, WY 1965

Day 4

Monday Sept 5, 1965

Insights:

- In acute, high-pressure situations, empower your people to do what needs to be done – confirm with officials and technical staff ASAP.

Decided to immediately fill void

Fontenelle Dam, WY 1965

Day 7

Thurs Sep 7, 1965

Governor visited, lots of press

Fontenelle Dam, WY 1965

Day 7

Thurs Sep 7, 1965

Insights:

- Major incidents attract a lot of press, public and governmental attention

Governor visited, lots of press

FEMA

Intervention Example

Day 8

Fri Sept 10, 1965

Fontenelle Dam, WY 1965

Day 10

Sunday Sep 12, 1965

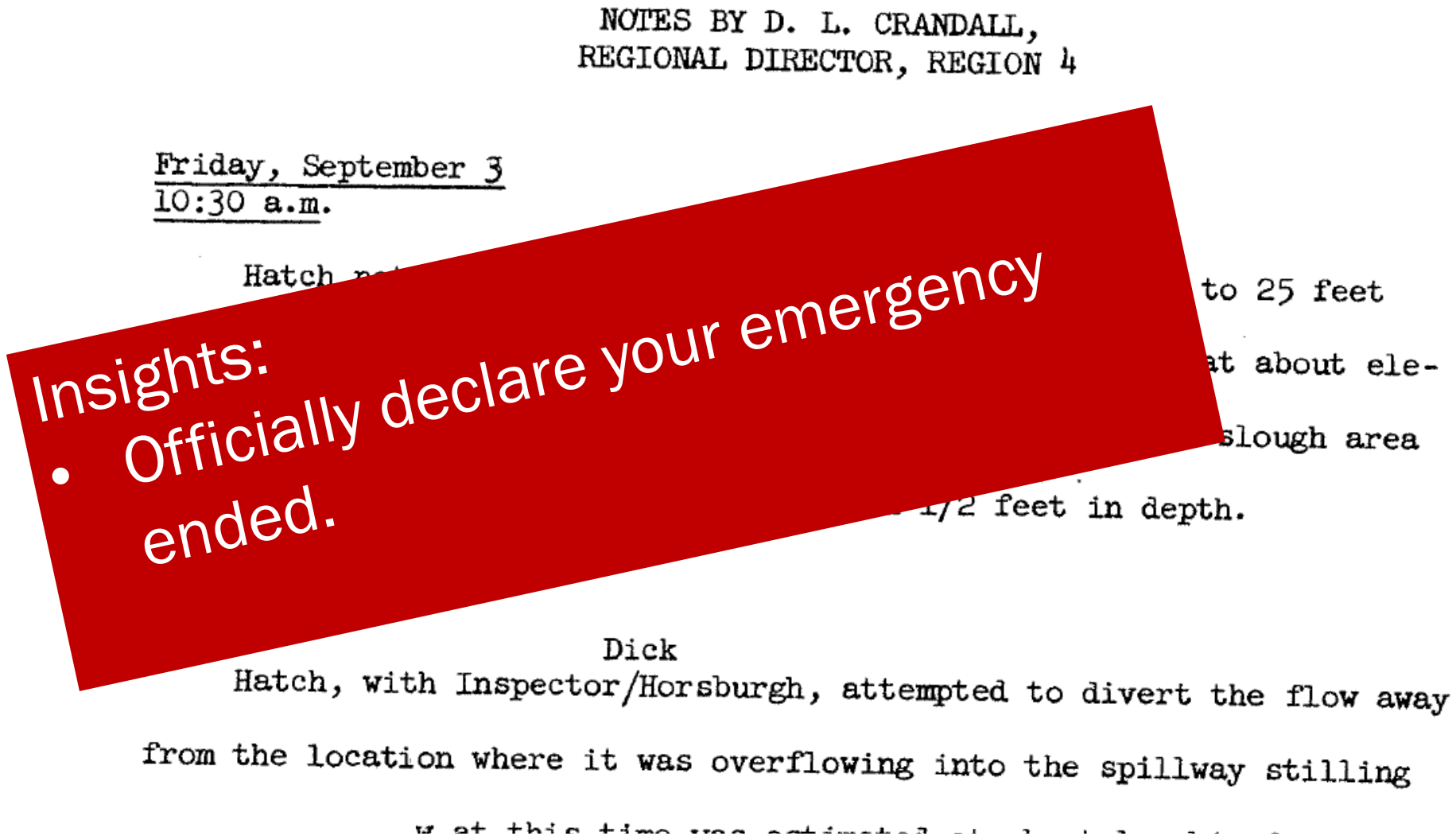
BUREAU OF RECLAMATION
Fontenelle, Wyoming
[illegible], Sunday, September 12, 1965

"The alert called on Friday, September 3, when developed a serious leak was lifted at 9:00AM today David L. Crandall announced at Fontenelle, Wyoming. of Reclamation crews under Project Construction Engi

Fontenelle Dam, WY 1965

Day 10

Sunday Sep 12, 1965



NOTES BY D. L. CRANDALL,
REGIONAL DIRECTOR, REGION 4

Friday, September 3
10:30 a.m.

Hatch

to 25 feet

at about ele-

slough area

1/2 feet in depth.

Dick
Hatch, with Inspector/Horsburgh, attempted to divert the flow away

from the location where it was overflowing into the spillway stilling

Insights:

- Officially declare your emergency ended.

Fontenelle Dam, WY 1965

NOTES BY D. L. CRANDALL,
REGIONAL DIRECTOR, REGION 4

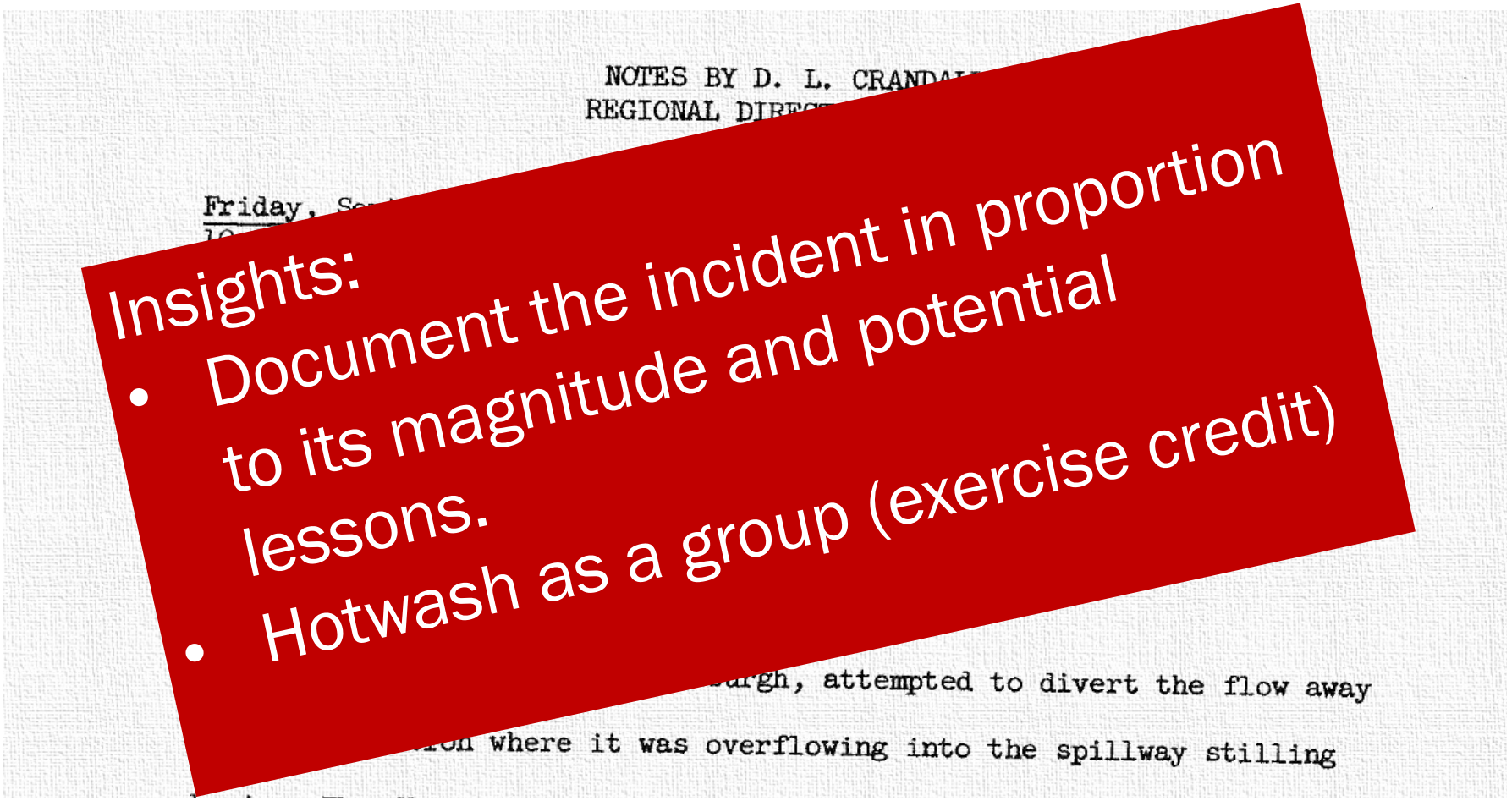
Friday, September 3
10:30 a.m.

Hatch noticed small trickle of water flowing out 20 to 25 feet east of the spillway wall opposite spillway station 4+35 at about elevation (obtained from map). Small "V" notch slough area being developed from this trickle about 1 1/2 feet in depth.

4:00 p.m.

Dick Hatch, with Inspector/Horsburgh, attempted to divert the flow away from the location where it was overflowing into the spillway stilling

Fontenelle Dam, WY 1965



Fontenelle Dam, WY 1965

Another Successful Intervention Example

- Ring Dam
- Edge of the Great Salt Lake and I-15
- 14.5 miles long
- 36-ft-High
- 215,000 ac-ft

A.V. Watkins Dam 2006

Day 1: November 11, 2006
Feedlot operator noticed seepage into the South Drain

A.V. Watkins Dam 2006

Day 1: November 11, 2006

Feedlot operator noticed seepage into the South Drain

A.V. Watkins Dam 2006

Day 2, November 12, 2006

Feedlot operator saw seepage continuing. No notification

A.V. Watkins Dam 2006

Day 2, November 12, 2006

Feedlot operator saw seepage continuing. No notification

Insights:

- Train people who live, work and frequent your dams what early problems at dams look like and “see something, say something”

A.V. Watkins Dam 2006

Day 3, November 12, 2006

- Feedlot operator saw seepage color change and notified district
- District visited dam and called Reclamation staff
- About 1:00PM Reclamation staff left for the dam

A.V. Watkins Dam 2006 1

November 13, 2006

- Reclamation responded - Declared EAP Response Level 1 but implemented some steps from Response Level 2

FEMA

A.V.WATKINS DAM &
RESERVOIR

EMERGENCY ACTION PLAN

Watkins UT

October 27, 2009

Bureau of Reclamation,
US Department of the Interior

November 13, 2006

A.V.WATKINS DAM & RESERVOIR

- Stationed equipment on west dam (LOW hazard section)
- Opened outlet works - just 4 inches/day lowering

FEMA

November 13, 2006

- Ordered Filter/drain materials and equipment
- Rented Light plants
- While in transit to site
- UNAUTHORIZED PURCHASES!!!!

FEMA

November 13, 2006

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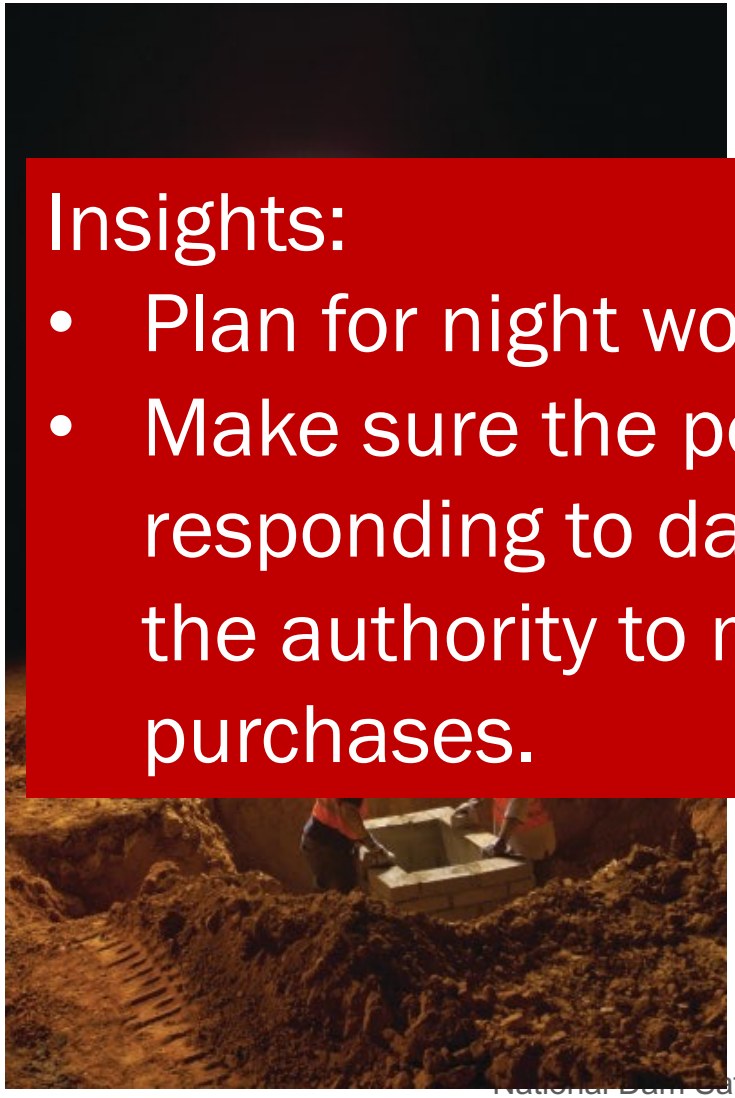


Insights:

- Plan for night work in an emergency
- Make sure the people who will be responding to dam incidents have the authority to make immediate purchases.

A.V. Watkins Dam 2006

What they found arriving on site was alarming:
Foundation Internal erosion was well-advanced

150 – 250 gpm of seepage exiting sand boils at toe of dam

A.V. Watkins Dam 2006

A.V. Watkins Dam 2006

A.V. Watkins Dam 2006

Slope stability failure initiating with cracking extended to upstream crest

A.V. Watkins Dam 2006

A.V. Watkins Dam 2006

A.V. Watkins Dam 2006

A.V. Watkins Dam 2006

A.V. Watkins Dam 2006

Insights:

- Continue regular monitoring even after you think the problem is resolved
- Don’t end the incident until a period showing sufficient satisfactory performance has passed.

A.V. Watkins Dam 2006

A.V. Watkins Dam 2006

A.V. Watkins Dam 2006

A.V. Watkins Dam 2006

Insight: It was a Team Effort

INTERNAL

- Area Office
- Regional Office
- Dam Safety Office
- TSC
- Washington

EXTERNAL

- WBWCD (District)
- County Authorities
- Congressional
- Public/Land Owners
- State
- Press

Source Credit

- Bruce Barrett, Bureau of Reclamation
  - Upper Colorado Regional Office

A.V. Watkins Dam 2006

Successful Intervention: 2006 Lake Needwood Dam Seepage Incident

- 65-ft-high Embankment Dam in Maryland
- Seep at left groin

Lake Needwood Dam Seepage Incident 1

Lake Needwood Dam Seepage Incident

- In June, 2006 heavy rains caused a 23 foot rise in Lake Needwood, located in suburban Washington, D.C.
- Uncontrolled cloudy seepage through the dam and foundation occurred and the dam was on the verge of failure.

Lake Needwood Dam Seepage Incident 2

Lake Needwood Dam Seepage Incident

Lake Needwood Dam Seepage Incident 3

Insight:
Ensure there is truck access to as many of the areas of the dam as possible - especially the downstream toe

Lake Needwood Dam Seepage Incident

Lake Needwood Dam Seepage Incident 4

A human “bucket brigade was used to transport sand and gravel to the seepage location

Lake Needwood Dam Seepage Incident

Lake Needwood Dam Seepage Incident 5

A human “bucket brigade was used to transport sand and gravel to the seepage location

Insights:

- Improvise if necessary
- EAPs should include sources for sand, gravel, equipment rental and operators

Lake Needwood Dam Seepage Incident

Lake Needwood Dam Seepage Incident 6

Filter fabric, sand, and gravel were used to control the seepage as the reservoir was drawn down.

Lake Needwood Dam Seepage Incident

Lake Needwood Dam Seepage Incident, 2006

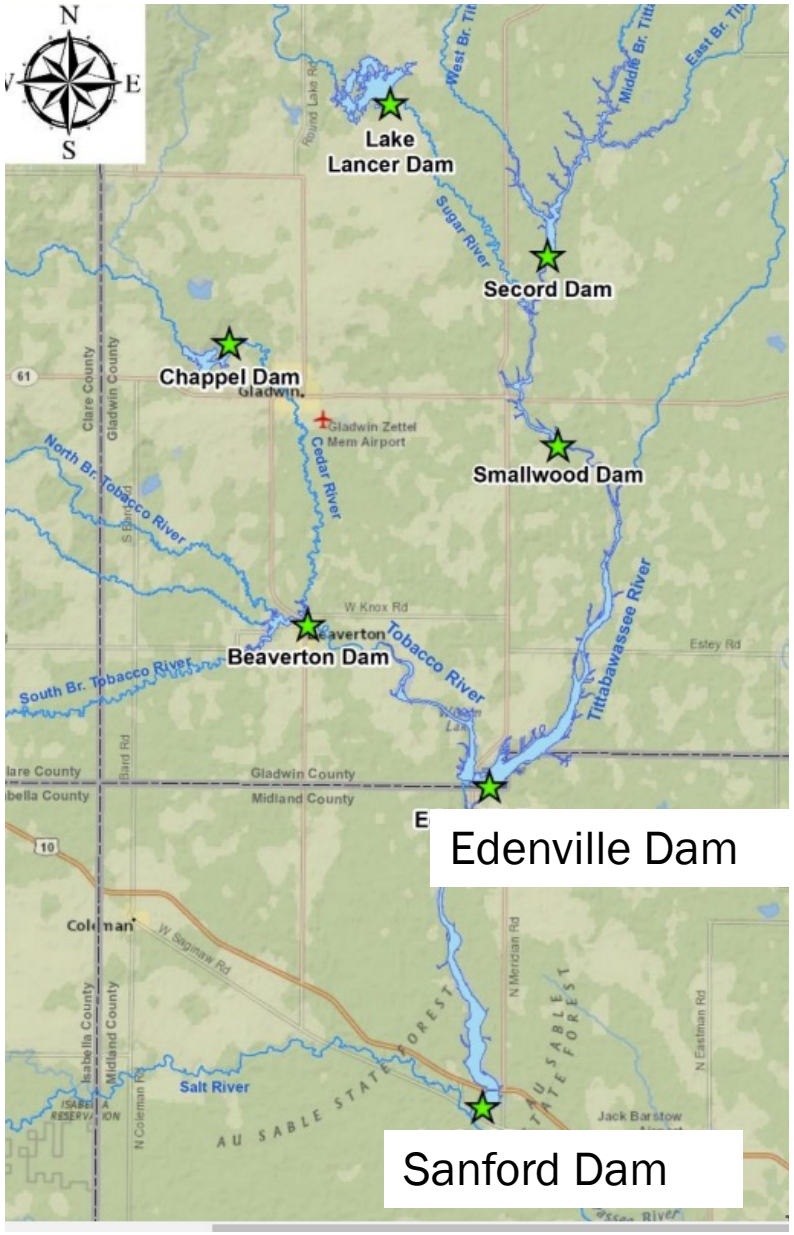
- After 2 nights, evacuees were allowed to return to their homes.

Detection with Monitoring, Warning and Evacuation (no intervention) and Failure 1

2020 Edenville and Sanford Dam Failures

Detection with Monitoring, Warning and Evacuation 2

- Edenville and Sanford dams were hydropower embankment dams on the same Titttabawassee River

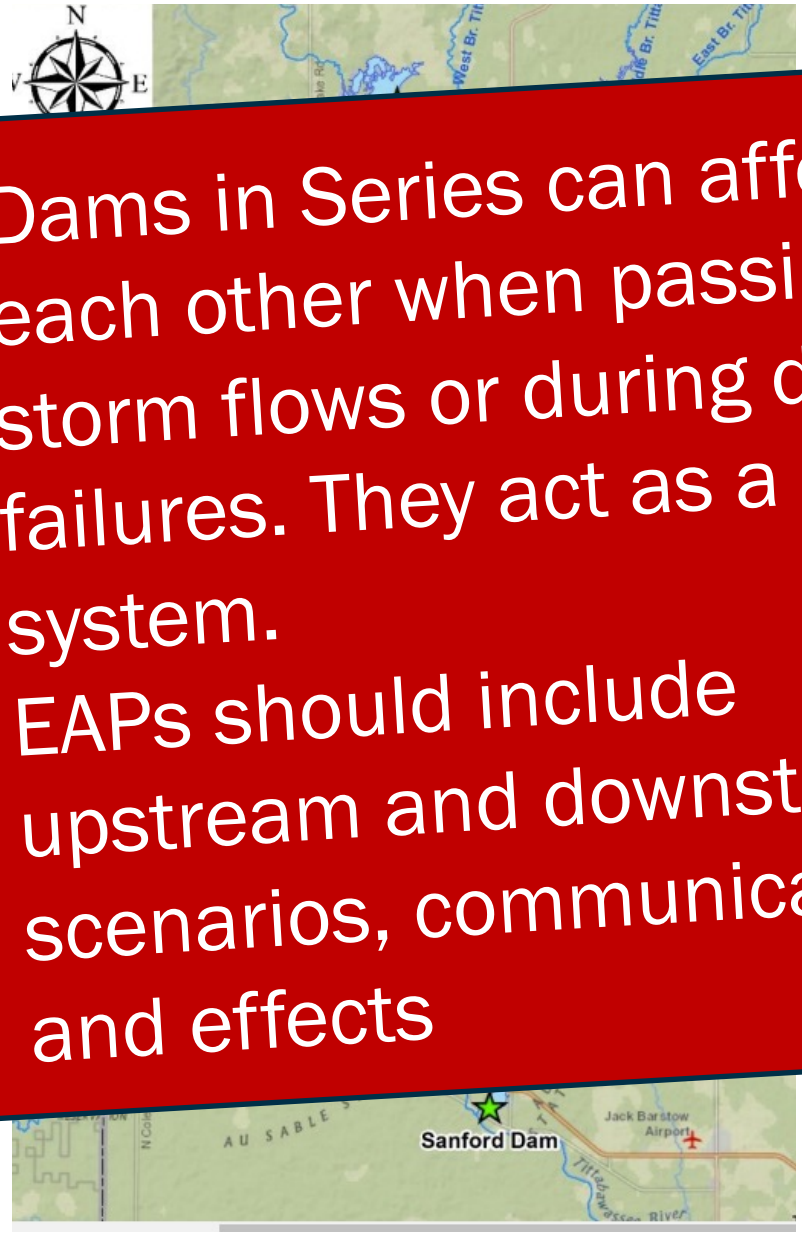


Edenville and Sanford Dam Failures

Detection with Monitoring, Warning and Evacuation 3

- Late May 2020: 3” to 6” of rain on frozen ground and snowmelt event

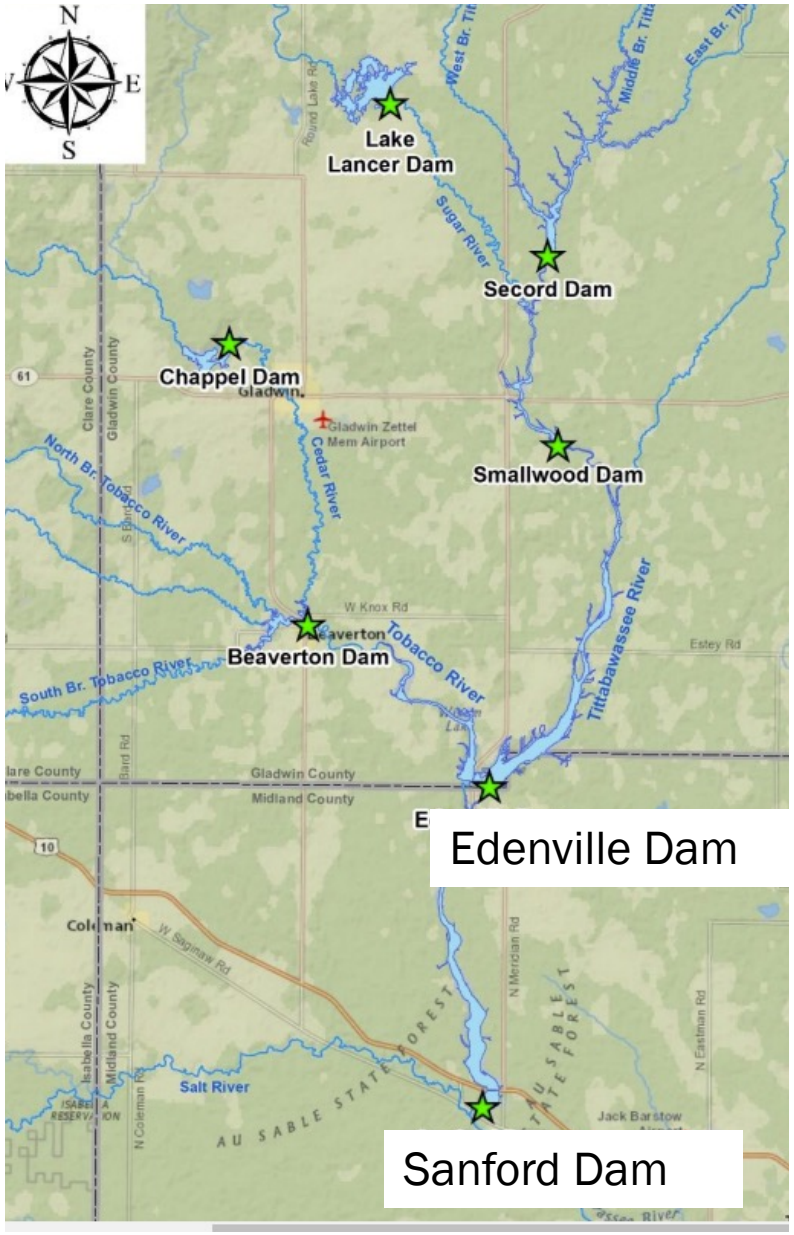
1. Dams in Series can affect each other when passing storm flows or during dam failures. They act as a system.
2. EAPs should include upstream and downstream scenarios, communication and effects



Edenville and Sanford Dam Failures

Detection with Monitoring, Warning and Evacuation 4

- Edenville and Sanford dams were hydropower embankment dams nearly 100 years old



Edenville and Sanford Dam Failures

Detection with Monitoring, Warning and Evacuation 5

- Edenville and Sanford d
  were hydropower
  embankment dams nea
  100 years old

Insight:

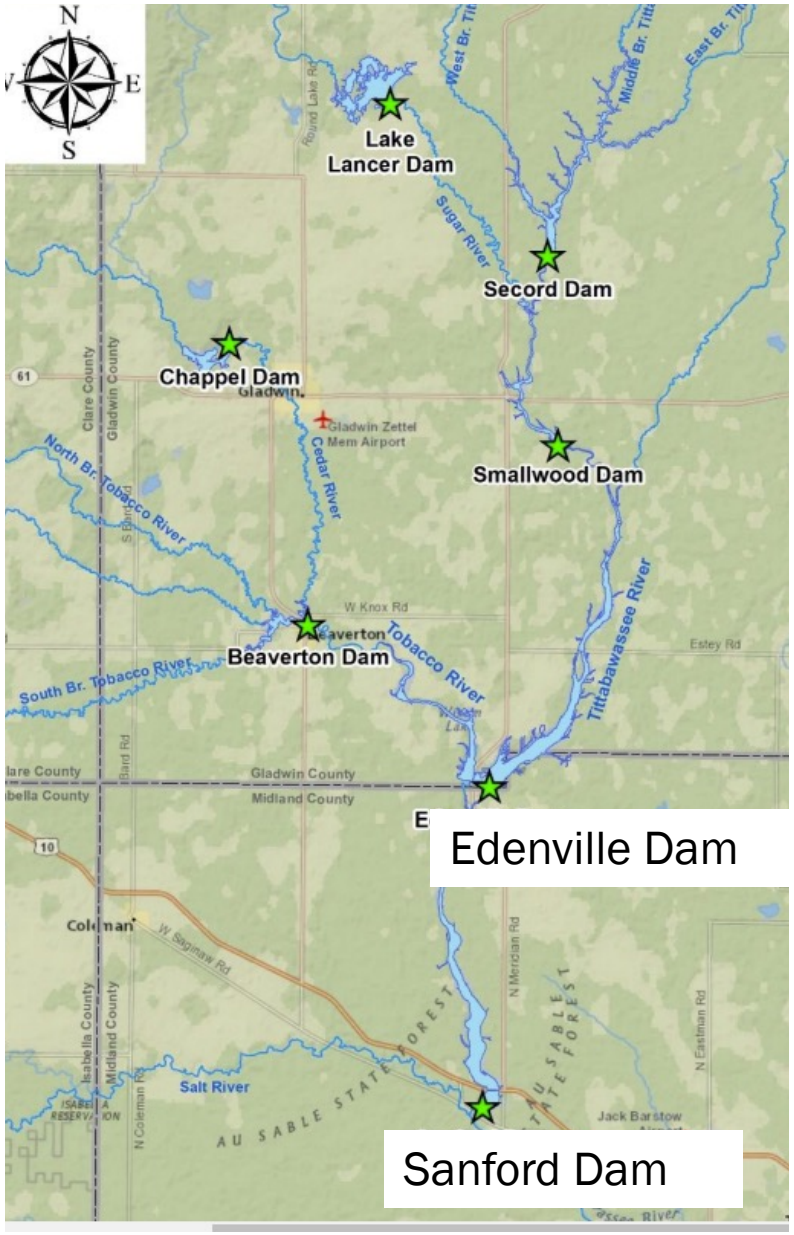
1. Even dams with decades of successful operation can fail.

Sanford Dam

Edenville and Sanford Dam Failures

Detection with Monitoring, Warning and Evacuation 6

- Late May 2020: 3” to 6” of rain on frozen ground and snowmelt event



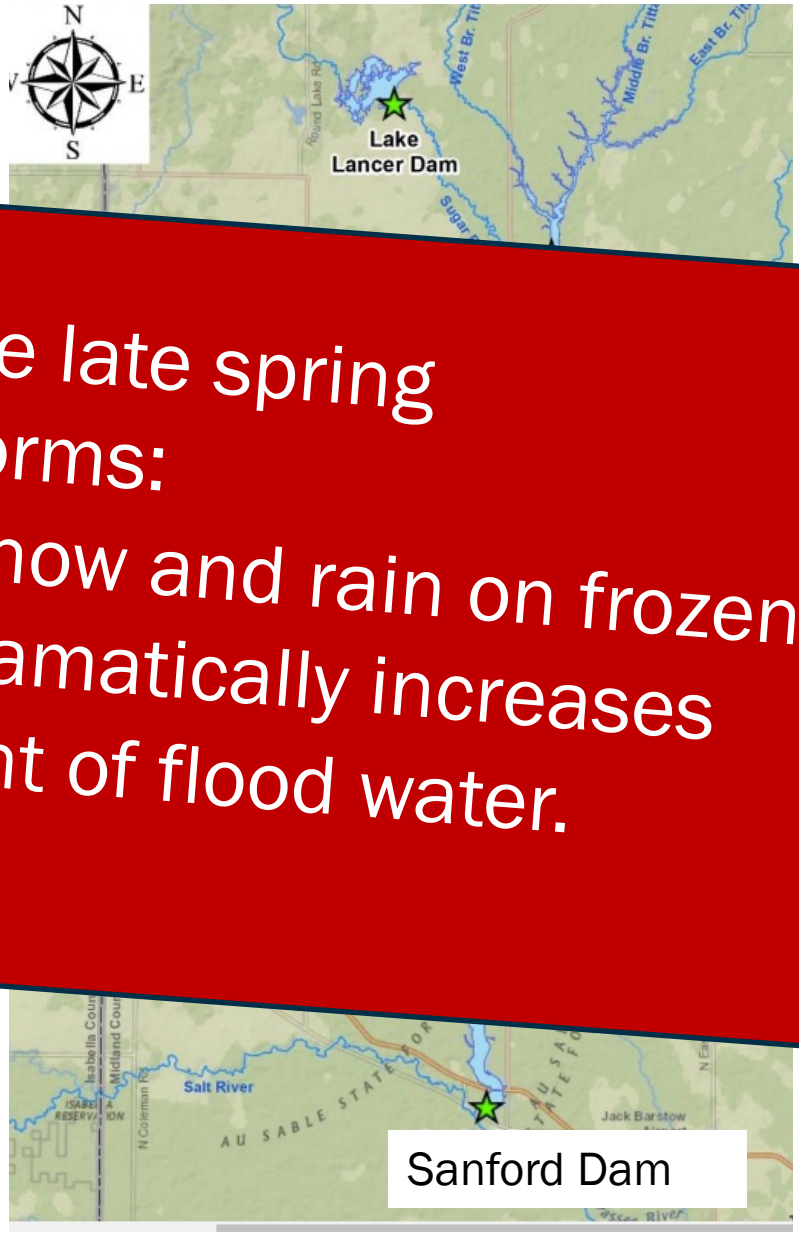
Edenville and Sanford Dam Failures

Detection with Monitoring, Warning and Evacuation 7

- Late May 2020: 3” rain on frozen grou snowmelt event

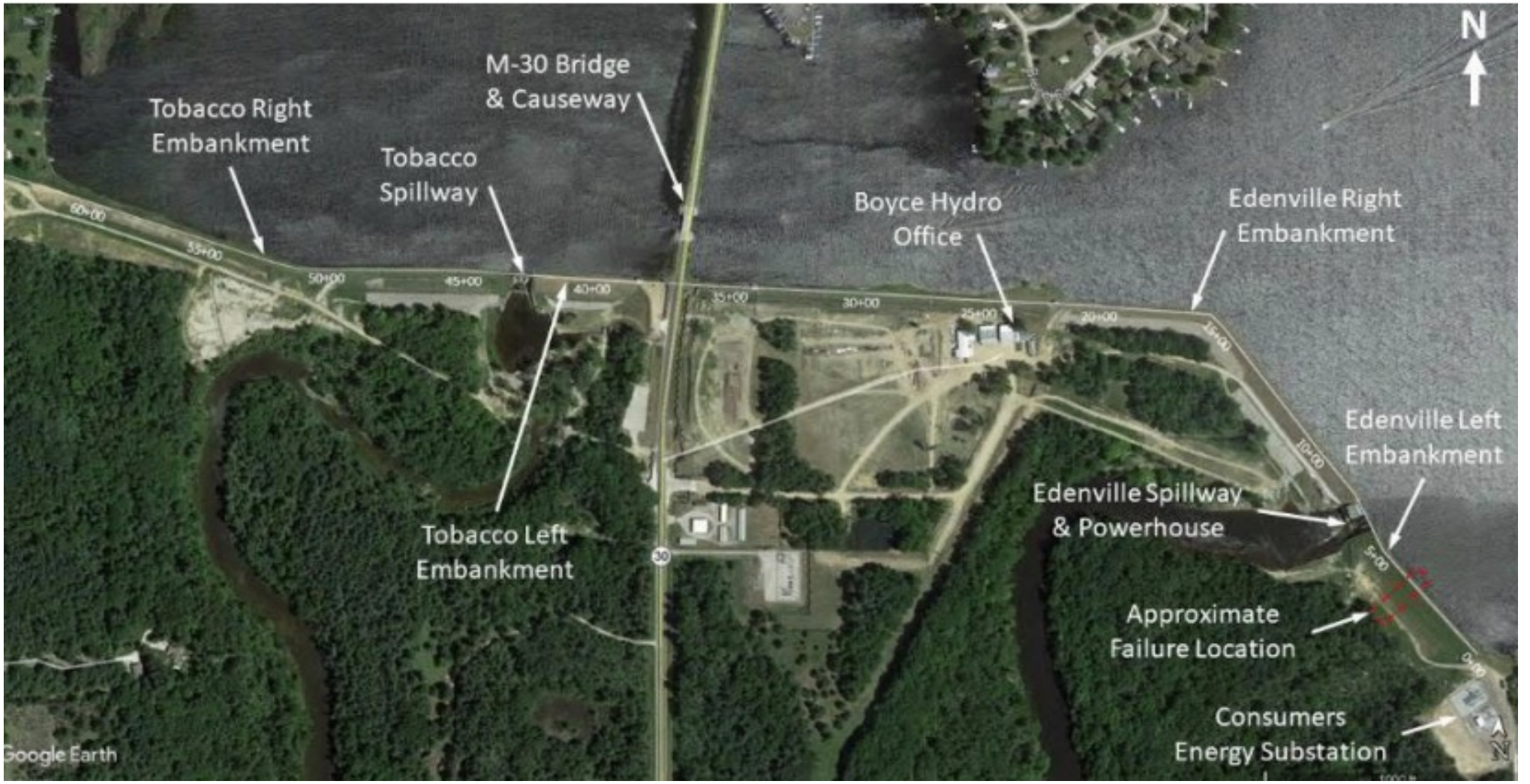
1. Beware late spring rainstorms:

Rain on snow and rain on frozen ground dramatically increases the amount of flood water.



Edenville and Sanford Dam Failures

Detection with Monitoring, Warning and Evacuation



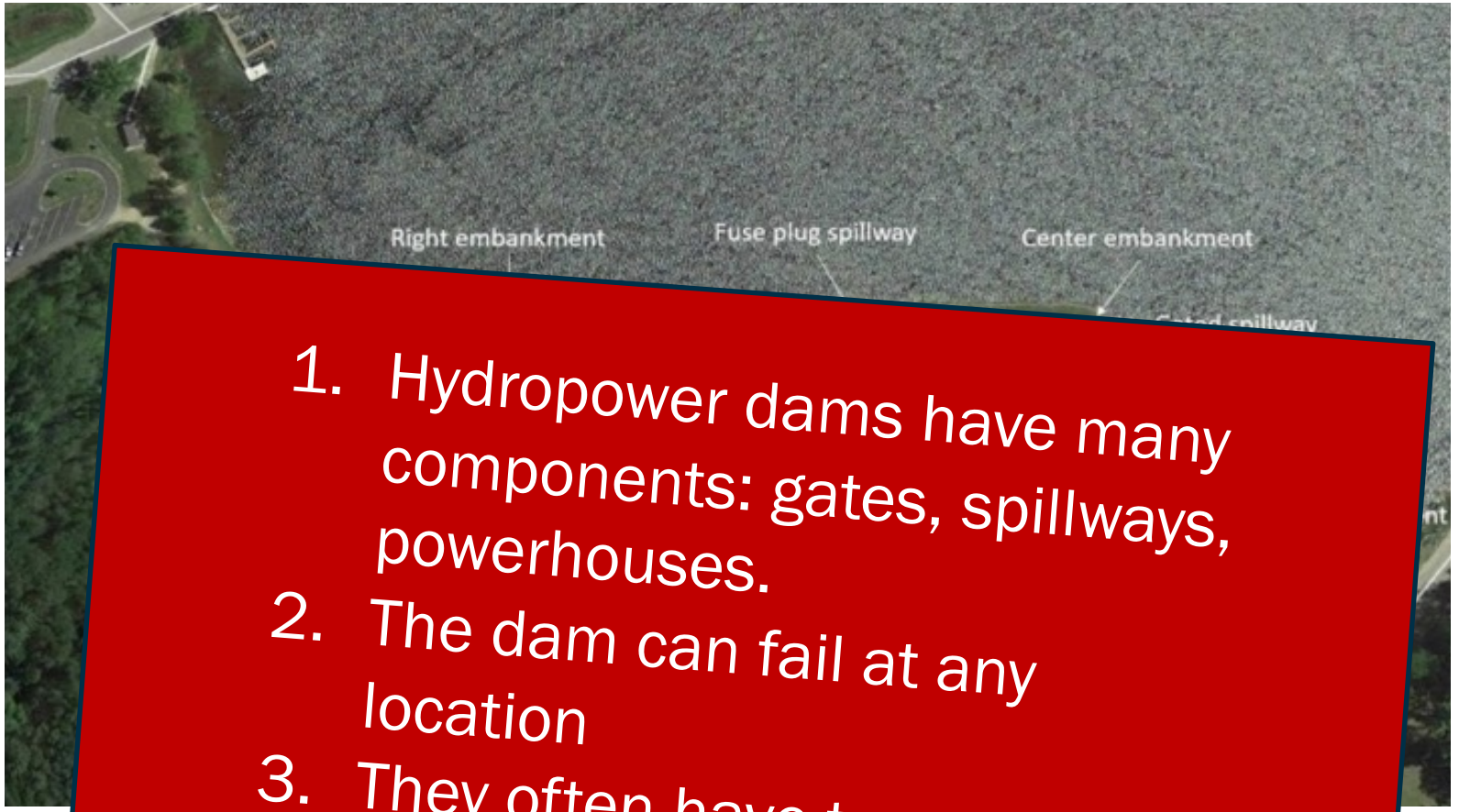
Edenville Dam

- Edenville and Sanford dams were hydropower embankment dams

Sanford Dam
10 miles
downstream

- Edenville and Sanford dams were hydropower embankment dams

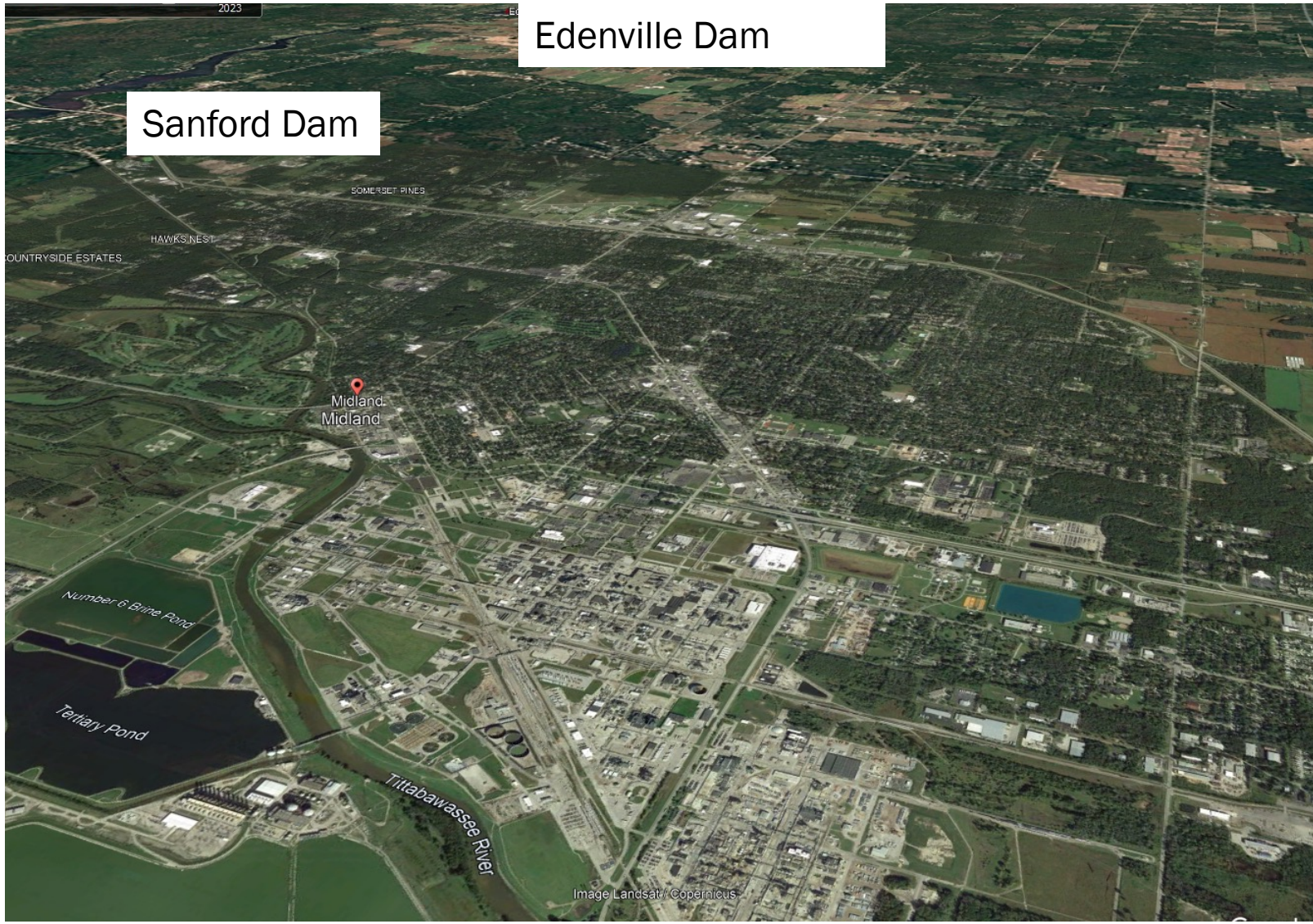
Sanford Dam



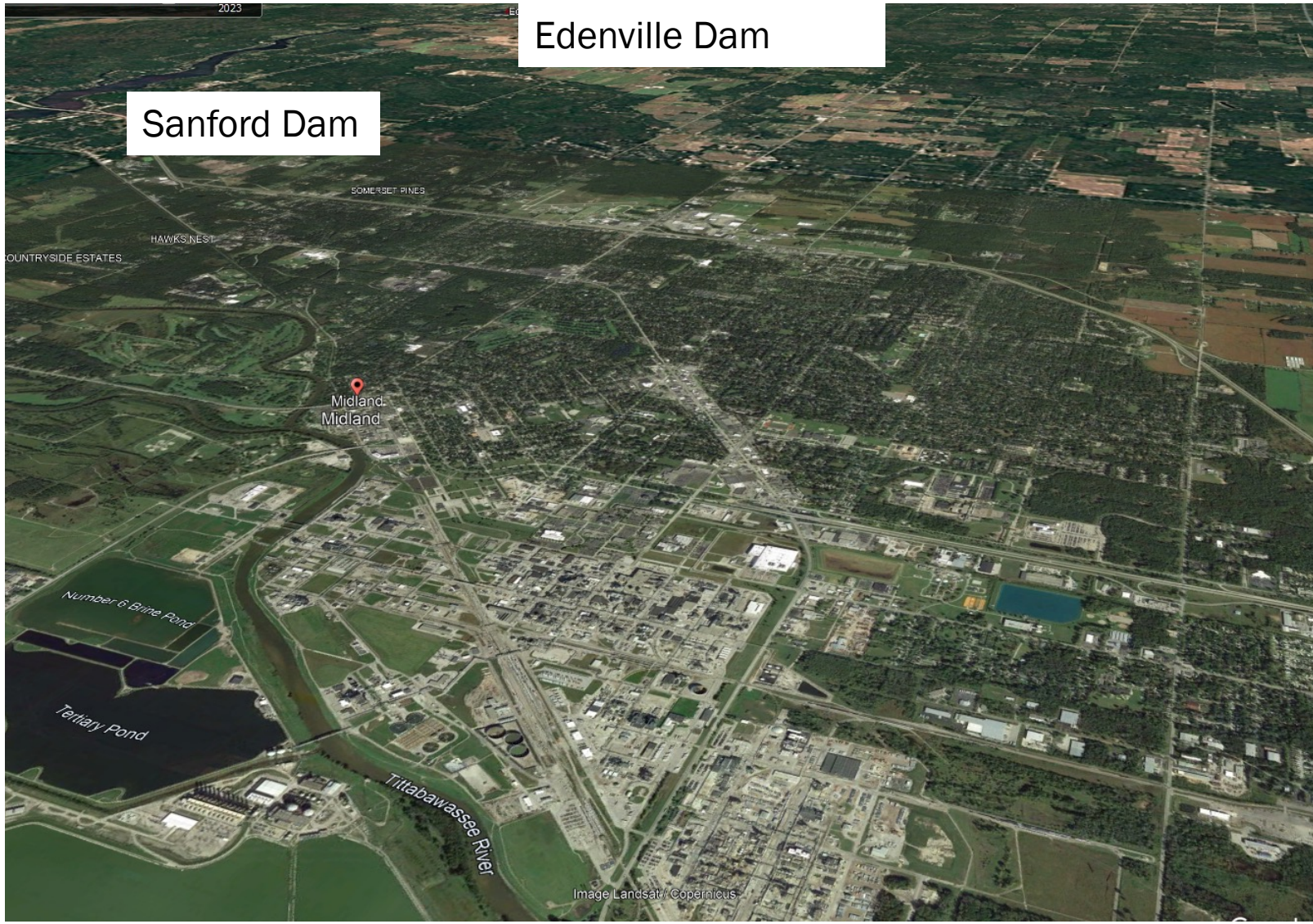
1. Hydropower dams have many components: gates, spillways, powerhouses.
2. The dam can fail at any location
3. They often have to open gates to pass large floods

- Edenville
  embankr

The City of Midland Mich, population 42,000 was about 8 miles from Sanford Dam.



On evening of May 18, the Midland County EM was in a quandary. Water was rising behind Edenville Dam. She was not comfortable with the reports she was receiving from the dam operator concerning conditions at the dam. The EAP stipulated that she was only to order evacuation if the failure was imminent, or the dam already failed.



Edenville and Sanford Dam Failures

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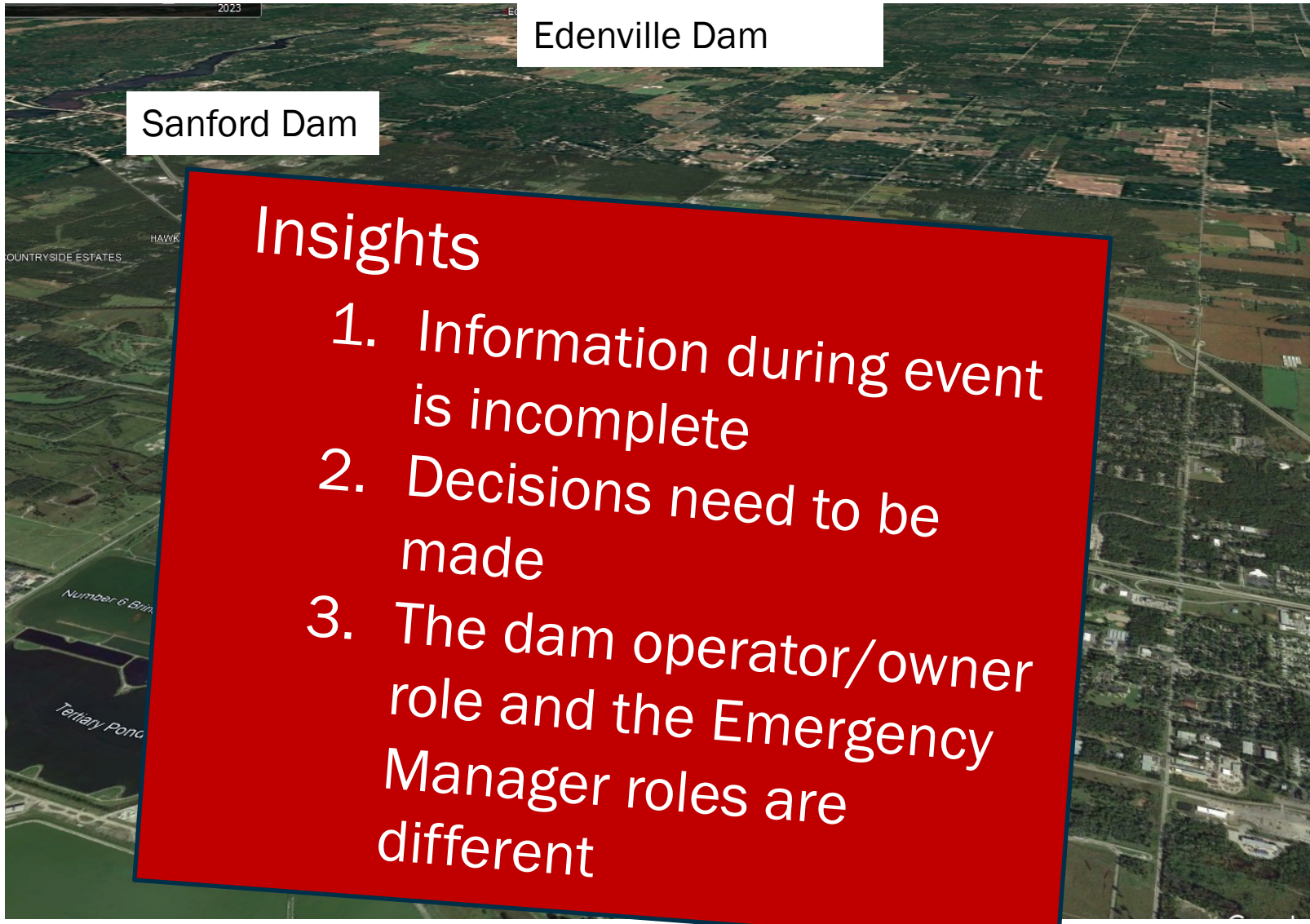
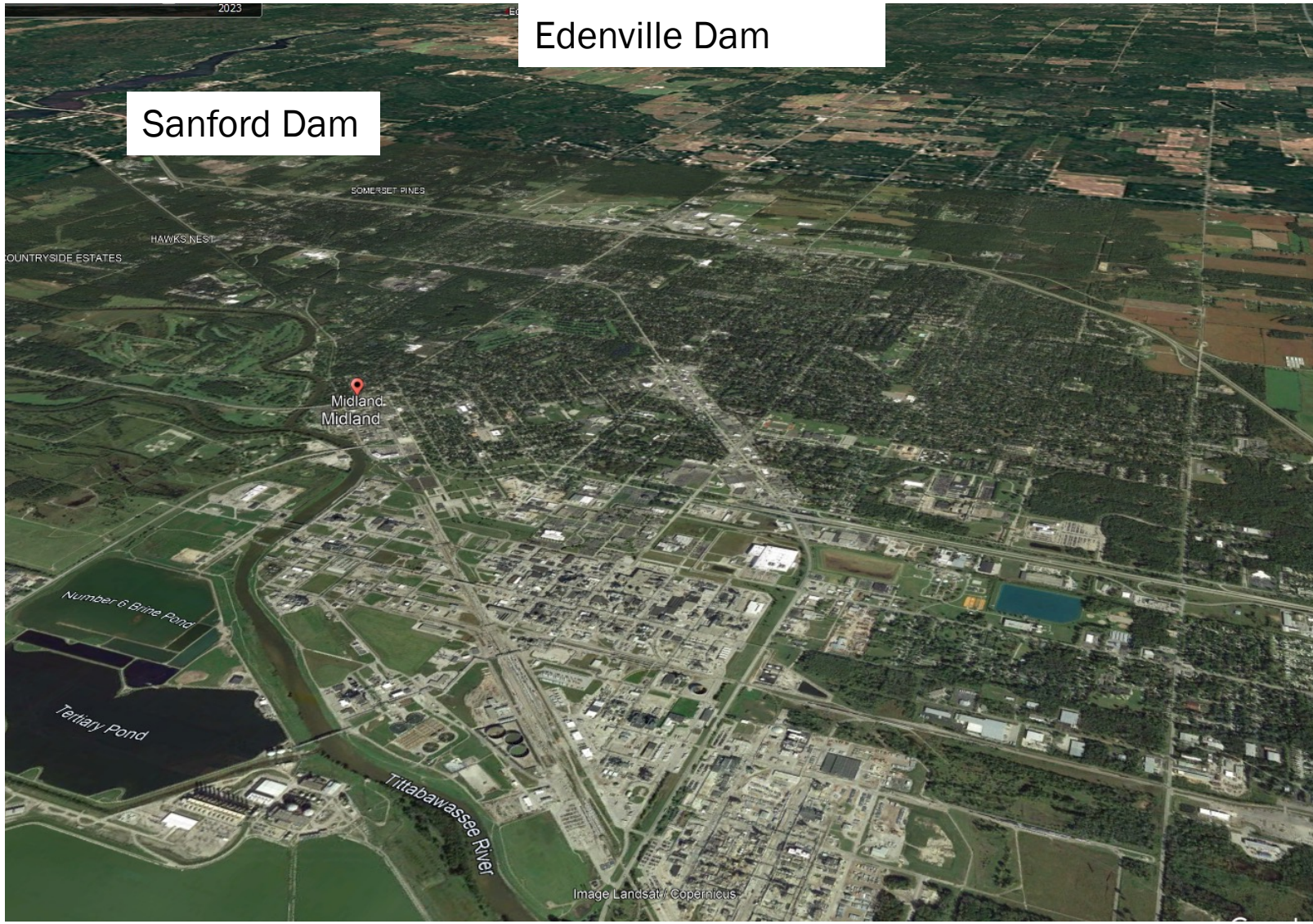


Detection with Monitoring, Warning and Evacuation 9

With 3,500 people in the path of the dam failure flood path, she weighed other factors:

- It would take six hours to evacuate everyone
- If Edenville Dam failed it would cut off many evacuation routes
- If she waited until the morning, the volunteer firefighters in Edenville and Jerome townships would be at work, unable to assist

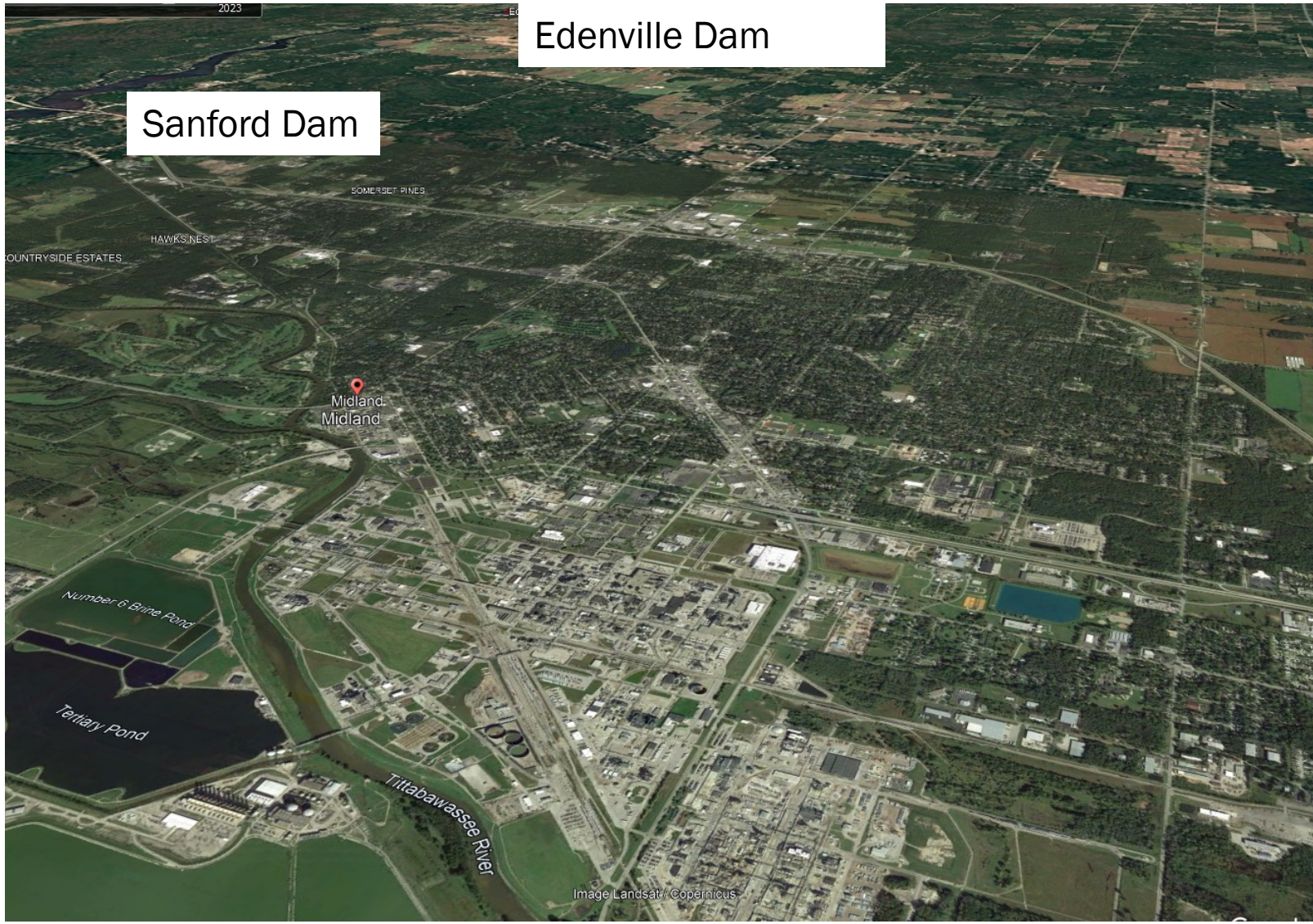


Edenville and Sanford Dam Failures

Detection with Monitoring, Warning and Evacuation 10

She ordered the evacuation. The evacuation was conducted during the night of May 18/May 19.

Edenville dam failed the next afternoon.



Edenville and Sanford Dam Failures

Detection with Monitoring, Warning and Evacuation Insights

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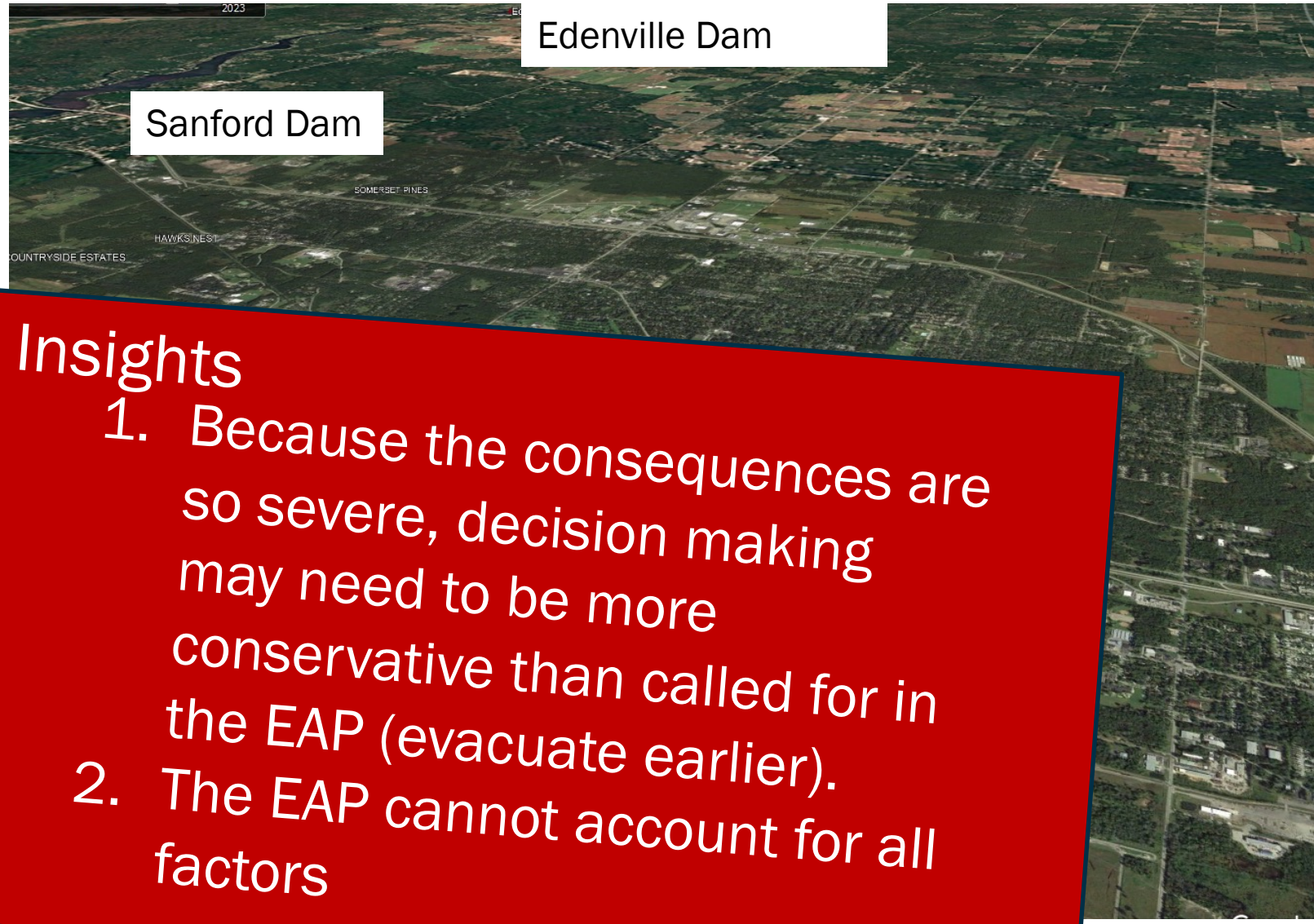

Insights

1. Because the consequences are so severe, decision making may need to be more conservative than called for in the EAP (evacuate earlier).
2. The EAP cannot account for all factors

The failure began with a drop in the crest of the dam.
Shown here at 5:31pm.

Edenville and Sanford Dam Failures 1

4 minutes later

Edenville and Sanford Dam Failures 2

4 minutes later
Plus 6 seconds

Edenville and Sanford Dam Failures 3

4 minutes later

Plus 8 seconds

Edenville and Sanford Dam Failures 4

4 minutes later

Plus 28 seconds

Cause: static liquefaction

Edenville and Sanford Dam Failures 5

4 minutes later
Plus 8 seconds

Edenville and Sanford Dam Failures 6

4 minutes later
Plus 8 seconds

Edenville and Sanford Dam Failures 7

4 minutes later
Plus 8 seconds

Edenville and Sanford Dam Failures 8

4 minutes later

Plus 28 seconds

Edenville and Sanford Dam Failures 9

Water from the failed Edenville Dam went downstream and overfilled Sanford Dam. About an hour and a half after Edenville Dam failed, Sanford Dam failed.

Edenville and Sanford Dam Failures 11

$200 million in damages, 2,500 buildings flooded, no loss of life, a Presidentially-declared disaster.

Jenifier Boyer, emergency management coordinator for Midland County. (Courtesy photo)

The emergency manager received an award from the Association of State Dam Safety Officials later that year for her actions during the event.

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FEMA