

Combined Events A Systems Perspective

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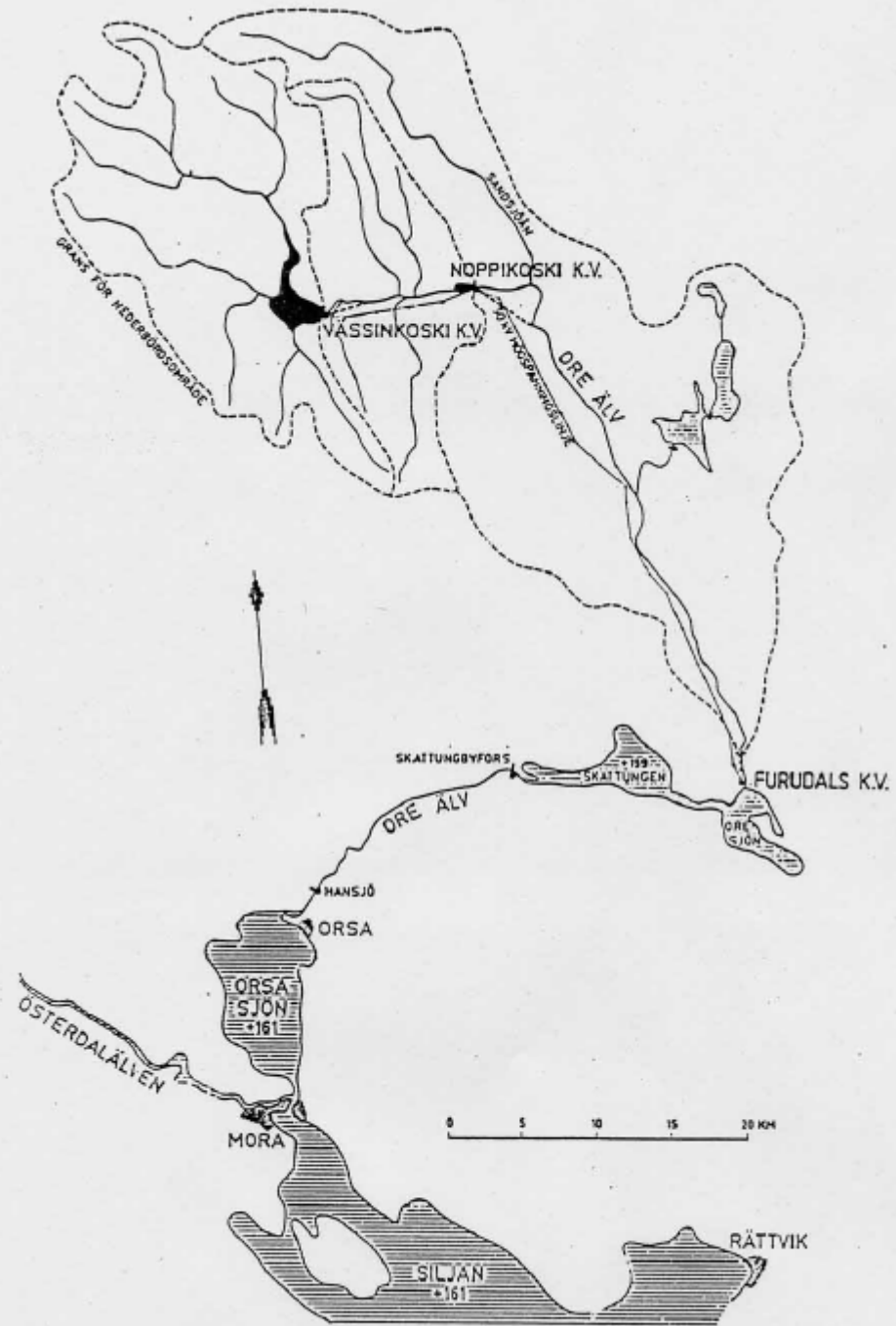
Federal Energy Regulatory Commission
Division of Dam Safety and Inspections

Failures are seldom the result of a single “root cause”

Most failures result from an unforeseen combination of events that include natural events (i.e. rainfall, landslides, etc.), man-caused events (i.e. failure of other man-made structures), and human/organizational factors (i.e. maintenance decisions, operational errors, staffing decisions, etc.)

If we focus on just the extreme storm, we may miss the more likely system failures that may have a similar or larger impact.





Översiktskarta.

Causes

The Simple Answer

- Too much rain
- Too little spillway capacity
- Mechanical hoist failure

Causes

A more complete list

- 1) Extreme precipitation and a high ground water level.
- 2) Mechanical fault in the hoisting equipment.
- 3) Great difficulties using roads, since ordinary brooks in the entire area cut off all roads. This excludes personnel reinforcements and availability of lifting equipment and tools.
- 4) The telephone went dead.

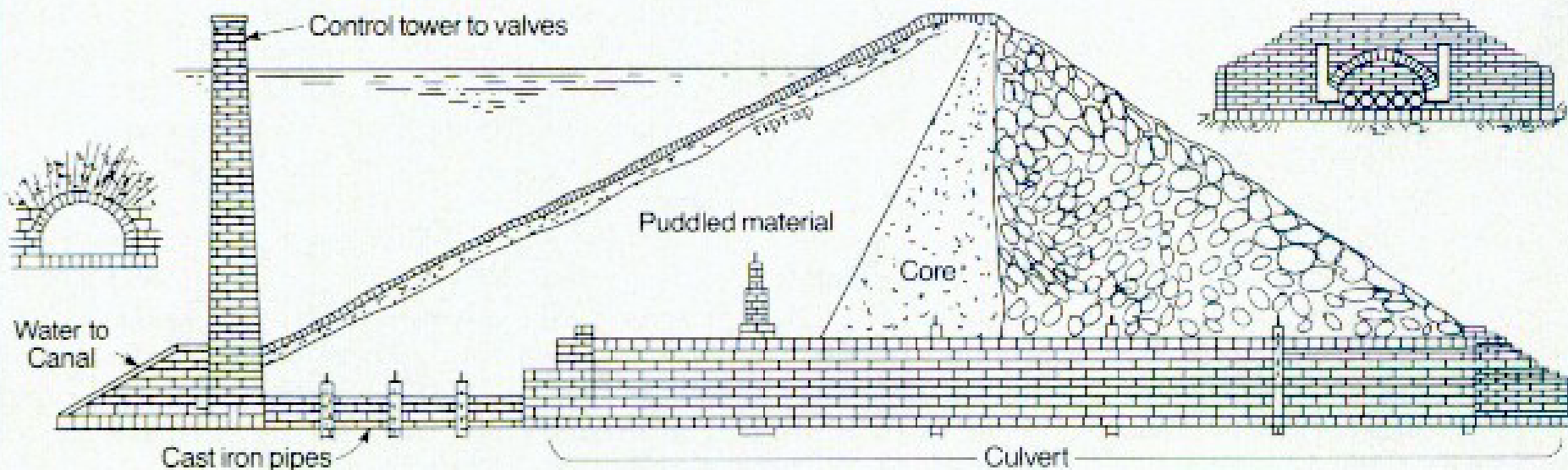
- 5) Transmission poles fell, resulting in blackouts.
- 6) It all occurred during the night – it is dark and rain is falling.
- 7) Problems getting hold of a mobile crane and not least crane operators – it could be Friday evening.
- 8) Helicopters are unable to fly when it is dark.

- 9) The helicopter radio could only communicate with an airforce base – but not on Saturdays, when it is closed.
- 10) At Vässinkoski there were difficulties providing large capacity pumps.
- 11) Exhausted personnel.
- 12) Unforeseen high downstream water level, preventing normal opening of the gate in the diversion tunnel.

- 13) Complications when trying to drain the tunnels, since the raised upper water level surpassed the intake gate, filling the tunnels.
- 14) Staff problems – getting hold of qualified extra personnel to work 24-hour shifts during a weekend.



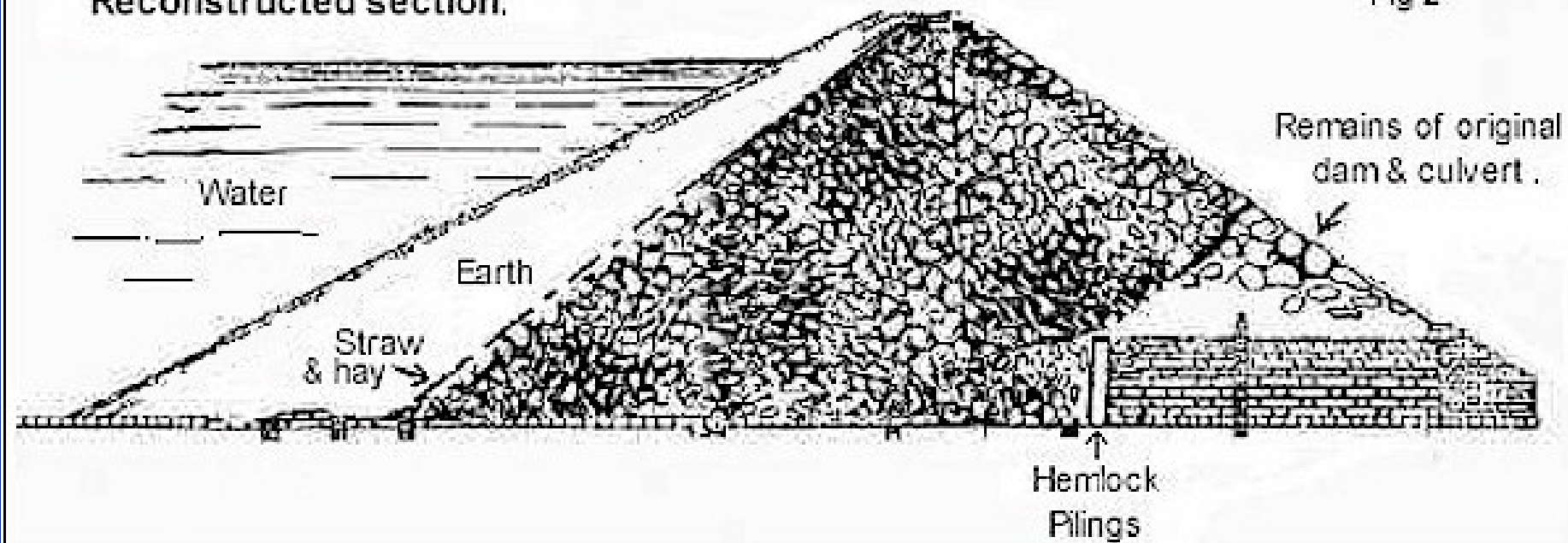
FIGURE 1
ORIGINAL DAM DESIGN



A schematic of the design for the Johnstown, Pa. South Fork Dam, circa 1840.

Reconstructed section.

Fig 2



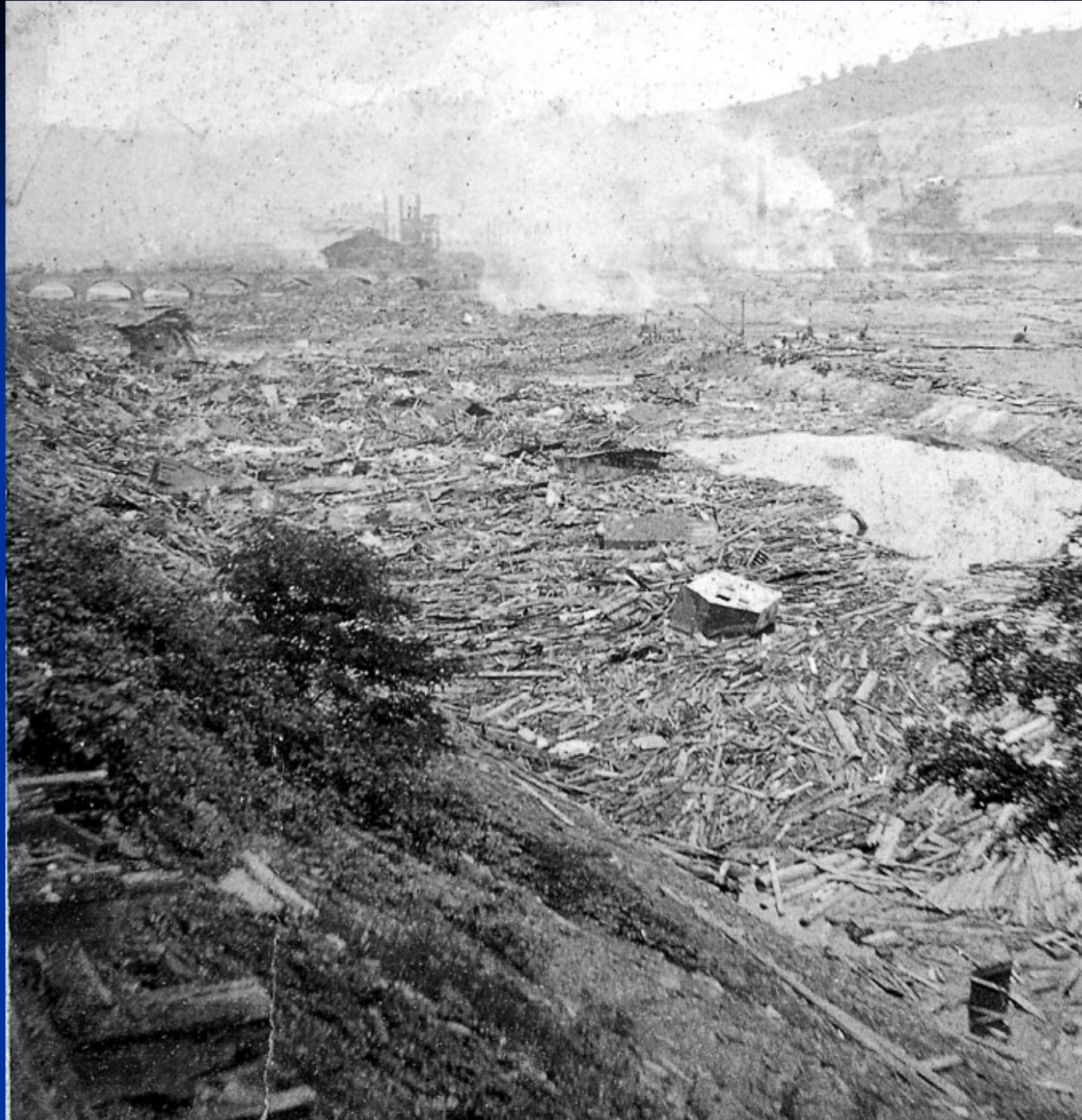
Causes of Failure

Overtopped and Failed

- 2' crest lowering to allow carriages to pass
(spillway capacity reduced to ~72% of design)
- 3.5' settlement due to poor re-build
(spillway capacity reduced to ~35% of design)
- Fish screen constructed in front of spillway
(spillway capacity reduced to ~21% of design)



LOOKING EAST THROUGH BREAK IN DAM





Finally I would like to convey a thought of mine. In the dam safety branch we are now at a point when we are to realize what has previously been analyzed scientifically – how precipitation could result in an influx unthought of.

Mr. Bengt Skog, Korsnäs AB
The Dam Failure at Noppikoski

In my opinion, the important question of how to adapt the plants – with the exception of augmented discharge functions – to practical operation, in view of the complications of the kind previously listed, has not been considered or documented to the same extent.