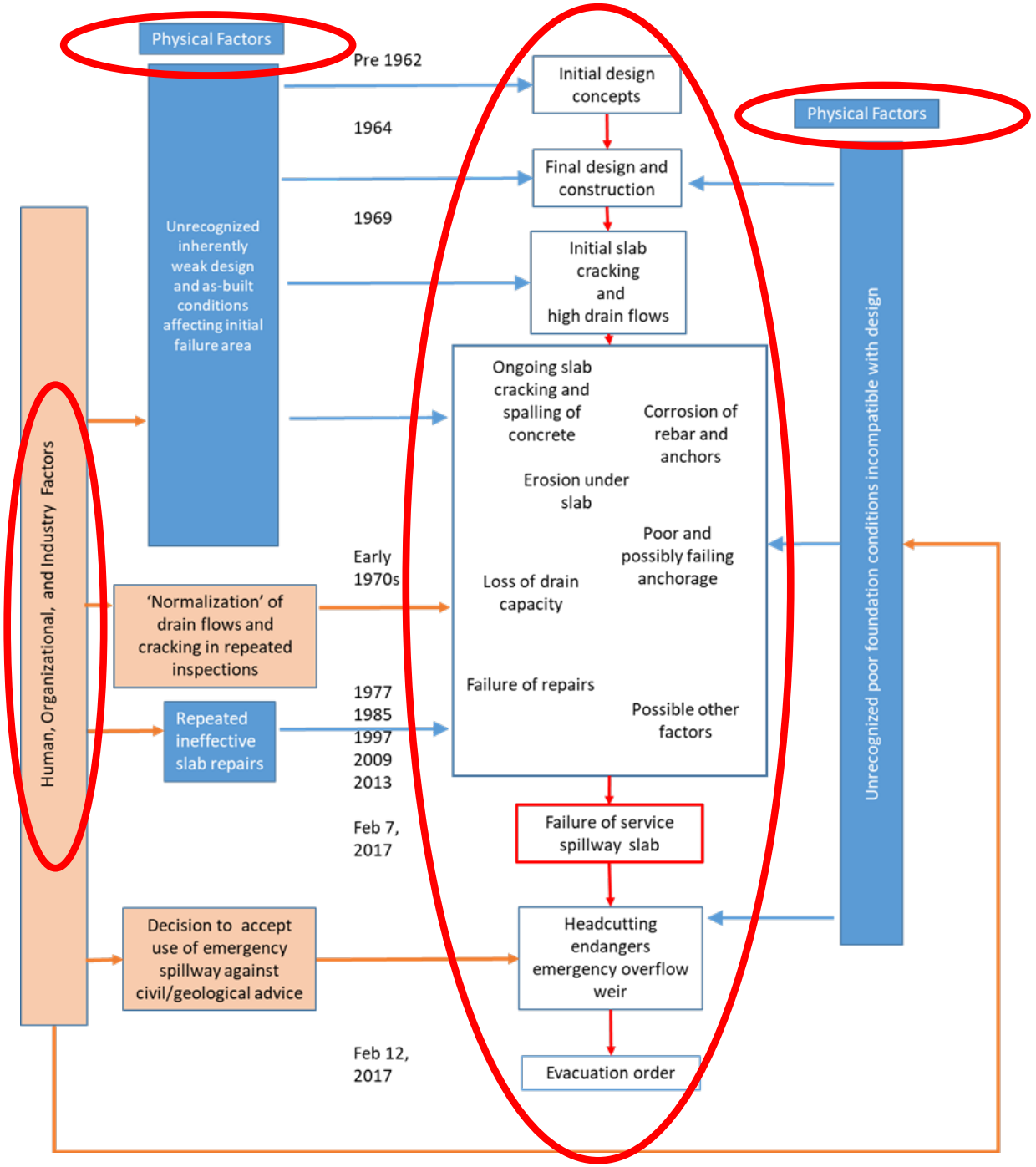
Looking Beyond Oroville
Where to from here?

Lessons ***to be*** learned from the Independent Forensic Team Report, January 2018

Summary of Findings

The Oroville Dam spillway incident was caused by ***a long-term systemic failure of*** *the California Department of Water Resources (DWR), regulatory, and general* ***industry practices*** *to recognize and address inherent spillway design and construction weaknesses, poor bedrock quality, and deteriorated service spillway chute conditions.*

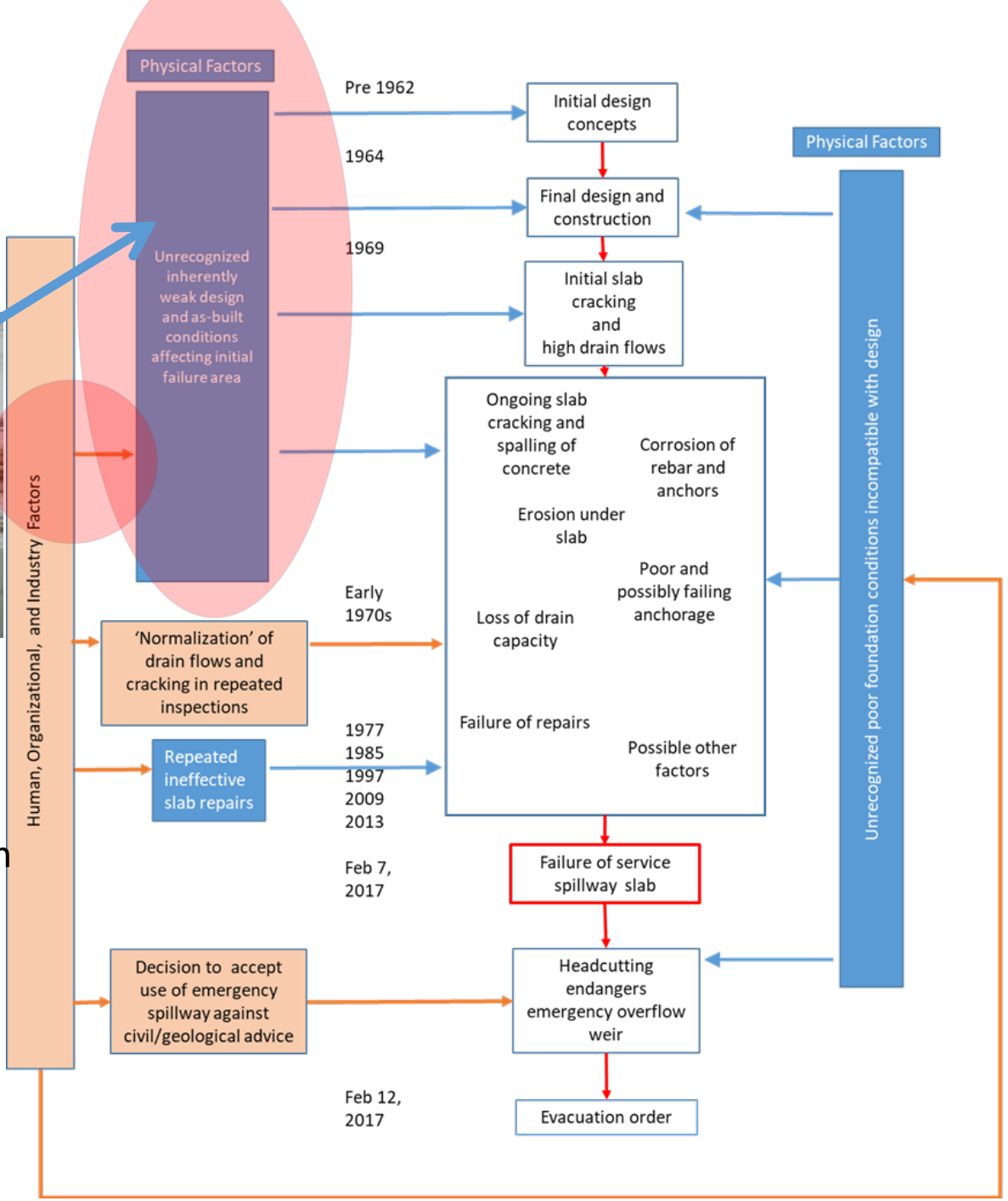
Timeline


Physical Factors
Pre 1962
Initial design concepts
1964
Final design and construction
1969
Initial slab cracking and high drain flows
Unrecognized inherently weak design and as-built conditions affecting initial failure area
Physical Factors
Unrecognized poor foundation conditions incompatible with design
Human, Organizational, and Industry Factors
Ongoing slab cracking and spalling of concrete
Corrosion of rebar and anchors
Erosion under slab
Poor and possibly failing anchorage
Loss of drain capacity
Failure of repairs
Possible other factors
Early 1970s
'Normalization' of drain flows and cracking in repeated inspections
1977
1985
1997
2009
2013
Repeated ineffective slab repairs
Feb 7, 2017
Failure of service spillway slab
Decision to accept use of emergency spillway against civil/geological advice
Headcutting endangers emergency overflow weir
Feb 12, 2017
Evacuation order

Timeline

Thin slab
Protruding Drains
No Waterstops
Incompatible with foundation

Inexperienced Designer
Little Supervision
Little emphasis as compared to dams
Corporate Silos



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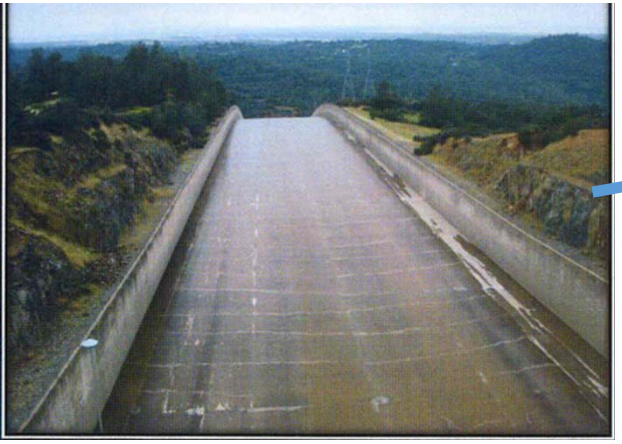
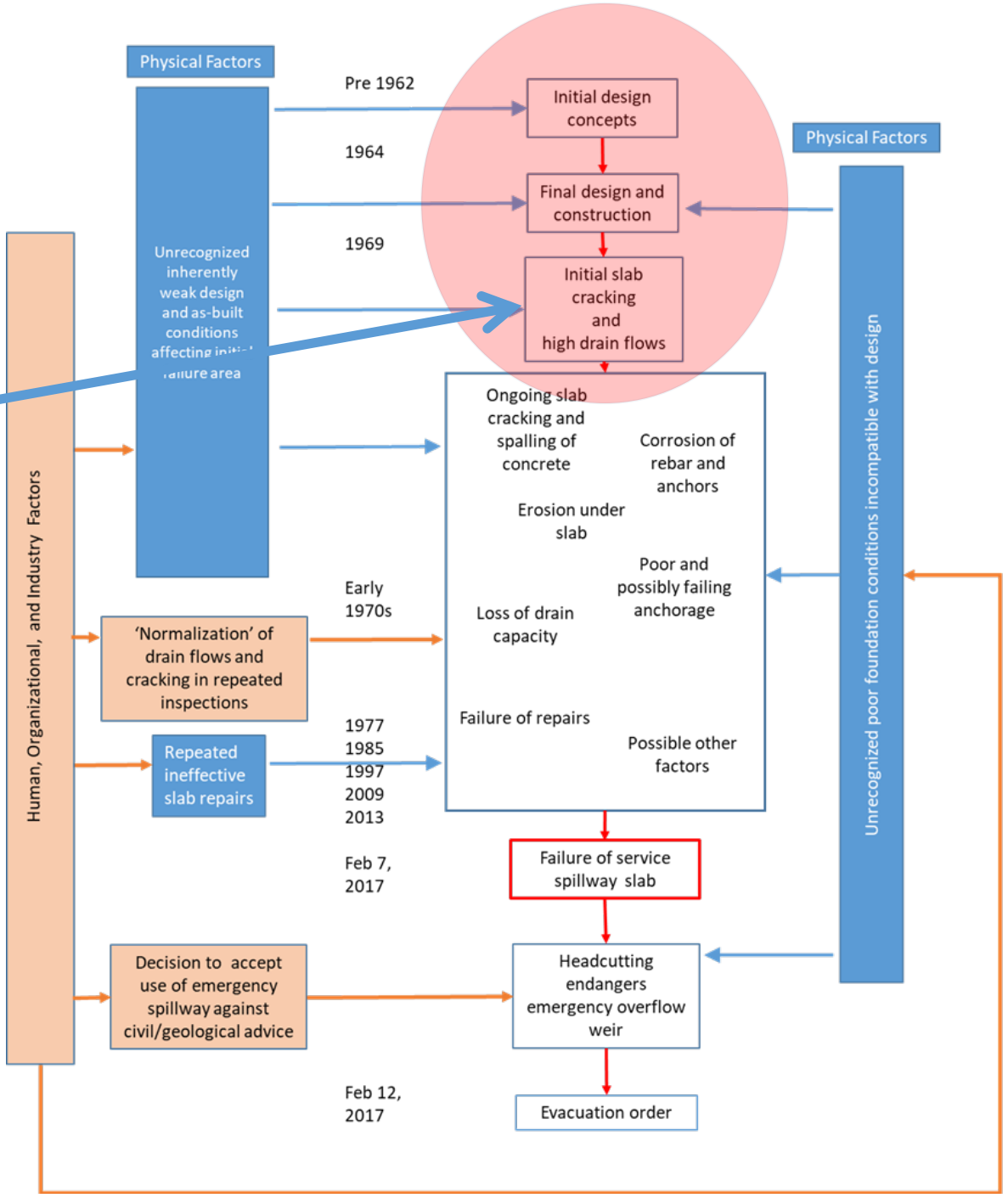


Major concerns
"Should consult designer"



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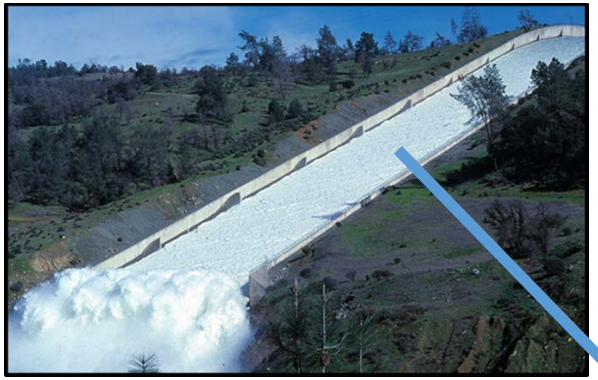
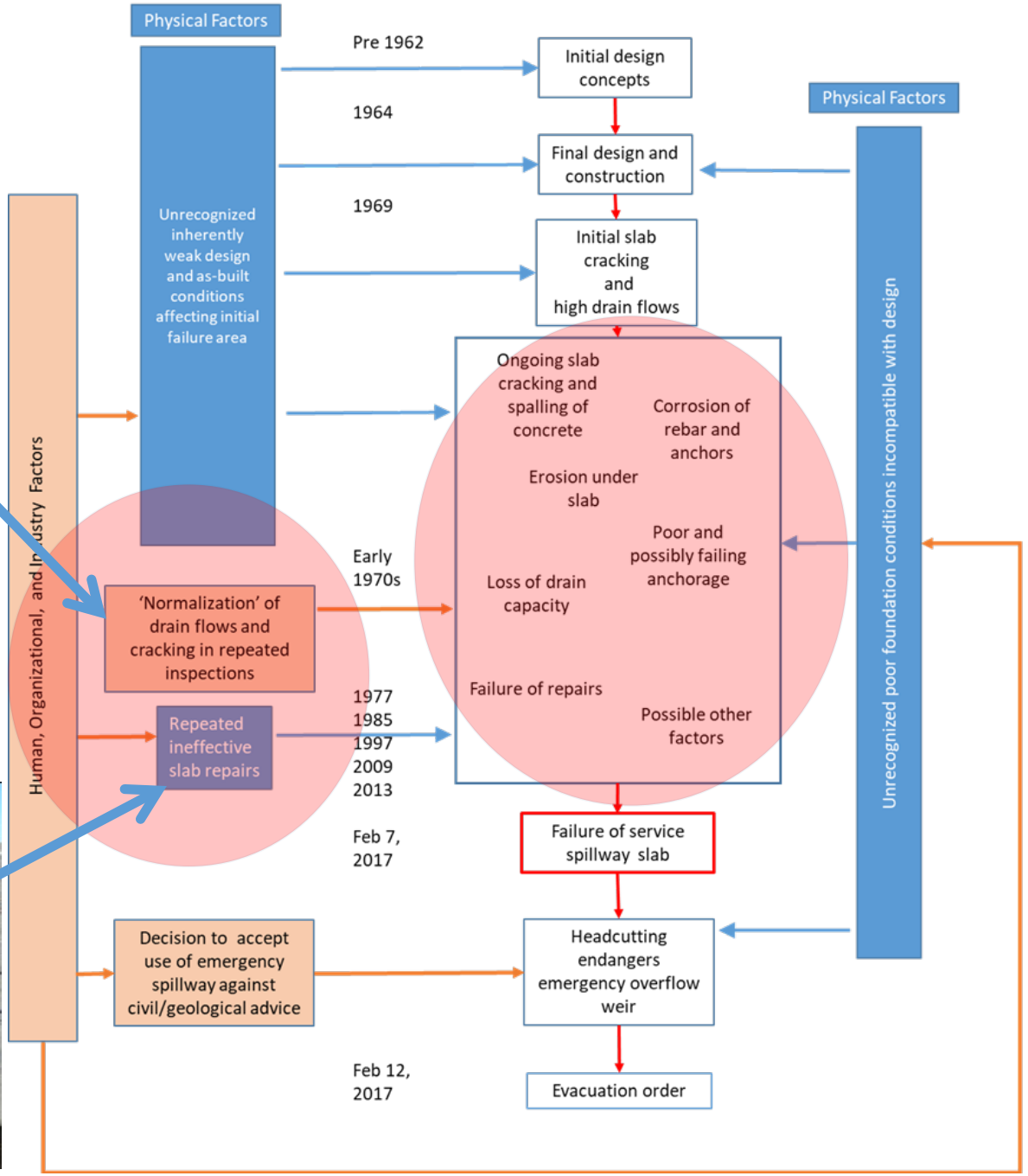


From ‘mystifying’ to normal

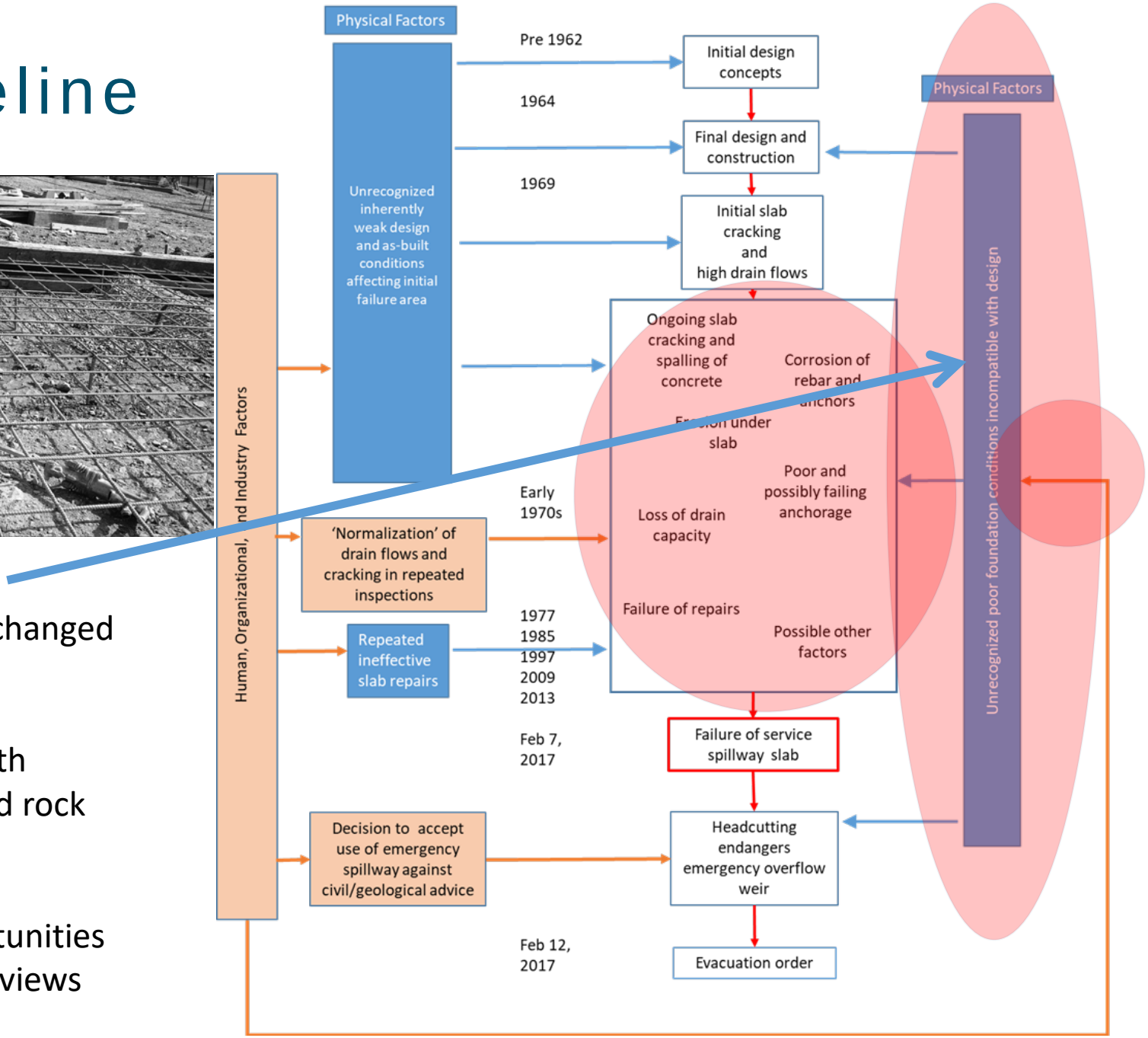


Timeline

Construction changed conditions

Corporate Myth regarding good rock

Missed opportunities in repeated reviews



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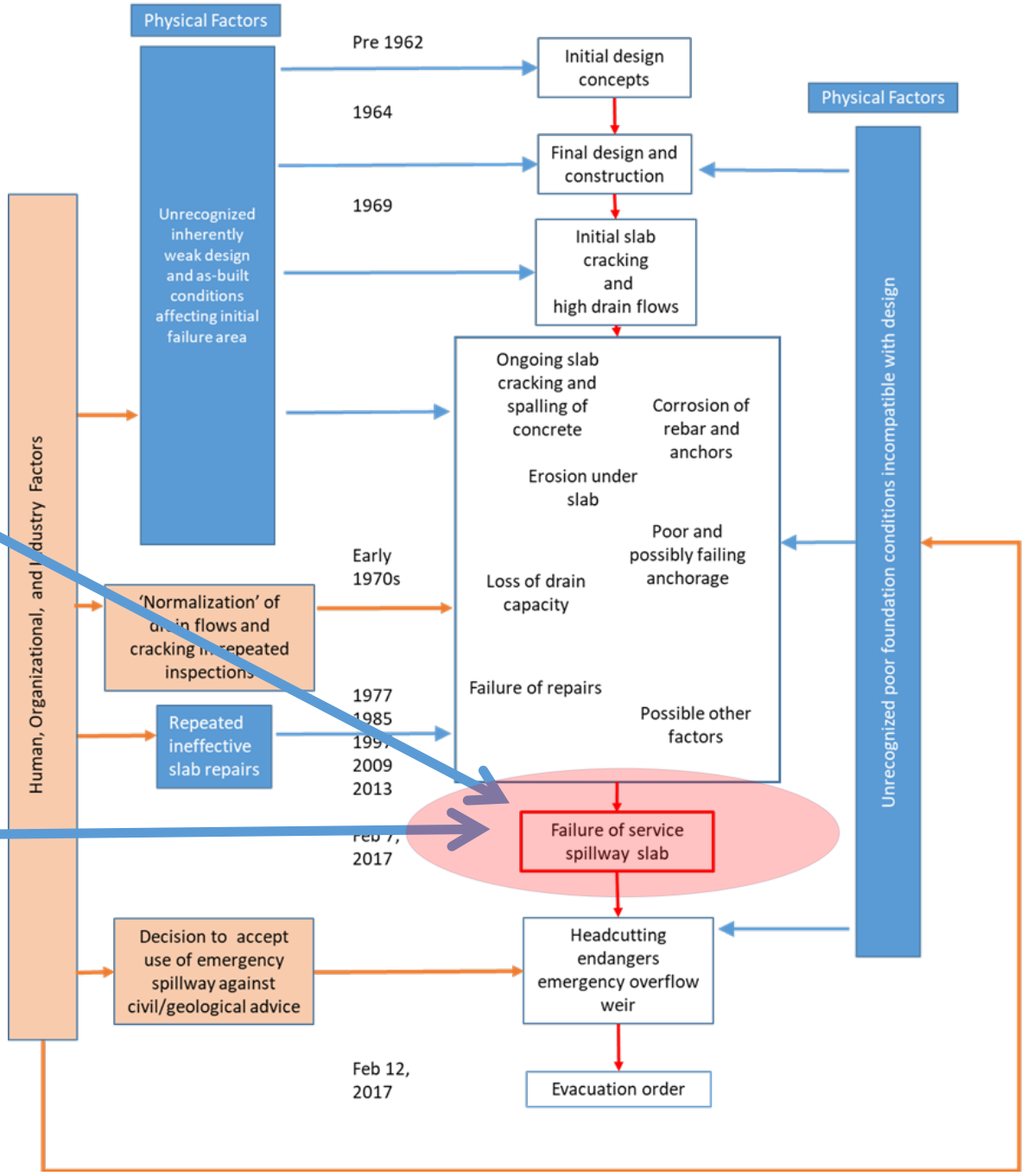
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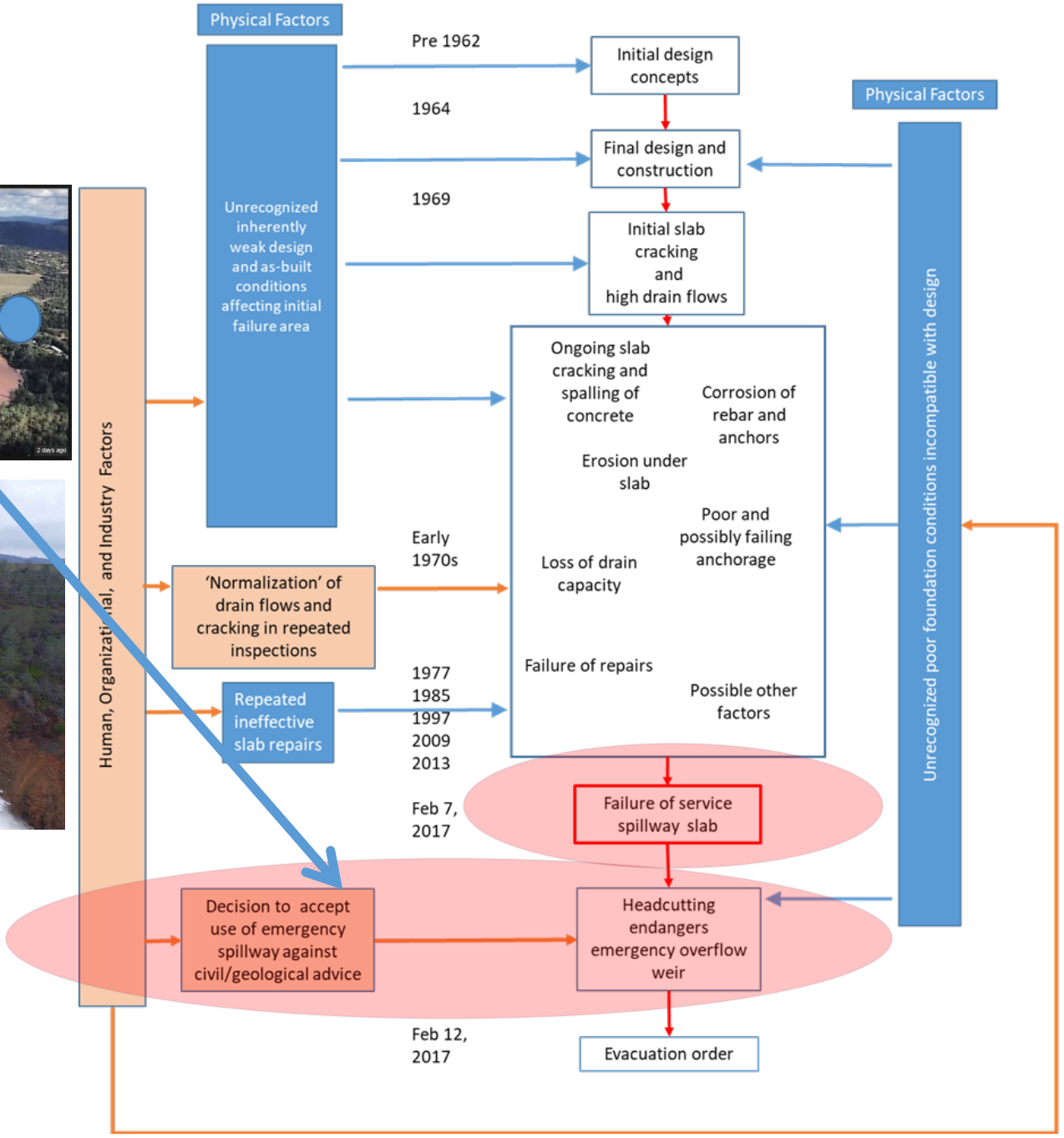
Timeline

2 points of view :

operators/executive

engineers/geologists



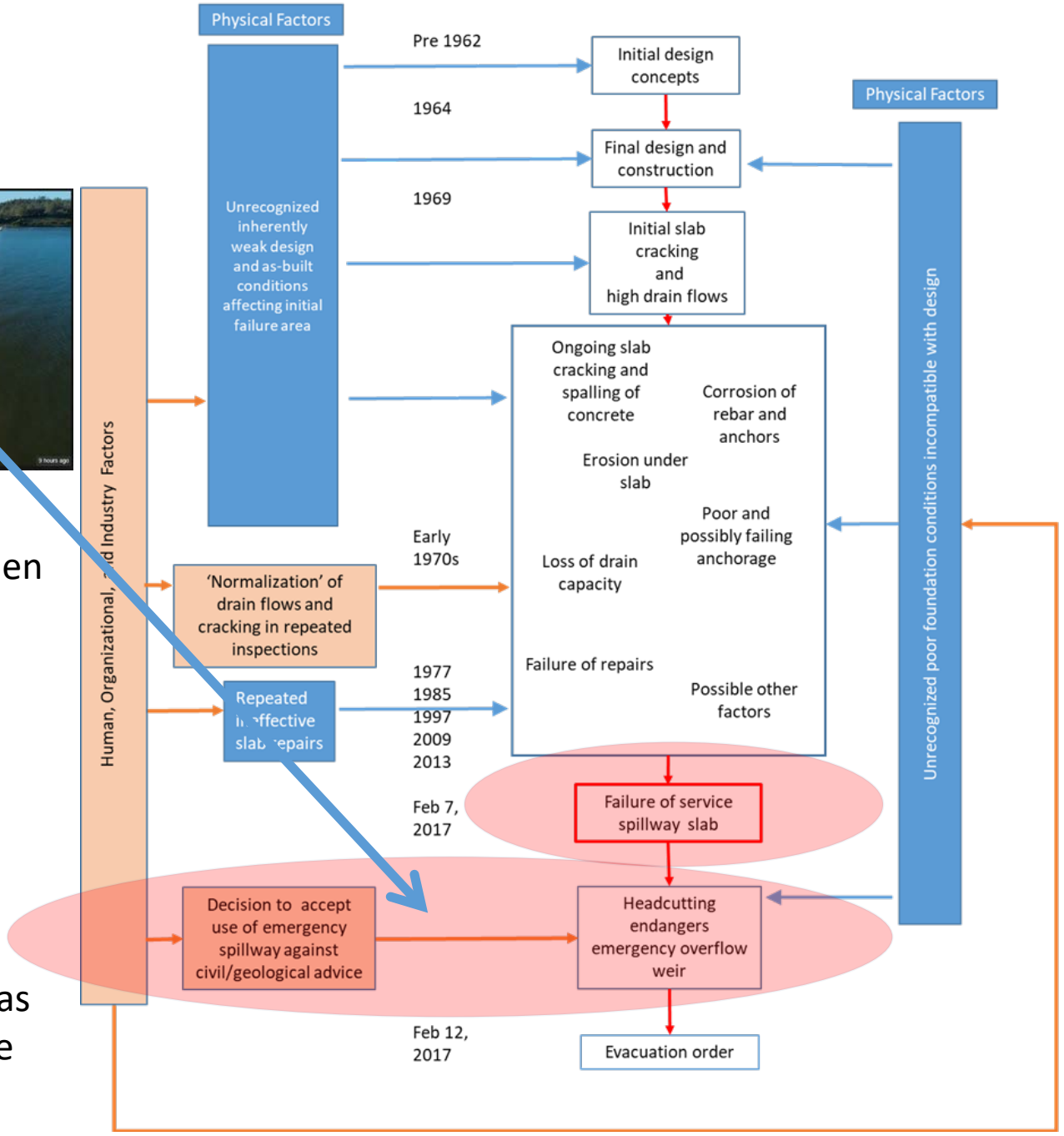
Timeline

Risks treated as equal when they were not !

Relative risk of trade-offs were not fully informed.

Consequences misunderstood

Likelihoods not adjusted as new information available



Lesson 1:

- Dam owners must develop and maintain mature dam safety management programs which are based on a strong “top-down” dam safety culture.
- There should be one executive specifically charged with overall responsibility for dam safety…

Lesson 2:

- Think about risks associated with events which may not result in uncontrolled release of reservoirs, but are still highly consequential.
  - No loss of water containment, no loss of life,
  - Non-catastrophic environmental effects
  - BUT – loss of flow control and a large public evacuation

  - EQUALS Extreme Consequences

Lessons 3 and 4:

- More frequent physical inspections are not always sufficient to identify risks and manage safety.
  - Periodic comprehensive reviews of original design and construction and subsequent performance are imperative.

- Don’t forget about appurtenant structures such as spillways!

Lesson 5

- Compliance with regulatory requirements is not sufficient to manage risk and meet dam owners' legal and ethical responsibilities.

Lesson 6

- "…. A critical review of (dam safety) processes in dam safety practice is warranted, comparing their strengths and weaknesses with risk assessment processes used in other industries worldwide and by other federal agencies."

- "…Challenging current assumptions on what constitutes 'best practice' in our industry is overdue."

Current 'Best' Practice :

Every inspection and evaluation, by the owner, two regulators, and numerous external consultants either did not identify the vulnerabilities, or eliminated them from further consideration

- Brainstorming sequences of events leading to failure
- Qualitative assessment of probabilities

Potential Failure Modes Analyses

3 PFMA's :

- first two missed the failure modes
- third identified, but dismissed them

Forensic Report points to numerous weaknesses

- Emphasis on extreme events
- Emphasis on total loss of water retention
- Overreliance on inherently fallible engineering judgement
- Difficult to capture systems thinking

Current PFMA Process

There are basic limitations *due to its practicality:*

- Unstructured brainstorming: not a methodical, structured process
- Allows quick categorization and elimination of failure modes, but….
- “If you do not fully develop a PFM, you cannot categorize it.” FERC Part 12D Refresher Training module

Thinking beyond PFMA's

- Look at risk processes in other industries and look internationally

- Systems Analyses
  - STPA and
  - FM
  - nalyses
  - ational modeling

TOO COMPLICATED??
(not for other high-hazard industries!)

Thinking beyond PFMA's

How about getting back to some basics??

Need to figure out how a system is supposed to work before understanding how it could fail

Basic functional questions :

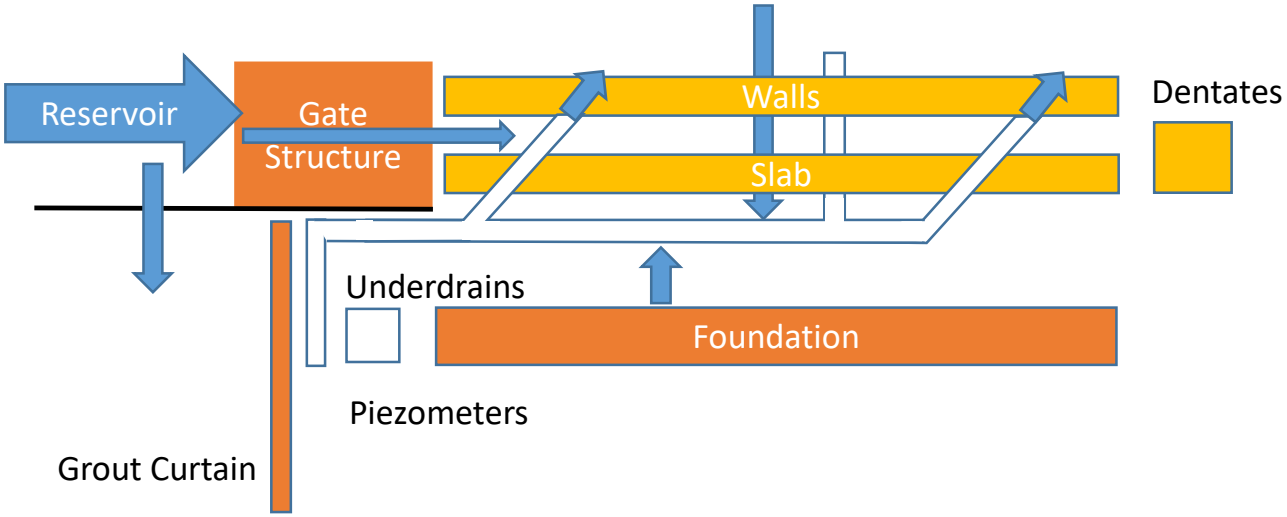
Do I know how each component is supposed to function?

Is it functioning the way it's supposed to?

Is that still good enough?

Simplistic Function Diagram

Oroville Spillway Chute



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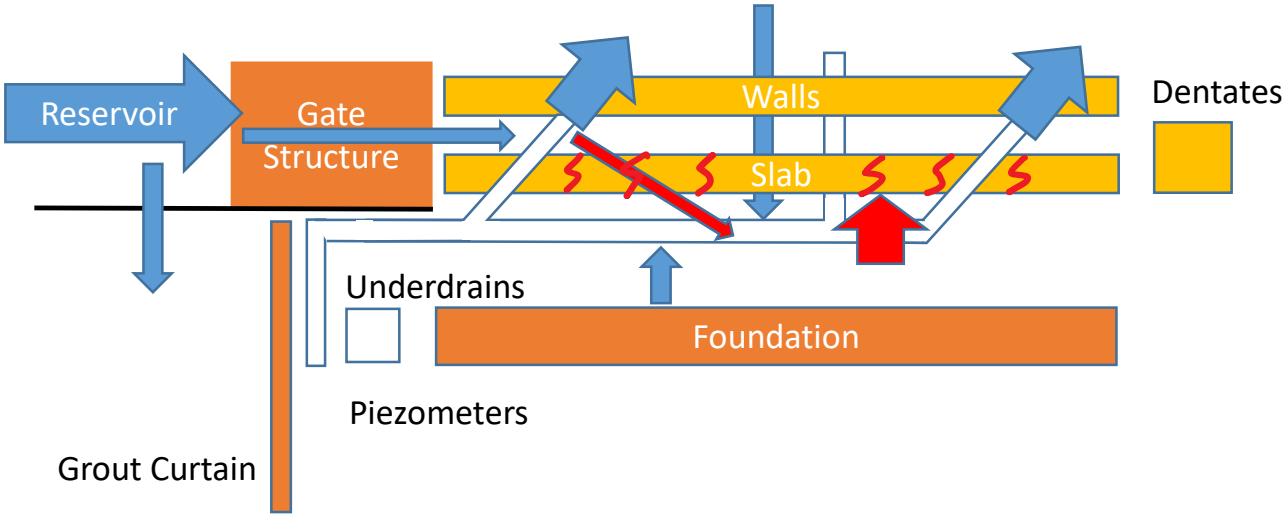

Component – Slab	Yes	No	??	Parameters	Justification
Fulfils original functions:					
Hydraulics	x			Concrete condition	
Protect Foundation	x			sab	
Contain water		x		Drain flows	
Original function still adequate			x		

Summary of Findings

Challenging current assumptions on what constitutes "best practice" *in our industry is overdue.*

….the fact that this incident happened to the owner of the tallest dam in the United States, under regulation of a federal agency, with repeated evaluation by reputable outside consultants, in a state with a leading dam safety regulatory program, is ***a wake-up call for everyone involved in dam safety****.*

HAS ANYONE WOKEN UP YET?

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