# Howard A. Hanson Dam Seepage Issues, Risk Assessment and Repairs

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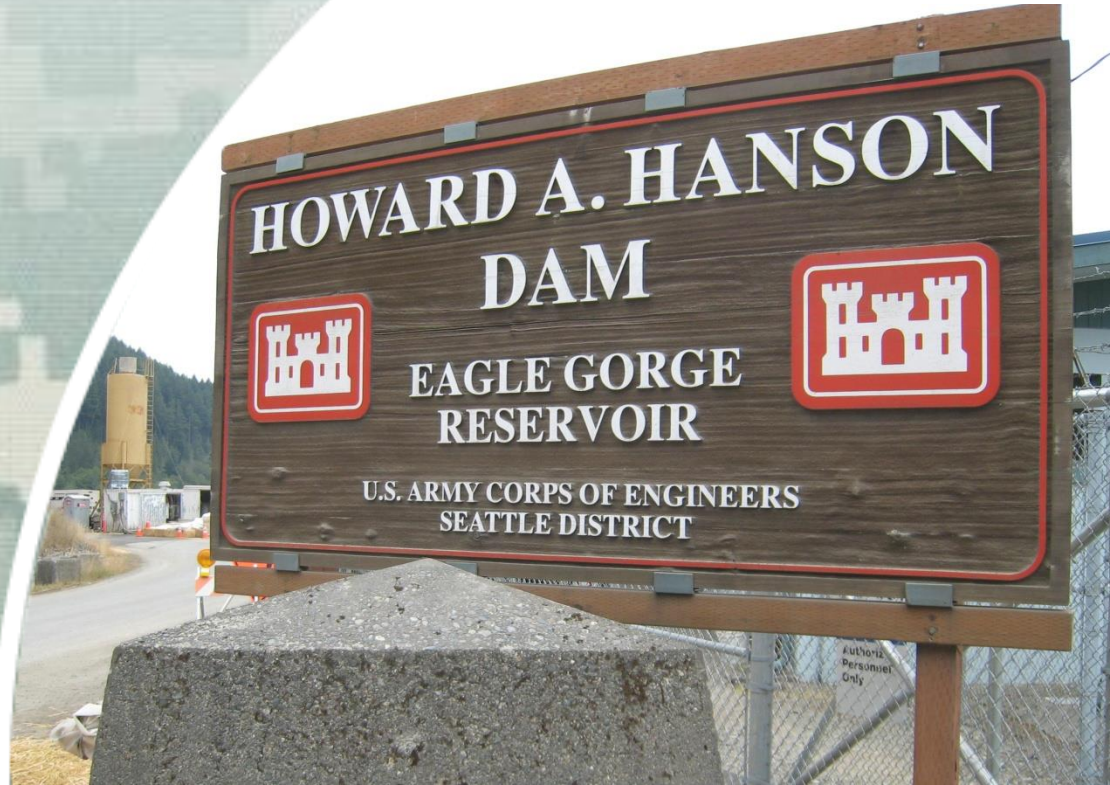
Seattle District
U.S. Army Corps of Engineers
May 2012




US Army Corps of Engineers
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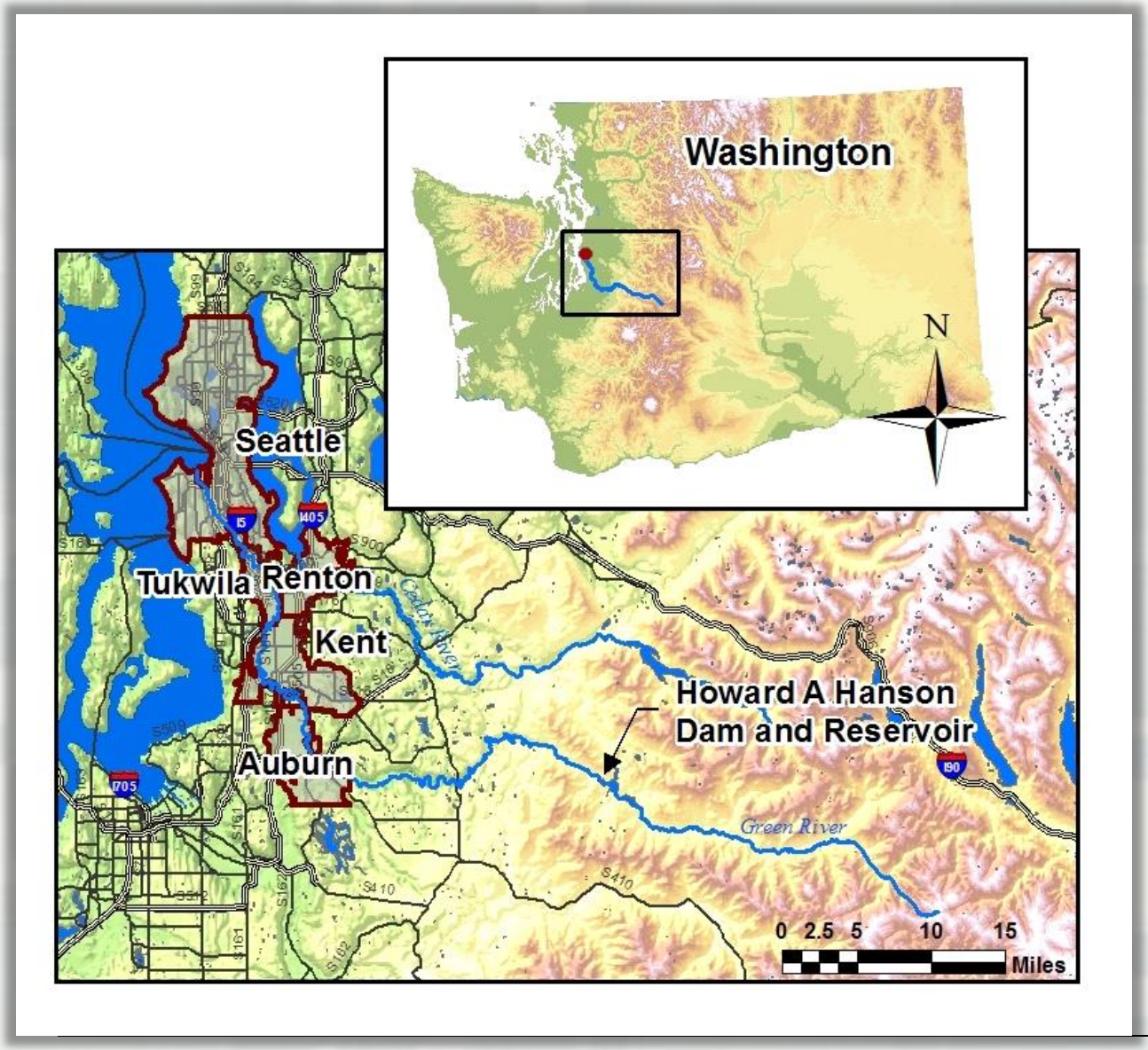
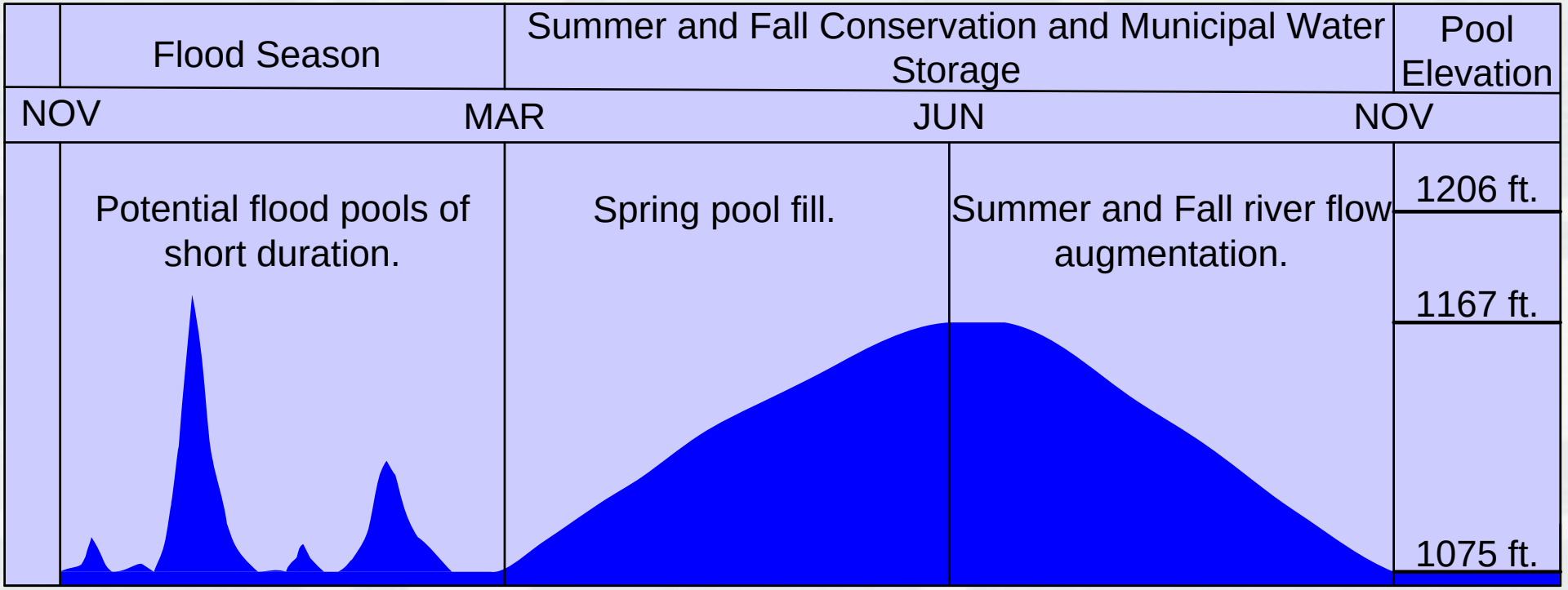
# Project Location




## Purpose

- **Flood risk mitigation (1950)**
- **Low flow augmentation (1950)**
- **M&I water storage (1998)**
- **Ecosystem restoration (2000).**

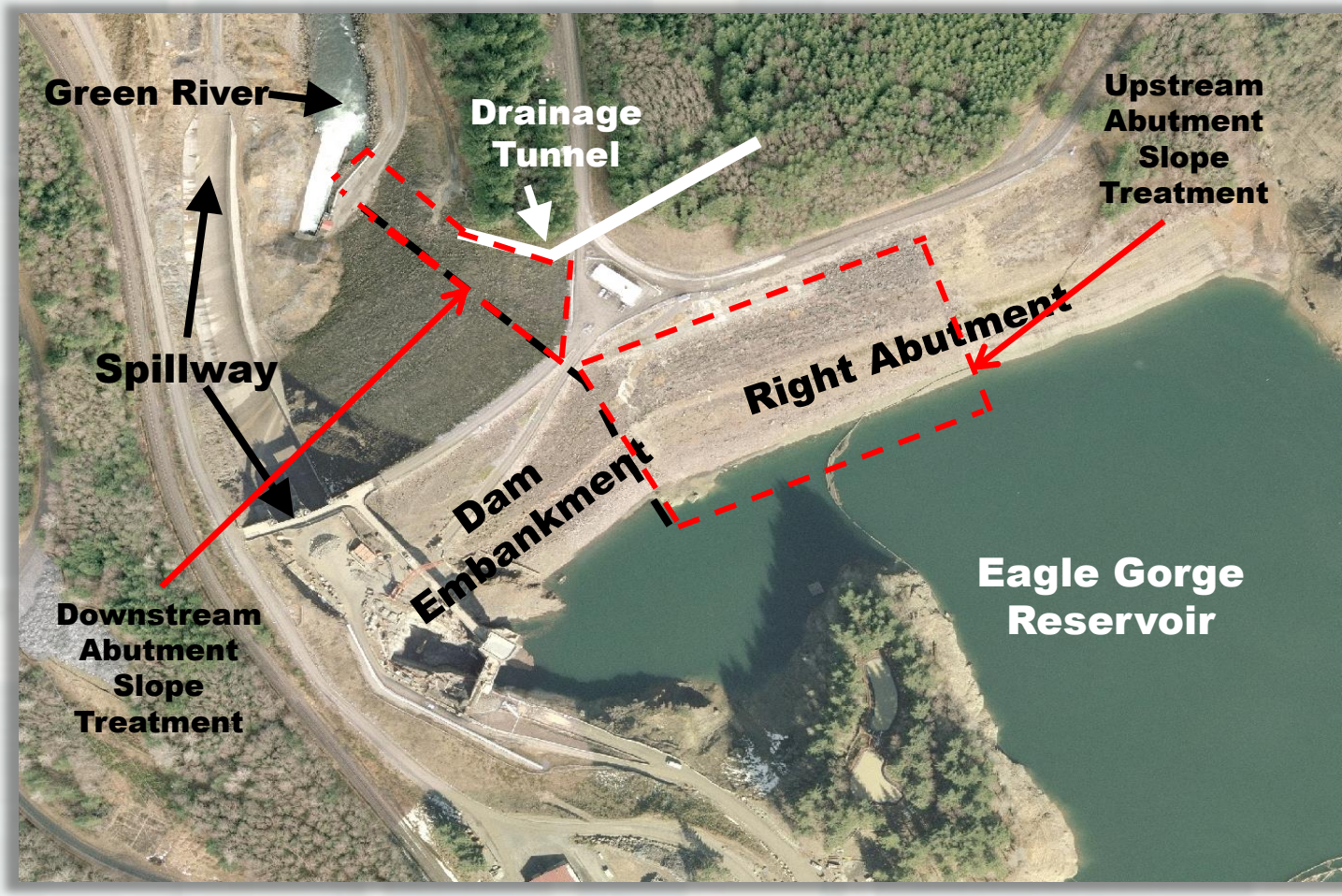
# Purpose/Operation



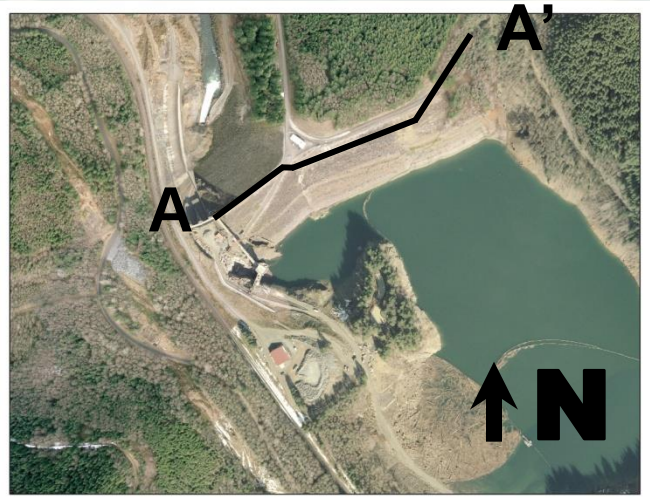

- Original authorized pool = 1141 feet (summer/fall river flow augmentation.
- Section 1135 project = 1147 feet (beneficial use for fish).
- Phase I Additional Water Storage = 1167 feet.
- Phase II Additional Water Storage = 1177 feet.
- Design flood pool = 1206 feet.
- PMF = 1224 feet (top of dam = 1228 feet).

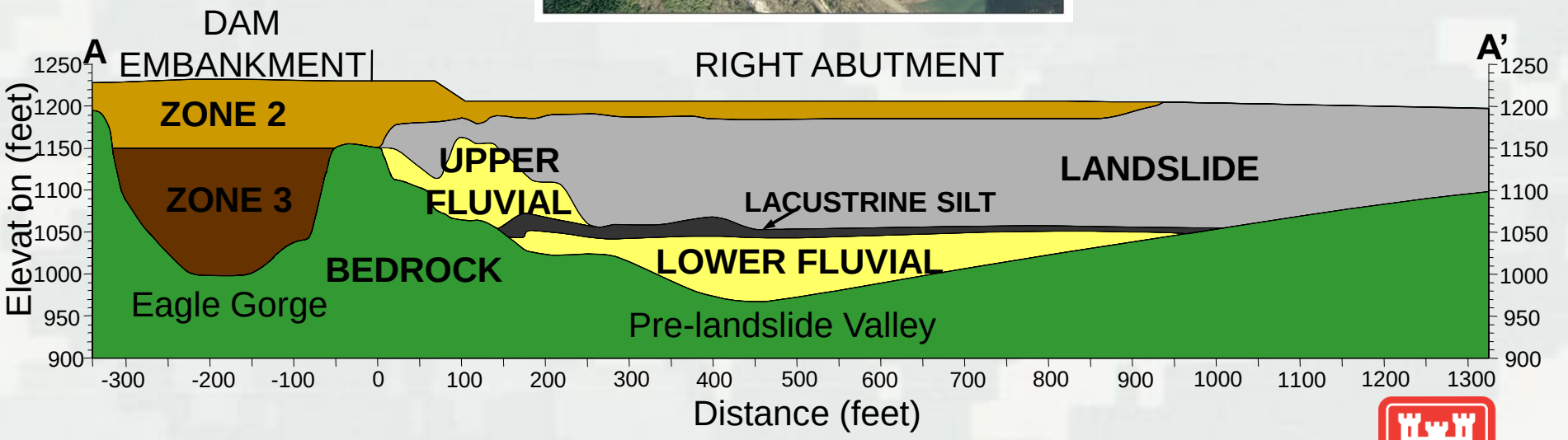
# Dam Features & Design

- Embankment is permeable and piping/erosion resistant.
- Right abutment seepage and piping risk known pre-dam construction.
- Upstream and downstream slope treatment designed to control seepage.
- Drainage tunnel added after dam construction (1969).
- Abutment monitored & evaluated since construction.

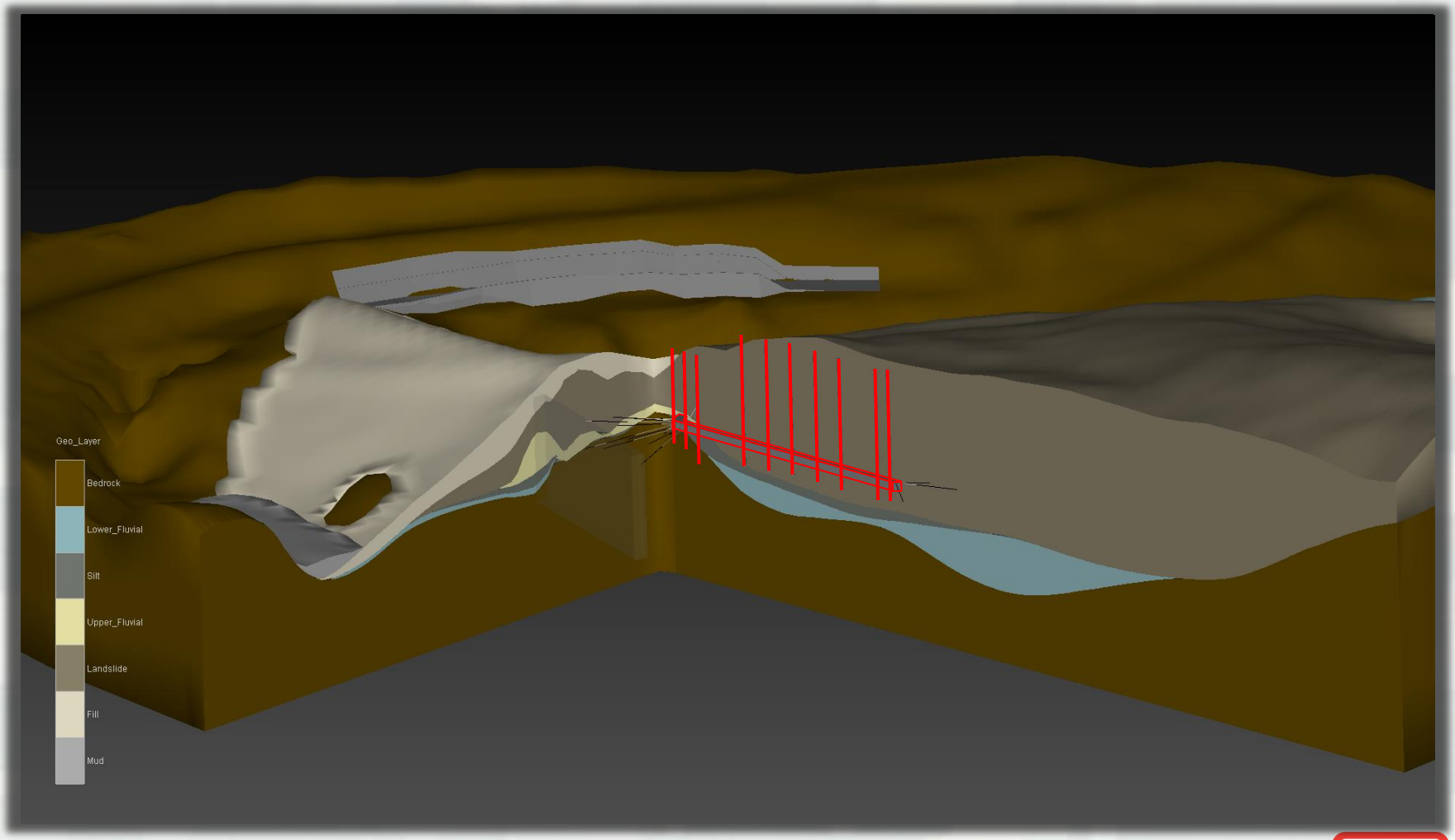


# Geologic Setting



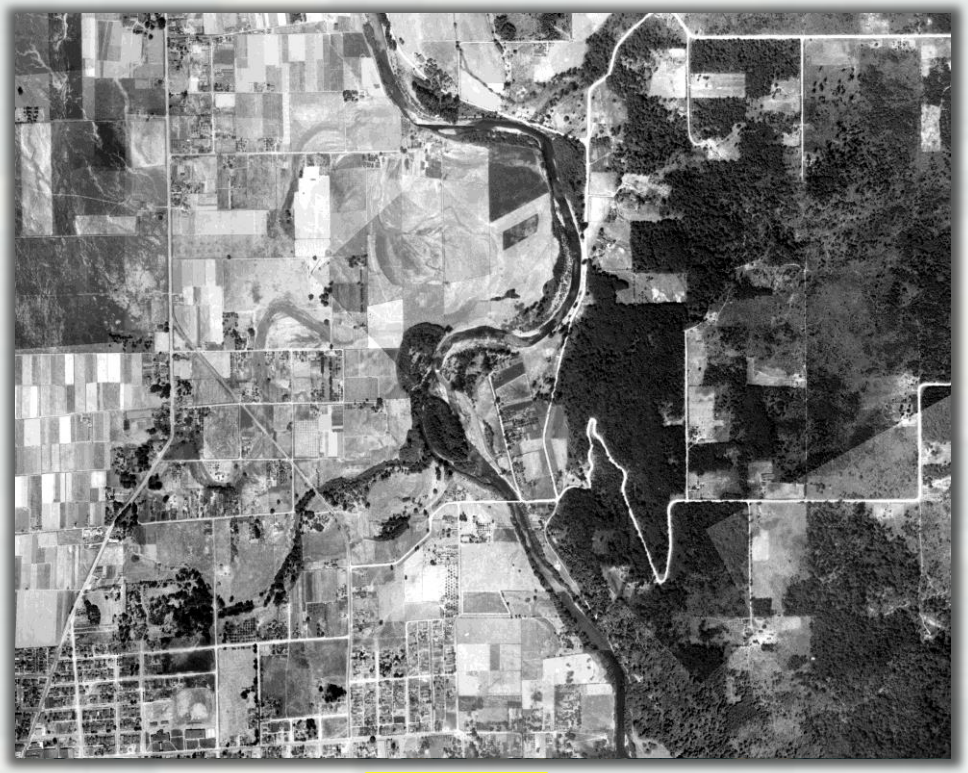



# Geologic Setting



# Consequences

- 32,000 residents and 65,000 jobs
- >80,000 commuters/day
- 4th largest continuous warehousing district in the US
- Hub for two major seaports (4 million containers $75B/year)
- $45M in economic output/day
- King County comprises 2% of US Gross Domestic Product (same as Louisiana and Mississippi combined)
- Olympic Pipeline
- Railheads (BNSF and UP)
- Electrical substations serving 35,000 residents.



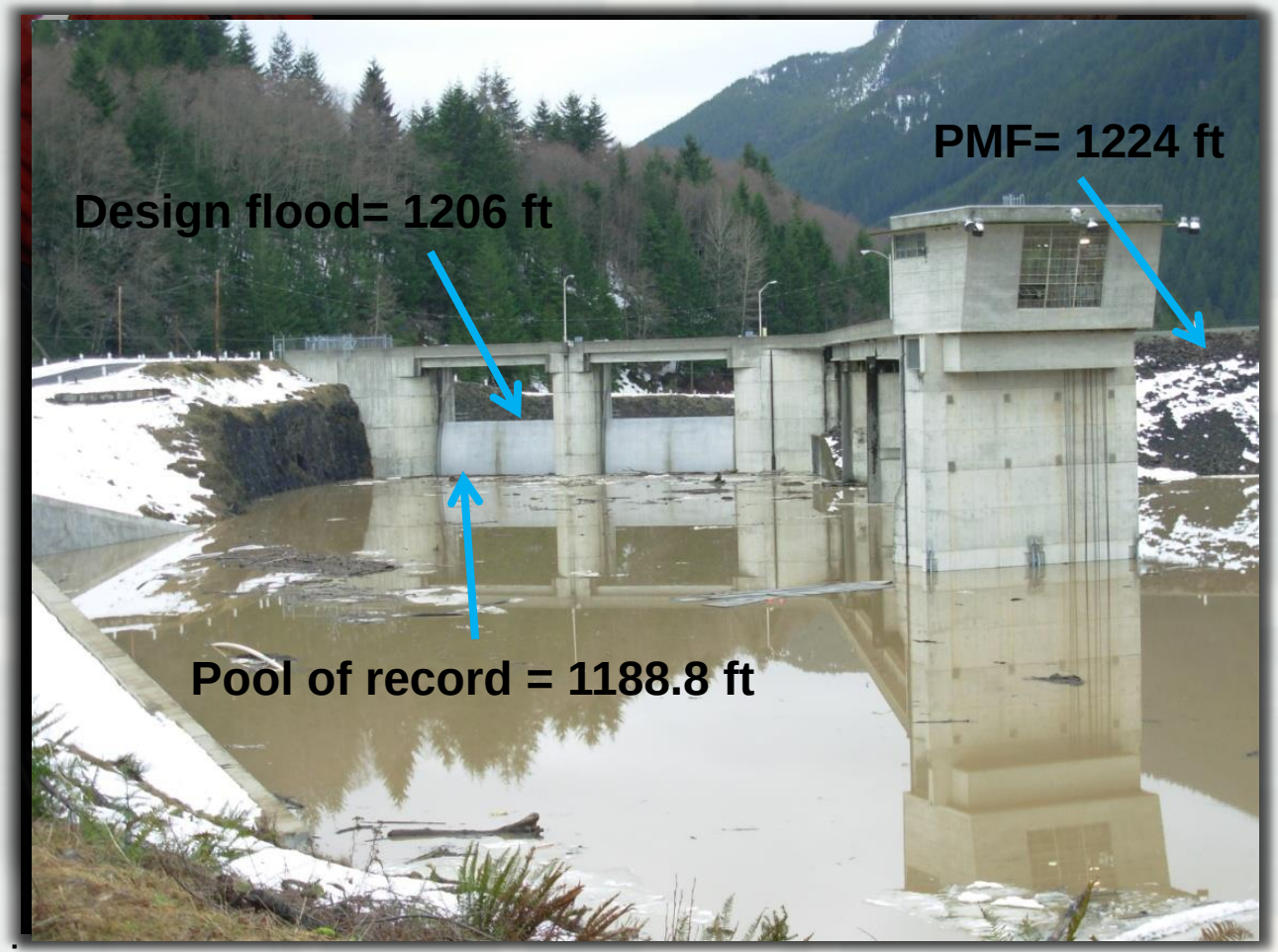
1940

# January 2009 Flood

Pool of Record

Vertical Tunnel Drains

Turbidity from Tunnel Drain



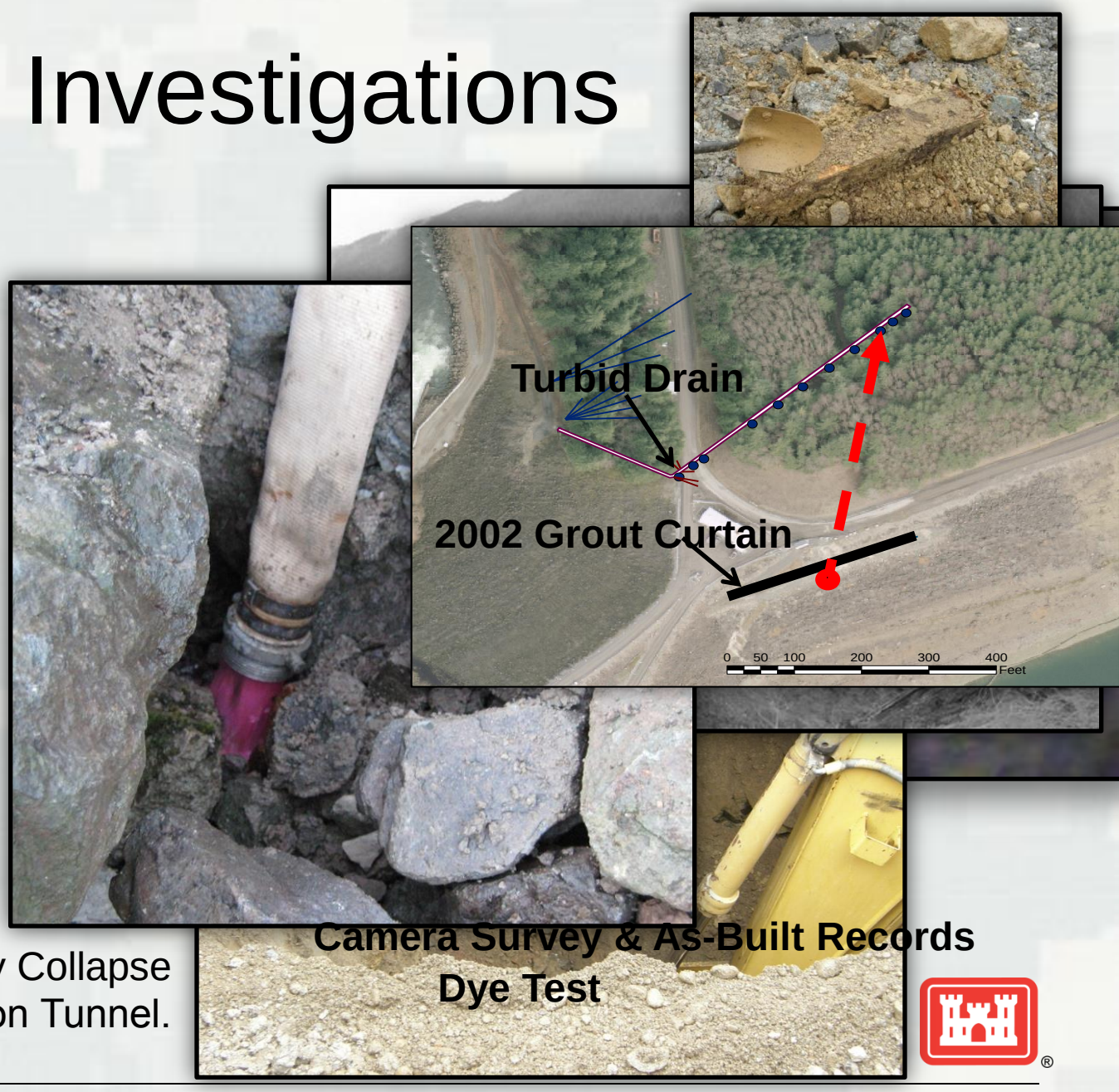

Depression on Upstream Face

# Investigations

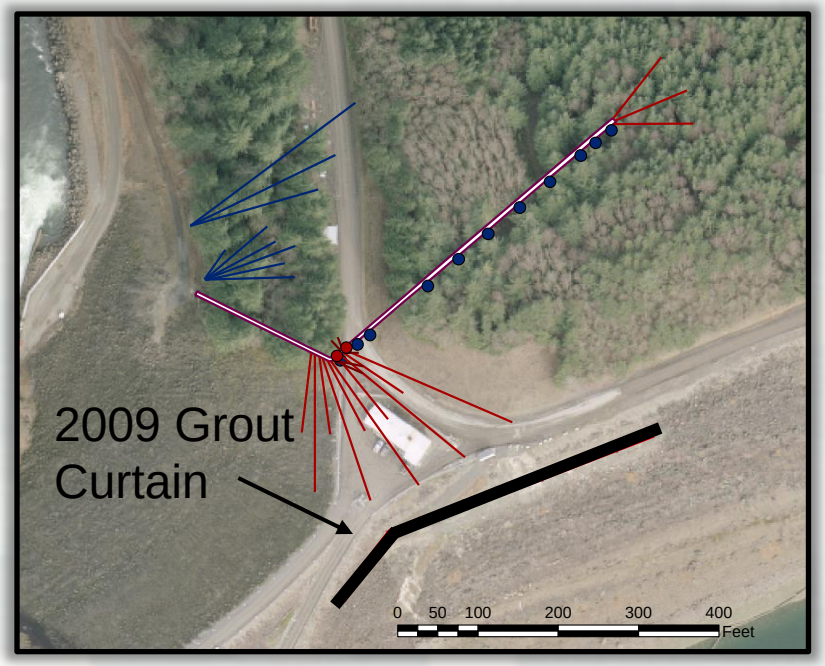
Unfiltered Vertical Drains

No Hydraulic Connection Between Turbid Drain and Depression

Depression Caused by Collapse of 1950's Era Exploration Tunnel.

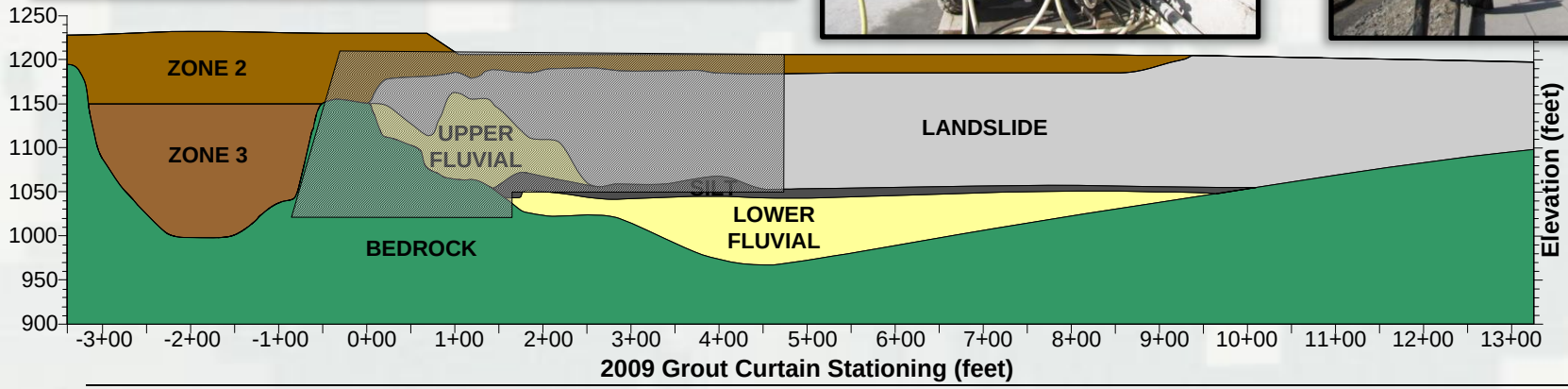


# 2009 Interim Repairs




## Grout Curtain

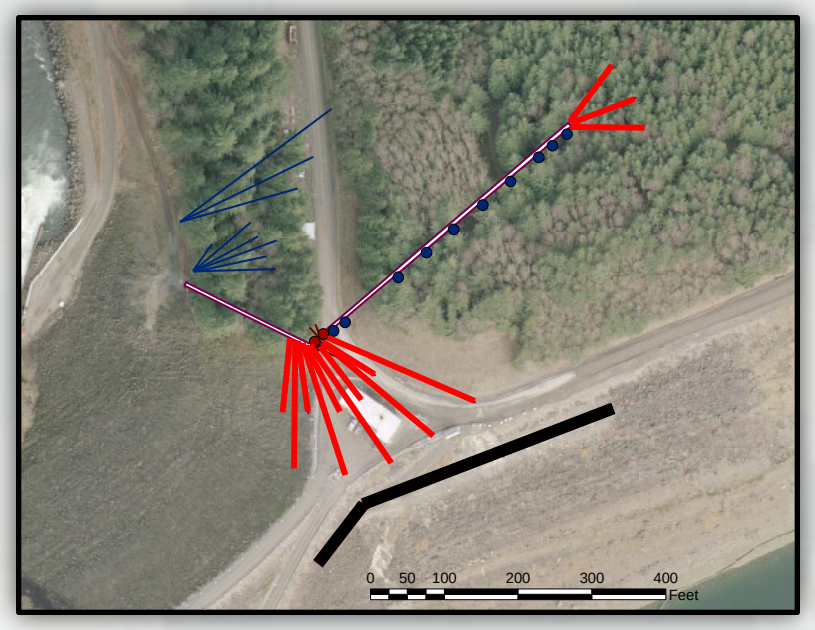
- 74,000 LF of drilling
- 550,000 gal. grout in overburden
- Substantially complete by 2009/2010 flood season



# 2009 Interim Repairs

## Drainage Tunnel Improvements

- Grouted vertical drain #25 and replaced with 2 new filtered vertical drains
- Installed 13 filtered horizontal drains.

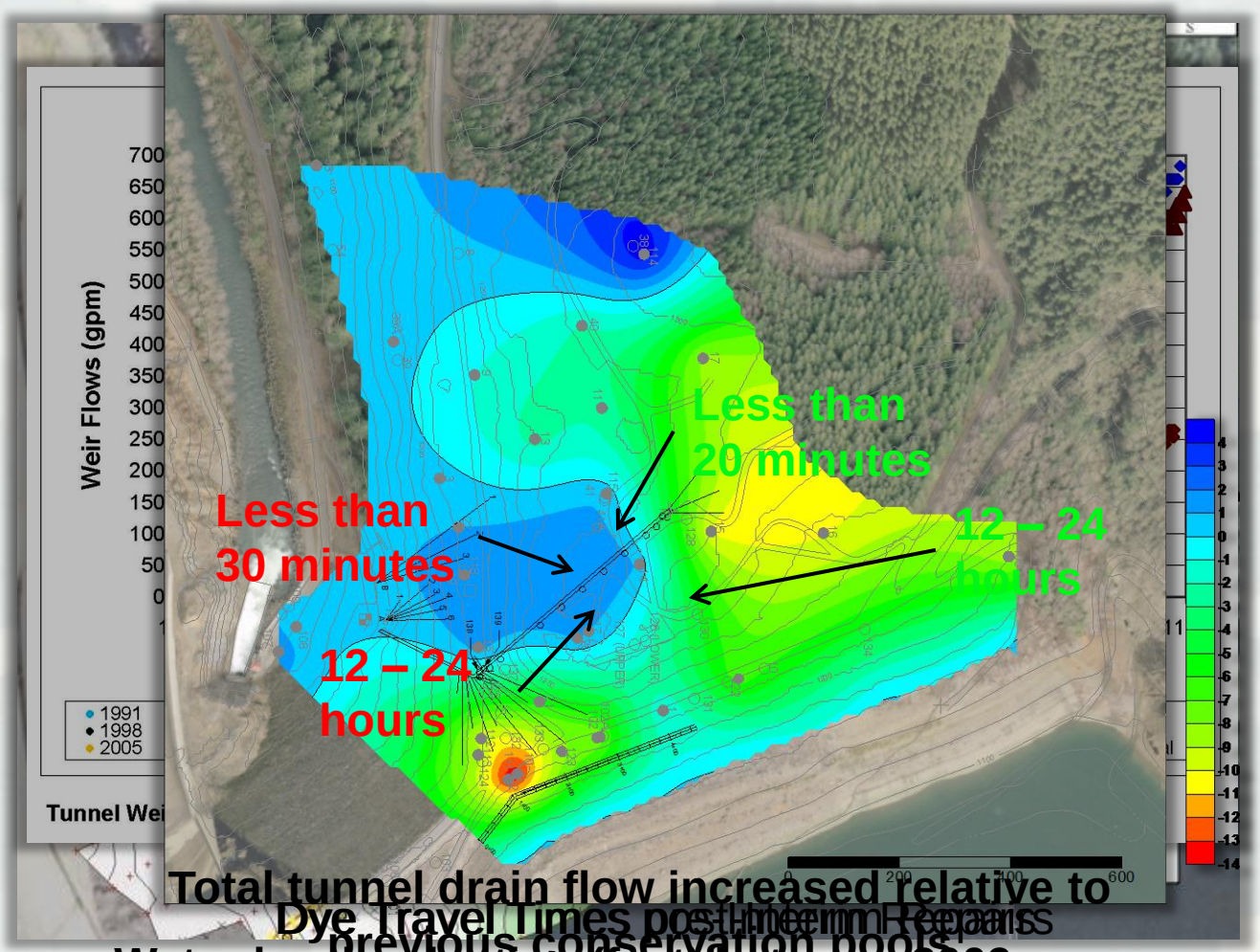



# Effectiveness of Interim Measures

Reduced groundwater travel times

Preferential pathways lengthened

Increased tunnel drainage efficiency




Total tunnel drain flow increased relative to previous conservation pools

Dye Travel Times post Interim Repairs

Water level reduced to early summer 2009 conservation pool

Geophysical results indicate no preferential pathways through new grout curtain.

# Risk Assessment

- Conducted concurrent with interim repairs
- Additional exploration.
- Review of dam design.
- Review of dam as-built records.
- Review of construction photos.
- **Potential failure modes analysis.**
- **Assessment of risk.**

- Congress lobbied by local electeds for funding and $44M in supplemental O&M provided for additional interim repairs.

# Failure Modes of Concern

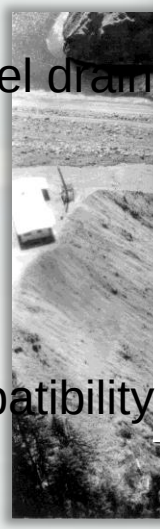
- **Short Path Seepage and Piping (Red).**
- Drainage Tunnel Seepage and Piping Blue).

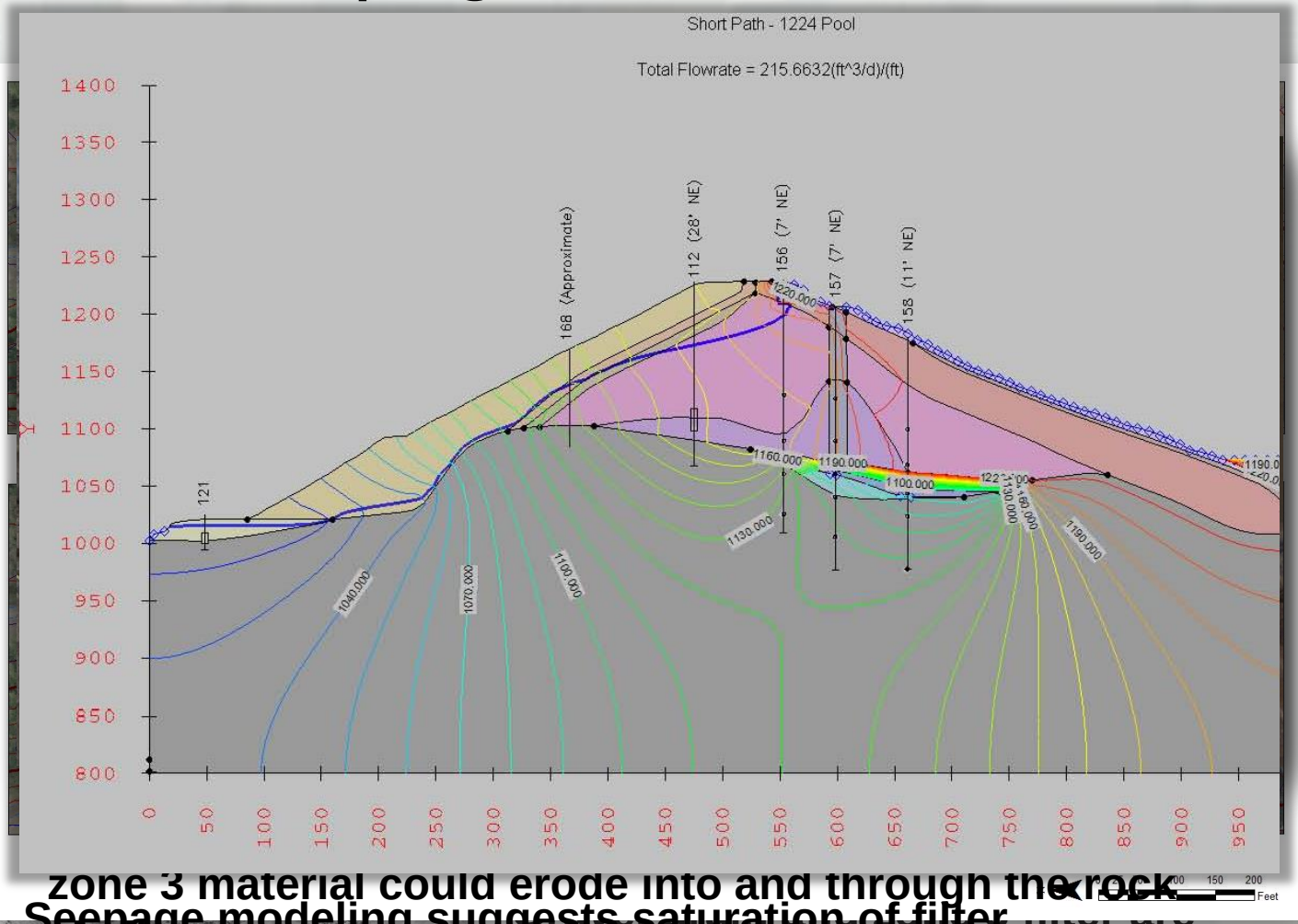
# Short Path Seepage Failure Mode

Downstream filter & drain

Lack of gravel drain

Filter incompatibility





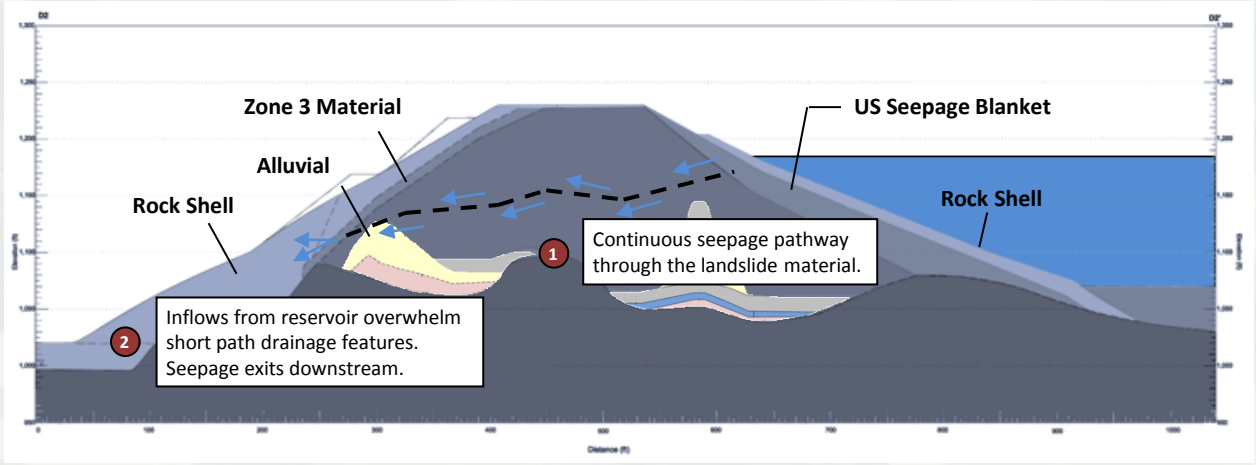

**zone 3 material could erode into and through the rock**

**Seepage modeling suggests saturation of filter**

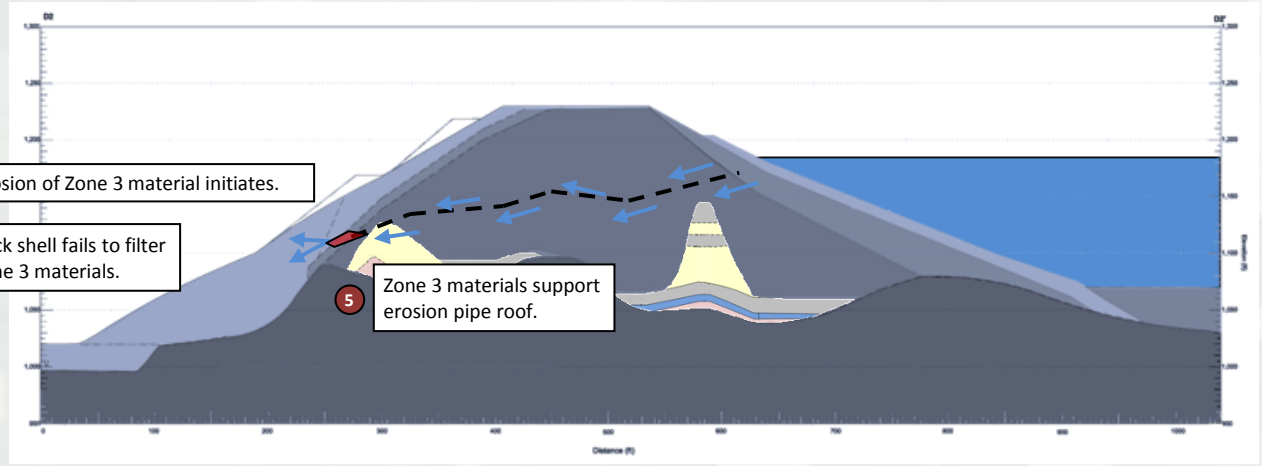
**Gravel drain ends at edge of rolled rock fill then incompatible material under greater than design flood pool conditions.**

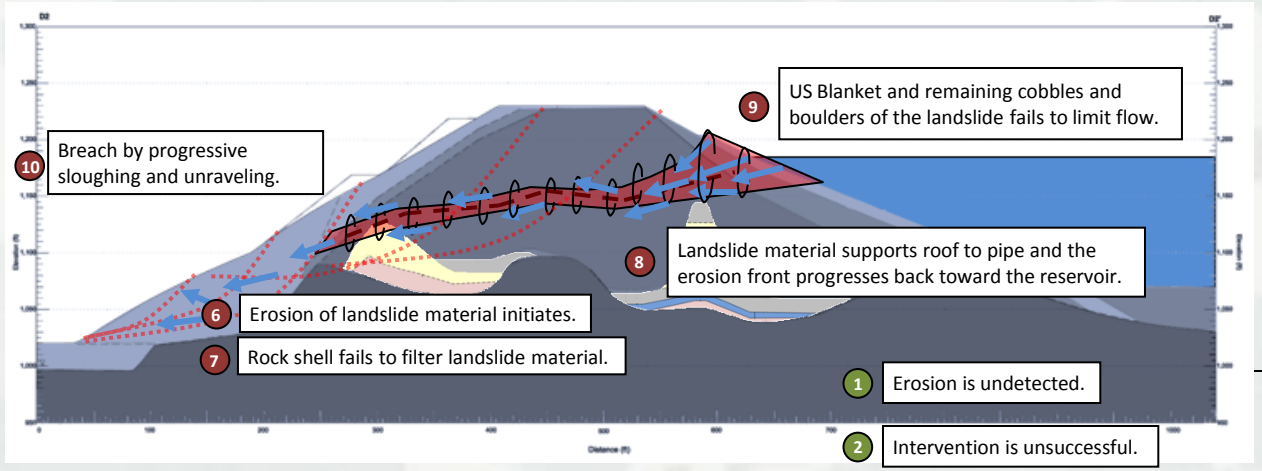
**rock shell and rock toe in contact with zone 3 filter.**

# Failure Progression

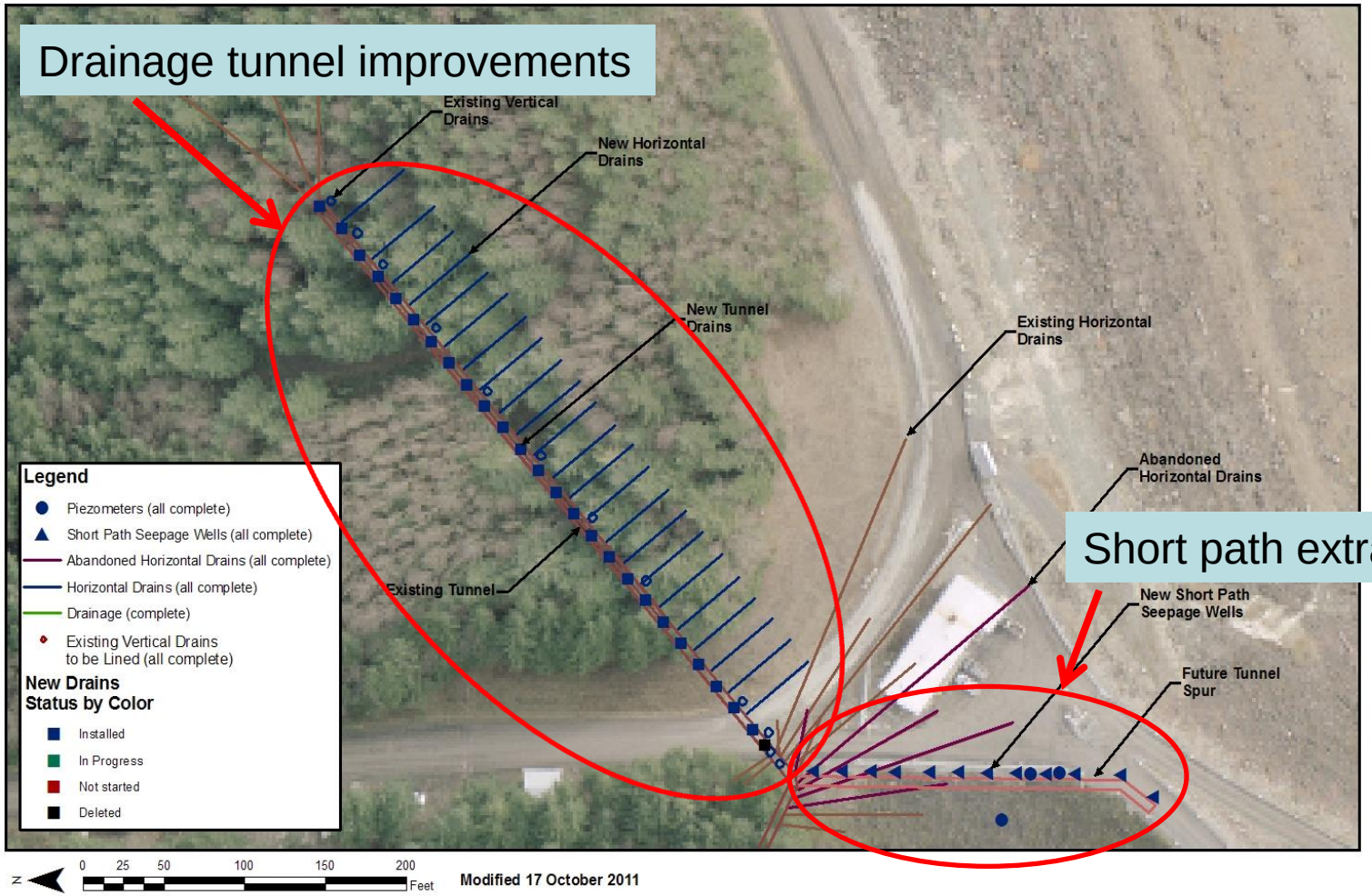



## Short Path Seepage

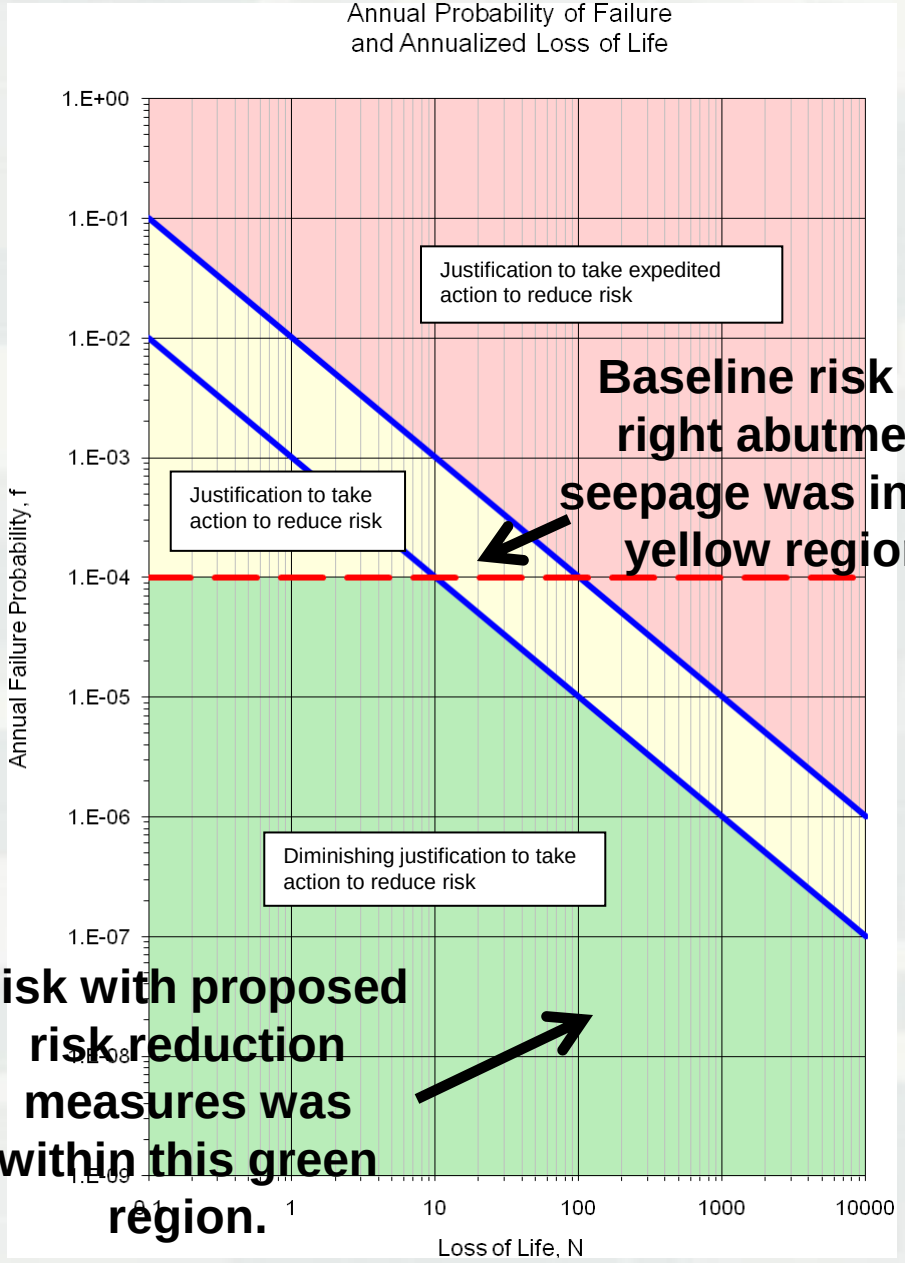


# Risk Reduction Measures



# Risk Assessment Results for Right Abutment Seepage

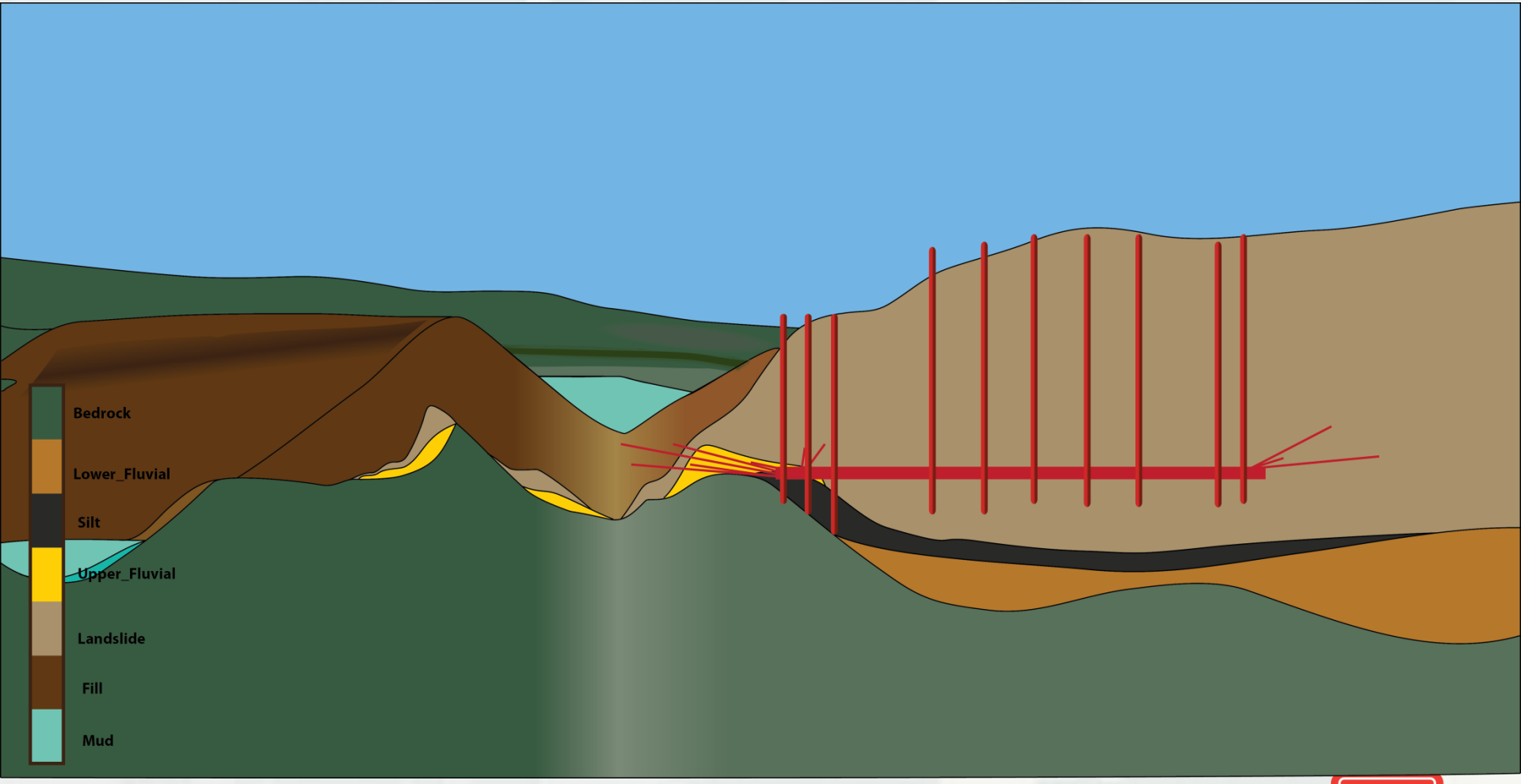



**Baseline risk for right abutment seepage was in this yellow region.**

**Risk with proposed risk reduction measures was within this green region.**

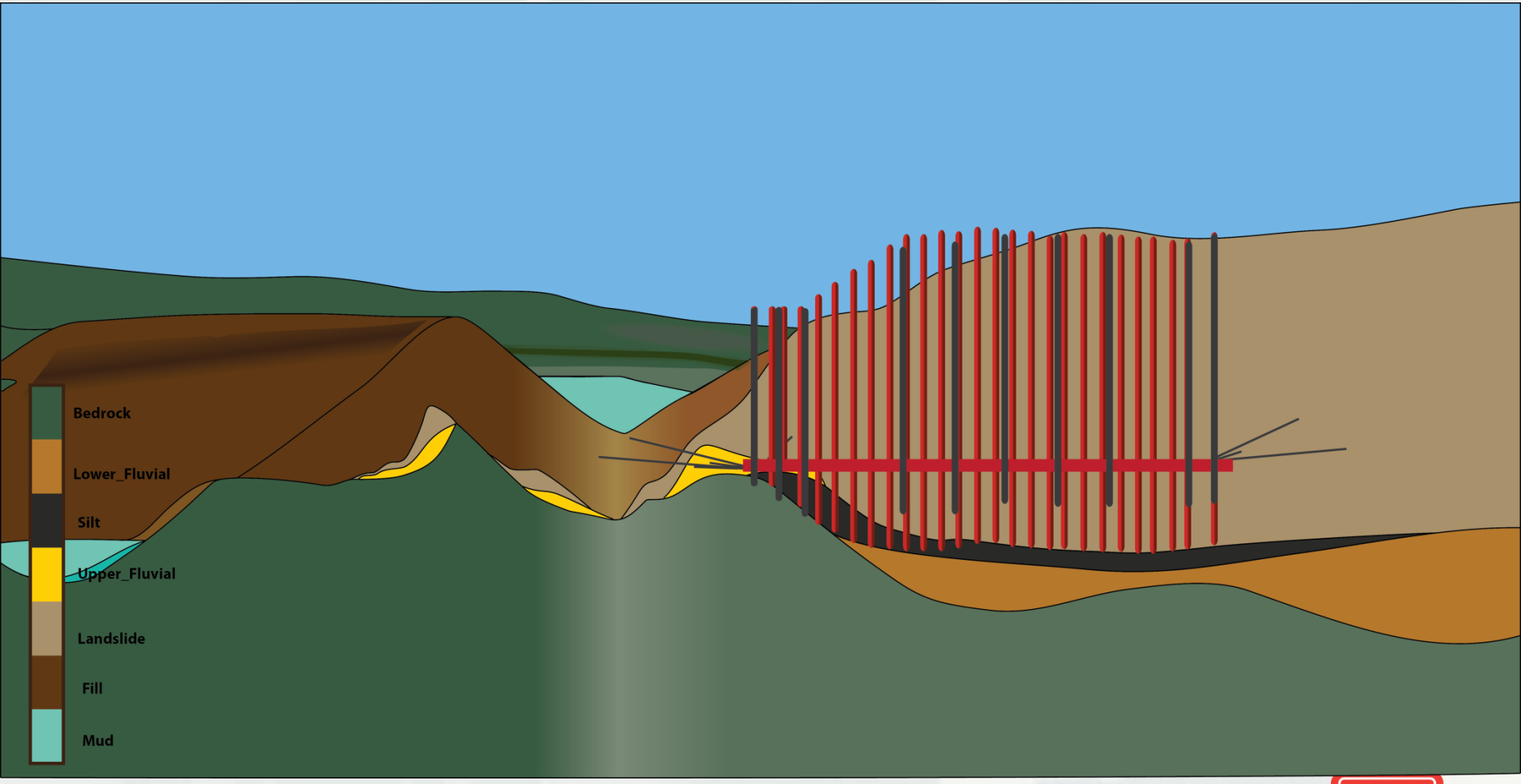
- Failure probability is annualized to account for return frequency of various pools.
- Not allowed to show results with loss of life numbers.

# Drainage Tunnel Improvements



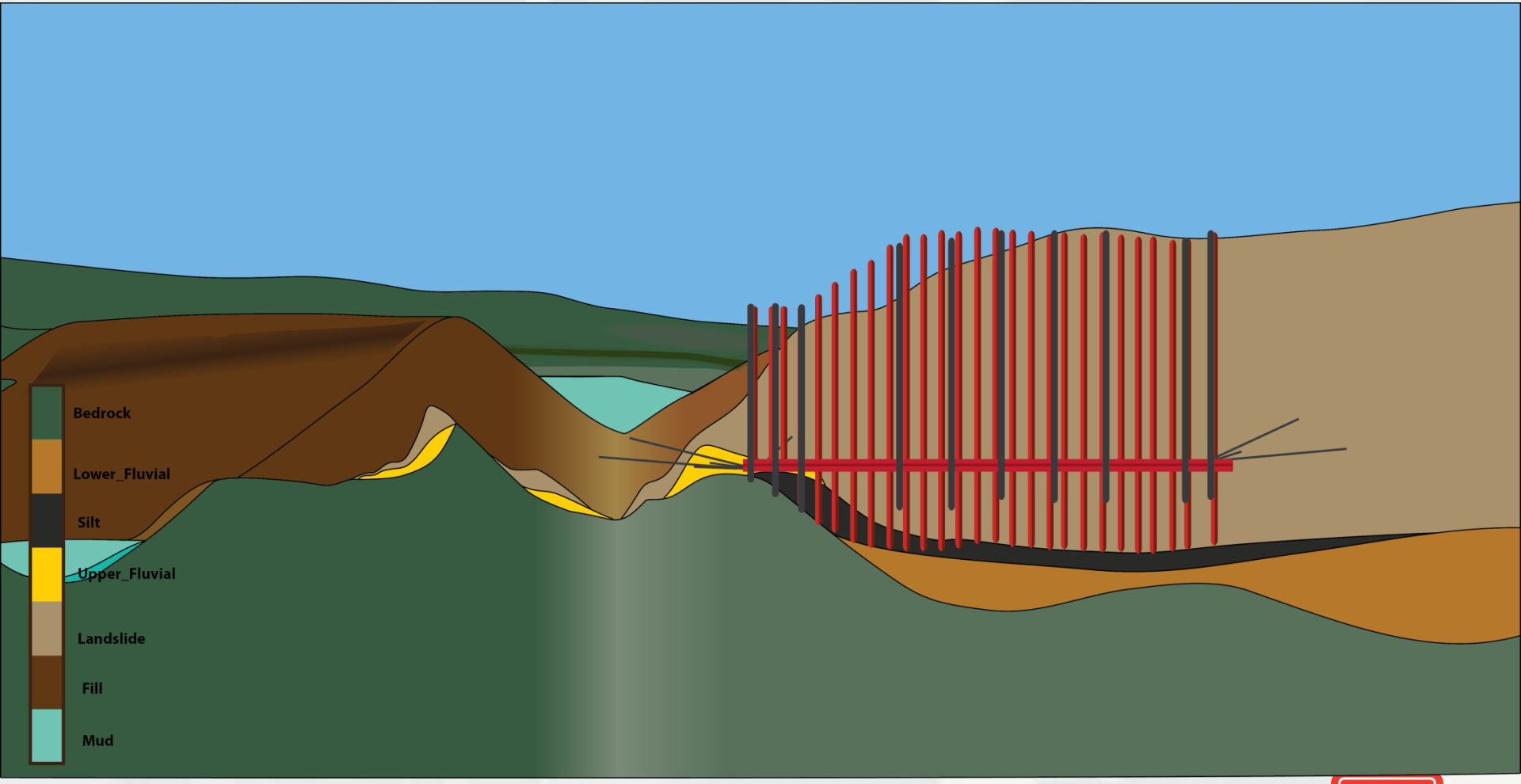

Existing Drainage Features

# Drainage Tunnel Improvements




New Vertical Drains

# Drainage Tunnel Improvements




New Horizontal Drains

# Completed Construction Activities


**Horizontal drains drilled from inside the tunnel.**

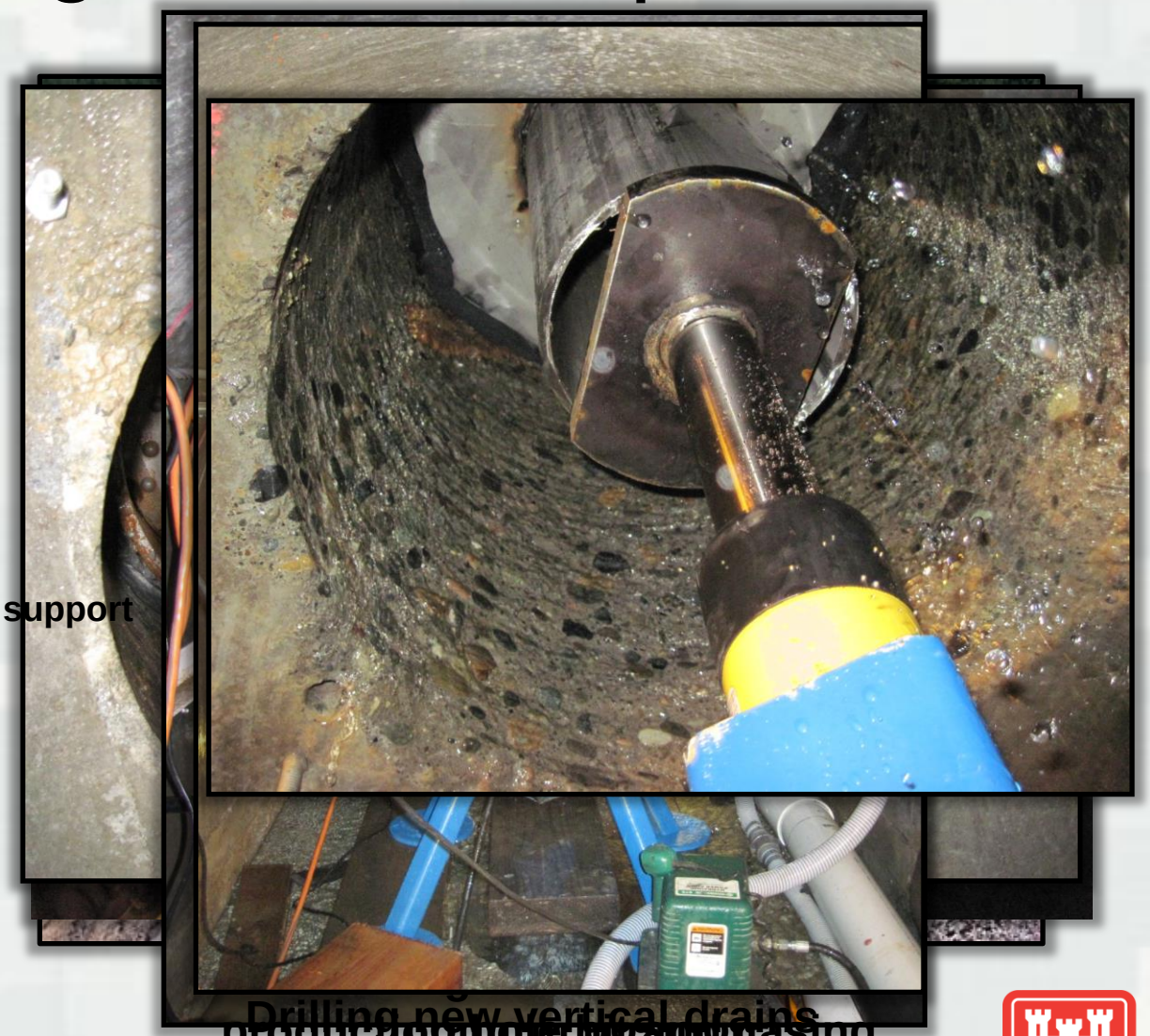
# 2011 Drainage Tunnel Improvements


Ver

Sm

creen support

Lar



Drilling new vertical drains

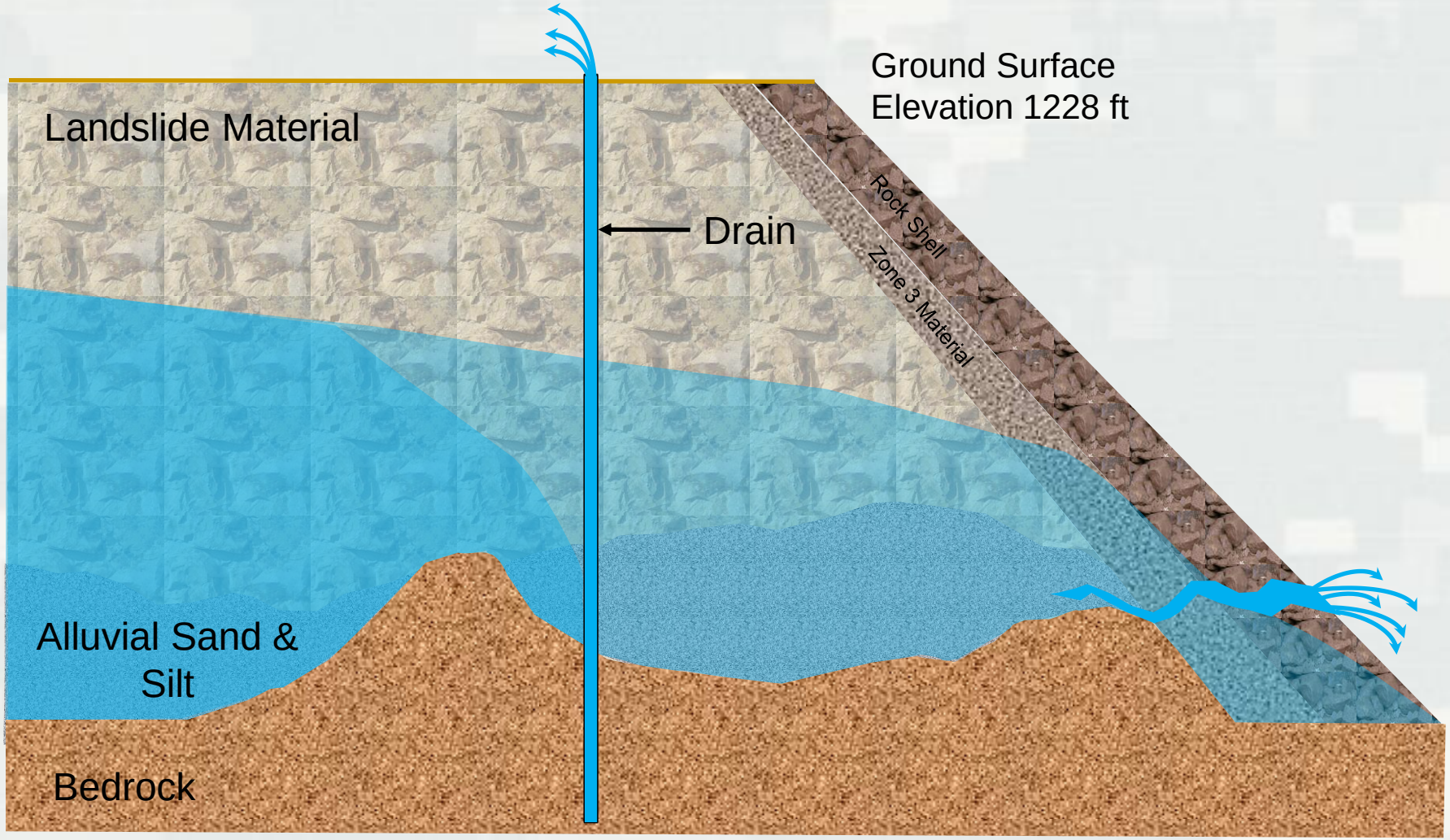
production monitoring and casing

Support for over drain screen

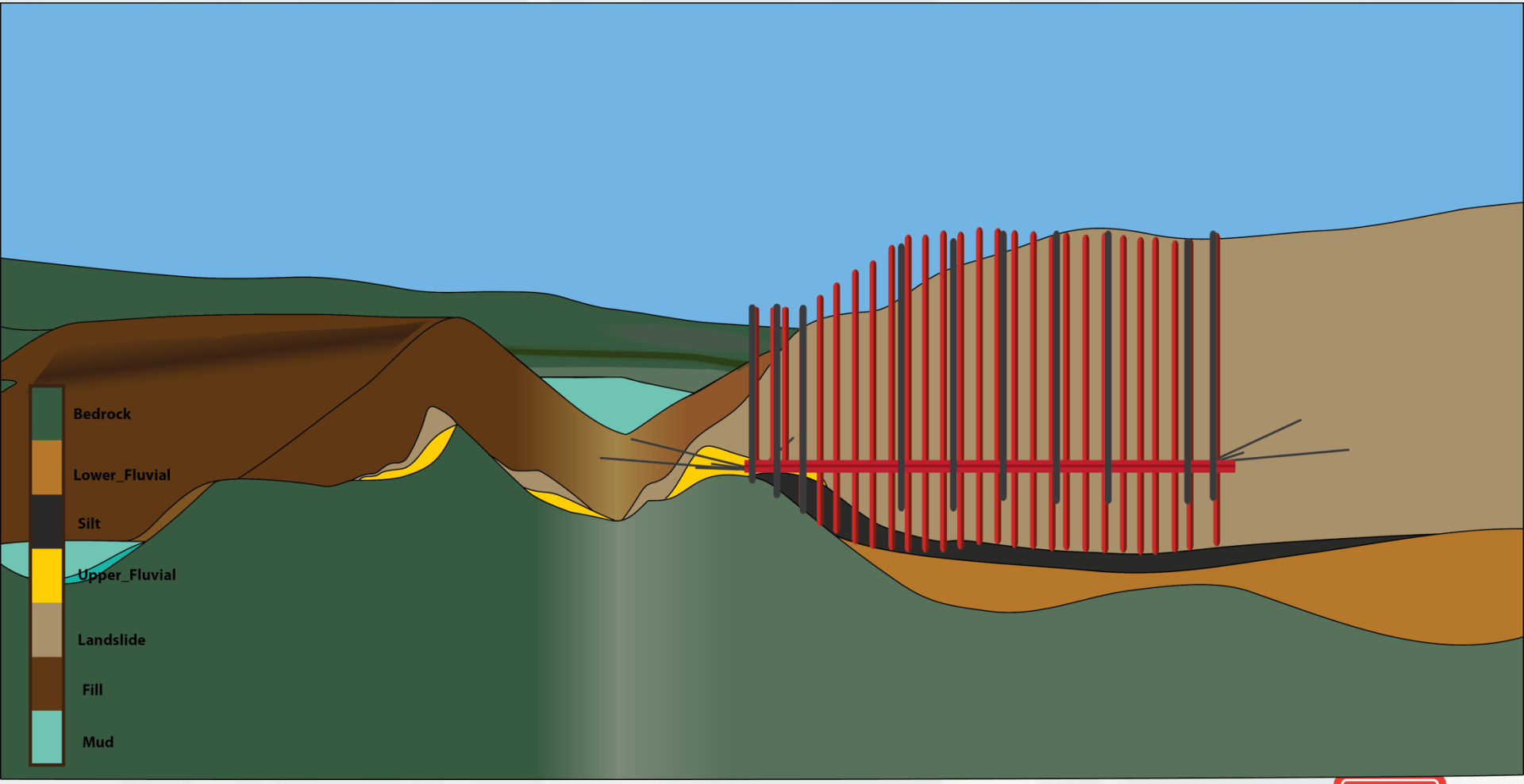
Large diameter through floor

Drilling through floor

# Short Path Dewatering Wells

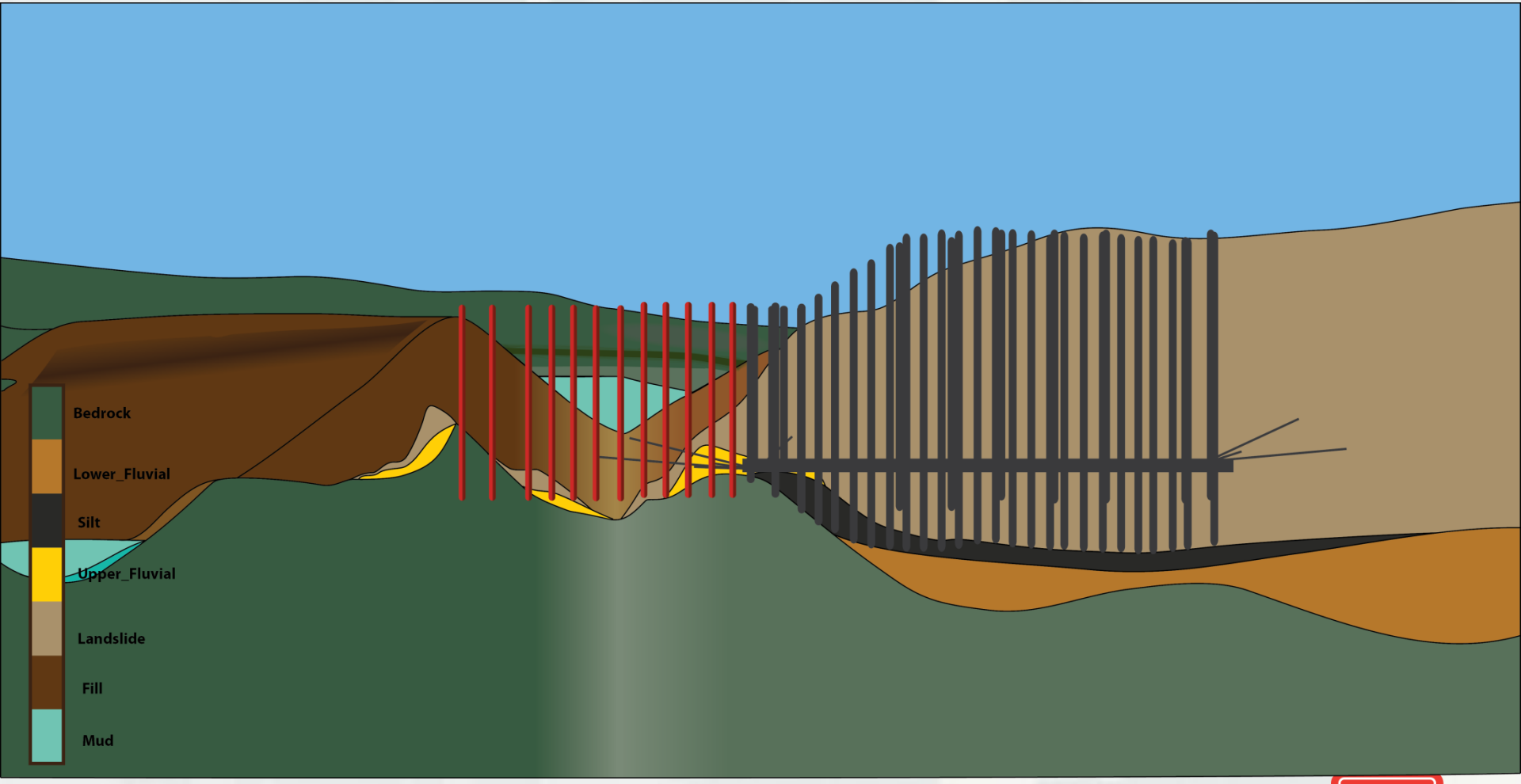


# Short Path Seepage Repairs




Existing Tunnel With Improvements

# Short Path Seepage Repairs




Dewatering Wells

# Completed Dewatering System

**Production drilling for dewatering.**

**Completed system.**

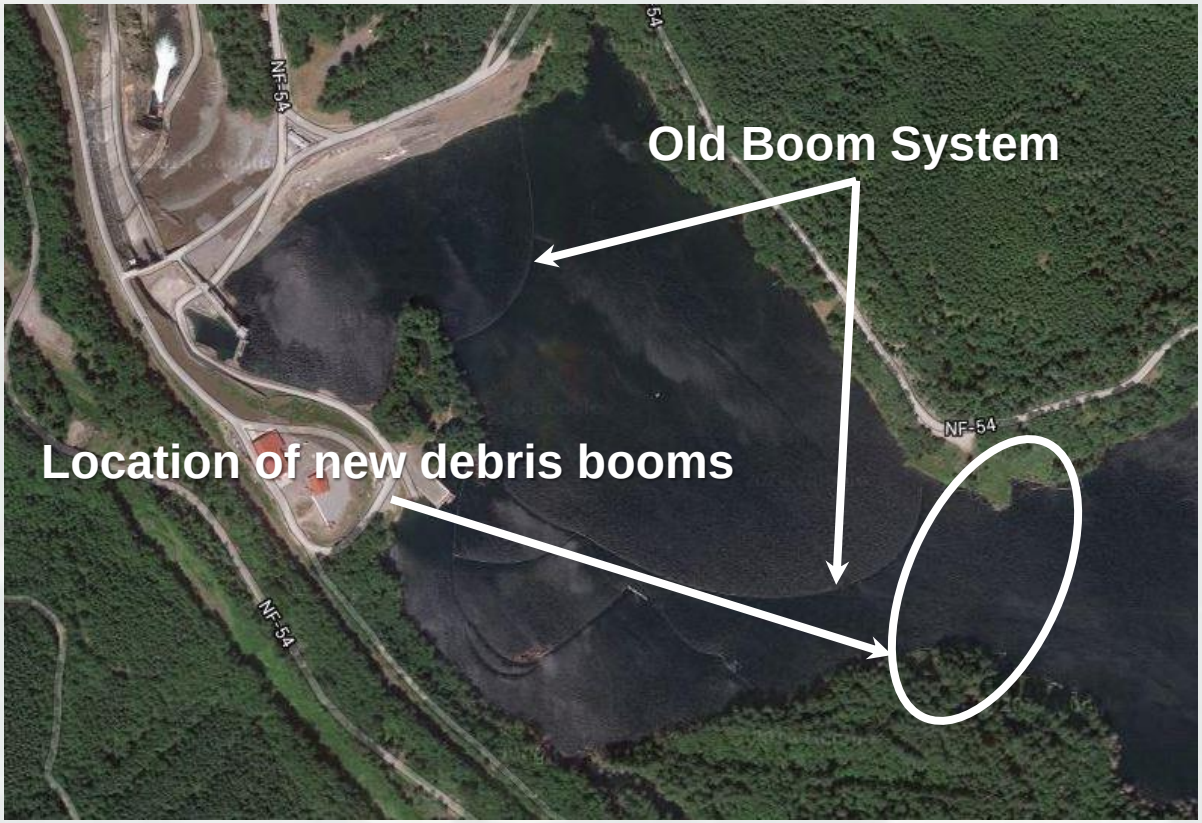
# Other Failure Modes

PFM 3 – Spillway debris plugging


PFM 17 – Left embankment erosion

**High velocity modeled water flow toward spillway. Spillway plugged by debris would lead to dam overtopping.**

# Spillway Debris Plugging




New debris booms system anchored above PMF 2061 – not functional when spillway gates opened.

# New Log Boom System

# New Rip Rap

Before

After

# Questions?