Management of Risks from Dams at Vattenfall

SWEDCOLD
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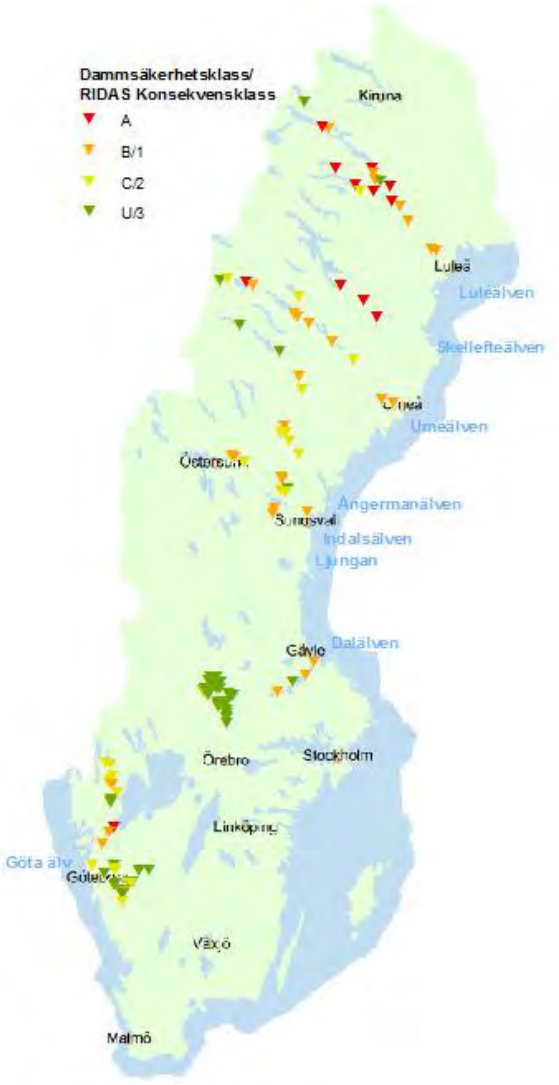
Claes-Olof Brandesten, Head of Dam Safety
Stefan Berntsson, Risk Manager Dam Safety

Portfolio of Dam Facilities – Dam Safety Classification

River / Water Course	A	B / 1	C / 2	U / 3	Total
009 Luleälven	7	7	1	2	17
020 Skellefteälven	3				3
028 Umeälven	1	7	3	1	12
038 Ångermanälven		2	5	2	9
040 Indalsälven		6	2	1	9
042 Gimån		2			2
053 Dalälven		3		1	4
061 Norrström			6	36	42
105 Viskan		3	1	10	14
106 Rolfsån				2	2
108 Dalbergsån				3	3
108 Göta älv	1	3			4
108 Säveån			2	2	4
108 Upperudsälven		1	7		8
Totalt	**12**	**34**	**27**	**60**	133



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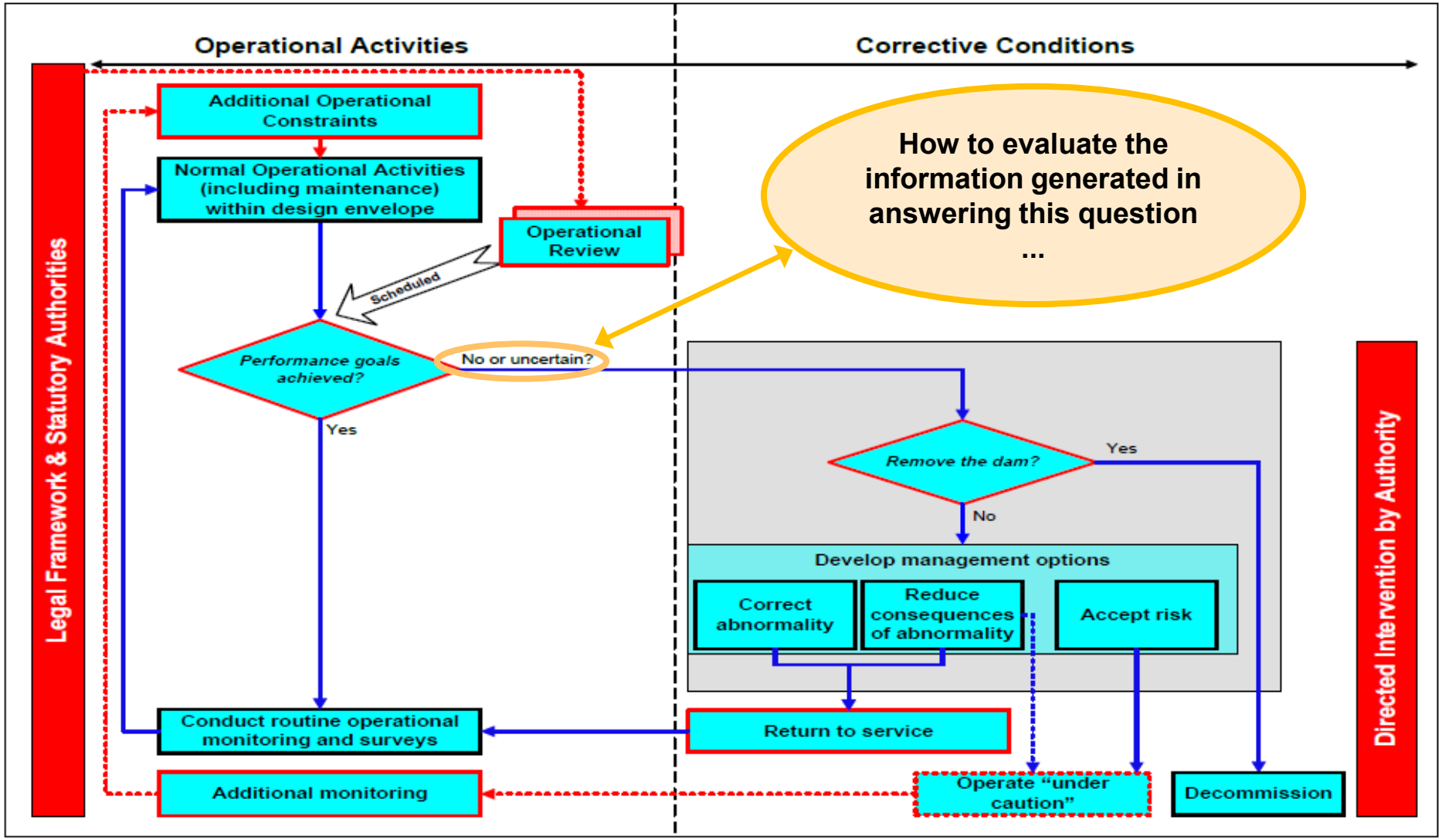
Systematic Risk Management Process (ICOLD Bulletin 154, Fig 3.4)



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Risk is managed in a systematic way

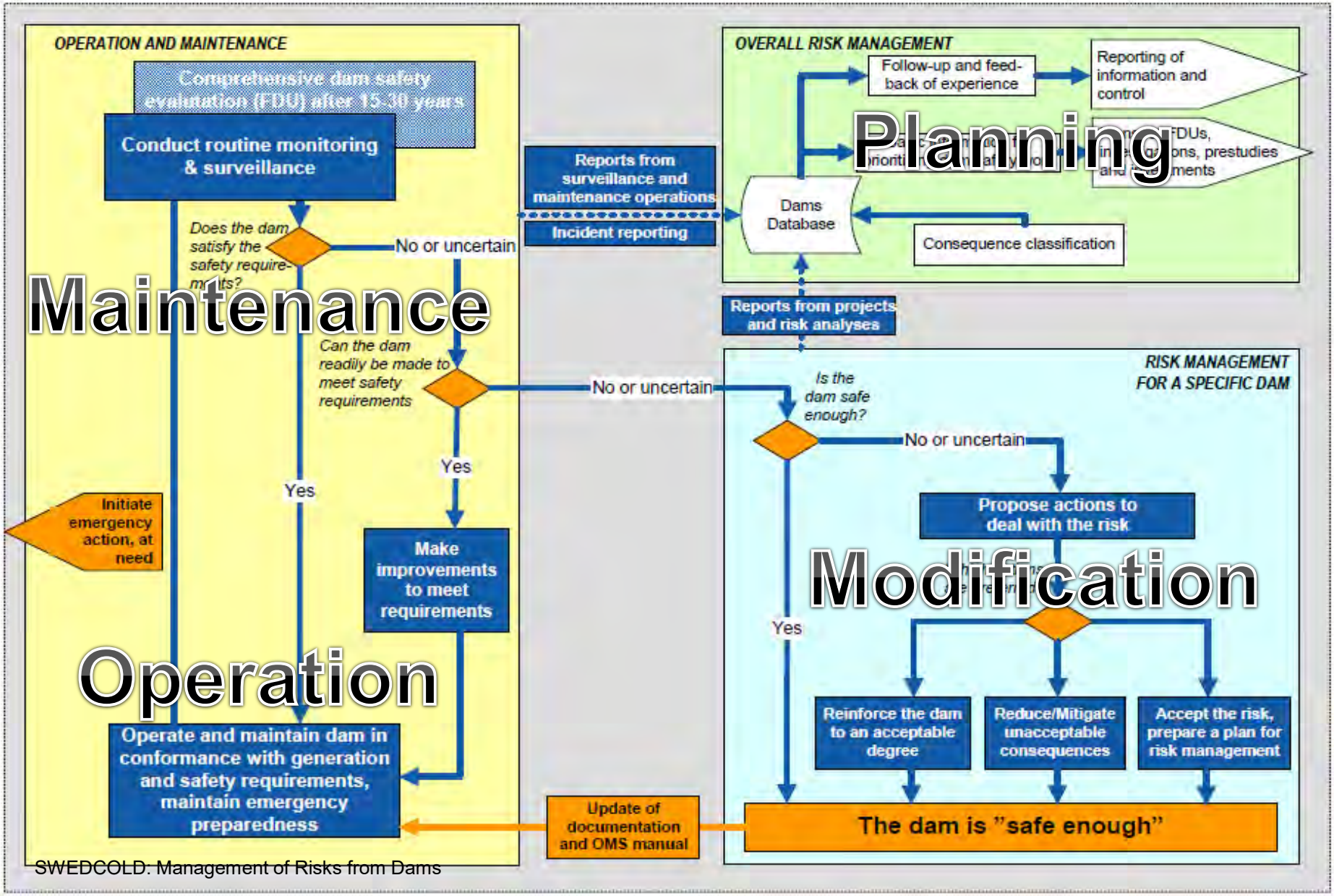
- Management system for all dam safety functions.

- Based on ICOLD Bulletin 154
  - integrated to other systems within Vattenfall Vattenkraft (ISO 14001, OHSAS 18001, ISO 55000)
  - integrated to the four core business processes
    - Planning
    - Modification
    - Maintenance
    - Operation

- Structured system of prioritisation
  - Reflects the vulnerability of the assets, components and parts
  - Transitioning to a systems based functional approach
    - In line with modern trends in dam safety management

BU Hydro Dam Safety Management System

is based on a Dam Risk Management Process aligned with ICOLD Bulletin 154



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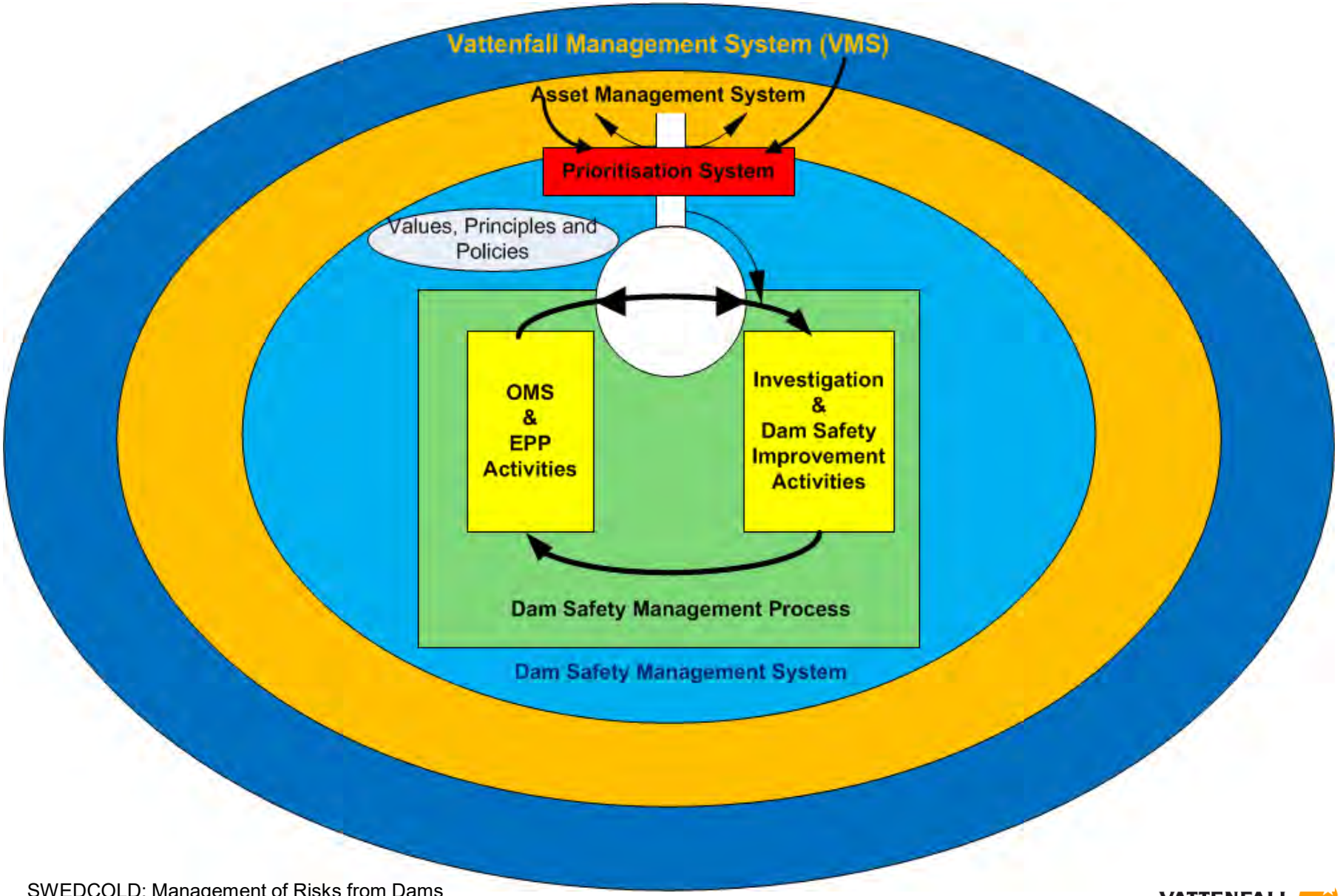
Risk Management of dams as a sub-management system

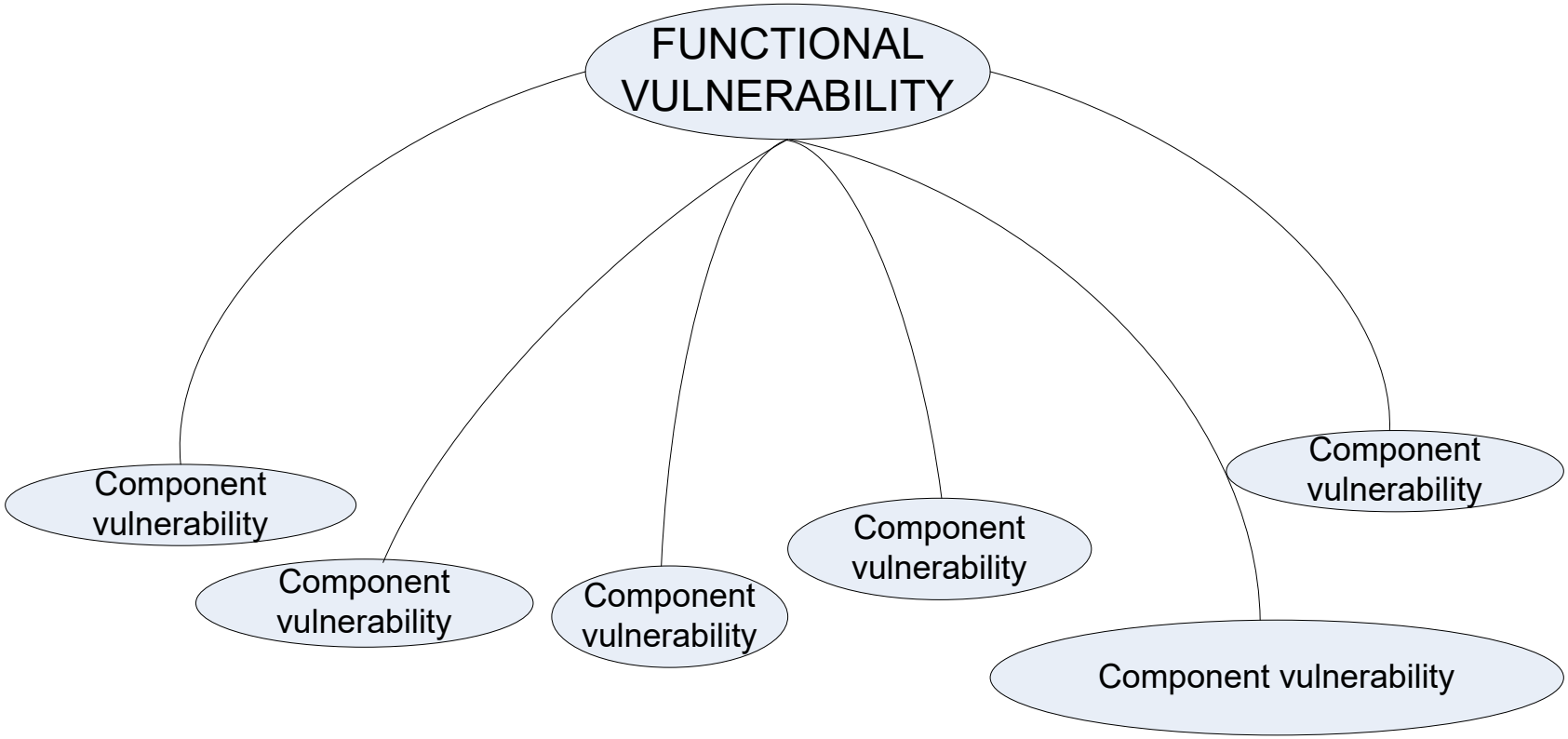


Risk management involves control of risk

- The vast majority of risk management activities focus on avoiding failure
  - Need to know the “vulnerabilities” of and within the system
    - Systems
      - System functions
      - Components and component functions
        - Physical
        - Software and communications
        - People as part of the system
  - Failures of components lead to failure of system functions which lead to system failures
- Maintain components and component functions to maintain system functions to control the risk in the system

Focus on Vulnerabilities

- Vulnerabilities of the components leads to functional vulnerabilities
  - Components can be vulnerable to failure to different degrees (magnitudes)



Dam Safety Management Principles

According to the Vattenfall Dam Safety Instruction

- The dam safety work is based on good and cost-effective risk management practices.
- Precautionary principle, implies that precautions are taken in proportion to the degree of uncertainty and the potential consequences of failure.
- Physical strengthening on dams should, where cost effective, be made with extra safety margin.
- Risks should be reduced to “as low as reasonably practicable” (ALARP).
  - *This is something to work towards when industry fully understand it*
    - *Maybe Best Available Technique and Precautionary Principle will do it.*
- Structural improvements are in principle preferred over operational restrictions.
- Advances in sciences and technology should contribute to continuous improvements.
- Dam safety management is, from an overall perspective, performed homogeneously across the dam portfolio.

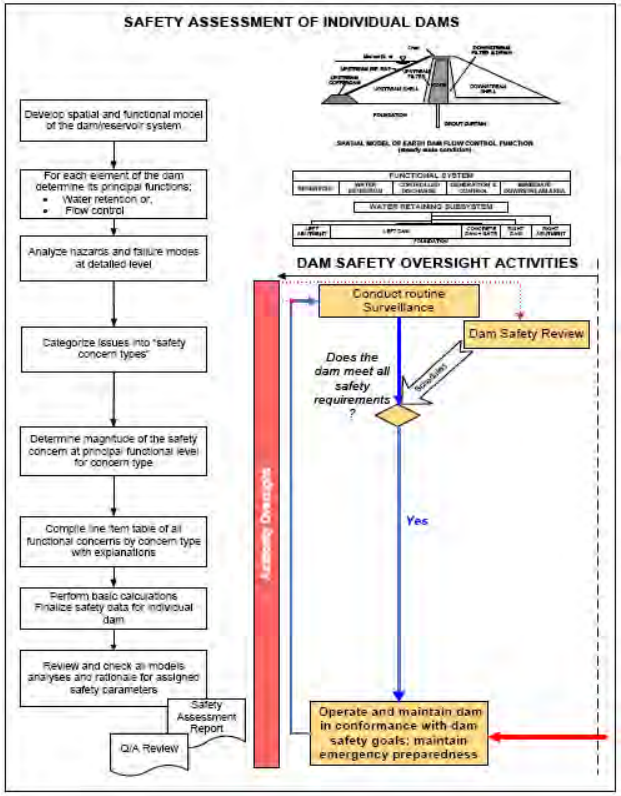
Guiding Documents for Dam Safety

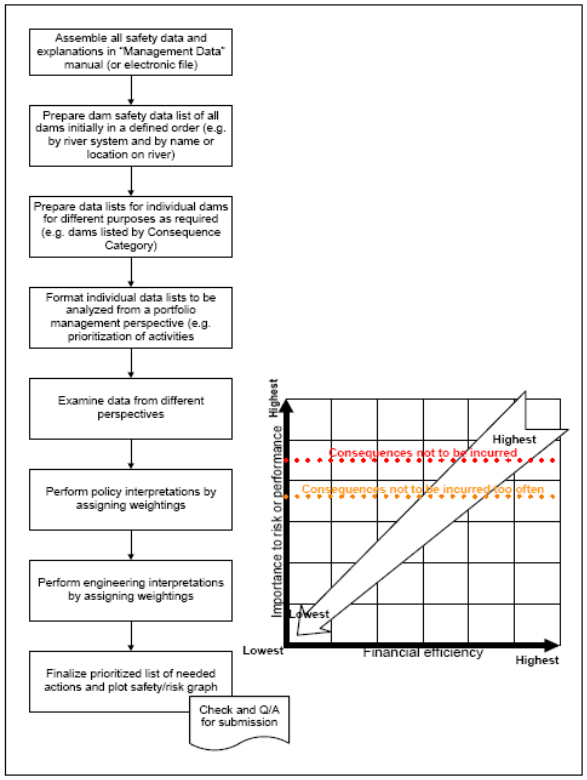
- Vattenfall's Safety Management Principles
- National and International Dam Safety Standards
  - Laws
  - Regulation
  - RIDAS
  - Guidelines for Design Flood Determination
  - European Community Directives
  - ICOLD
  - other
- Strategic Direction of Vattenfall Vattenkraft
  - BU Hydro

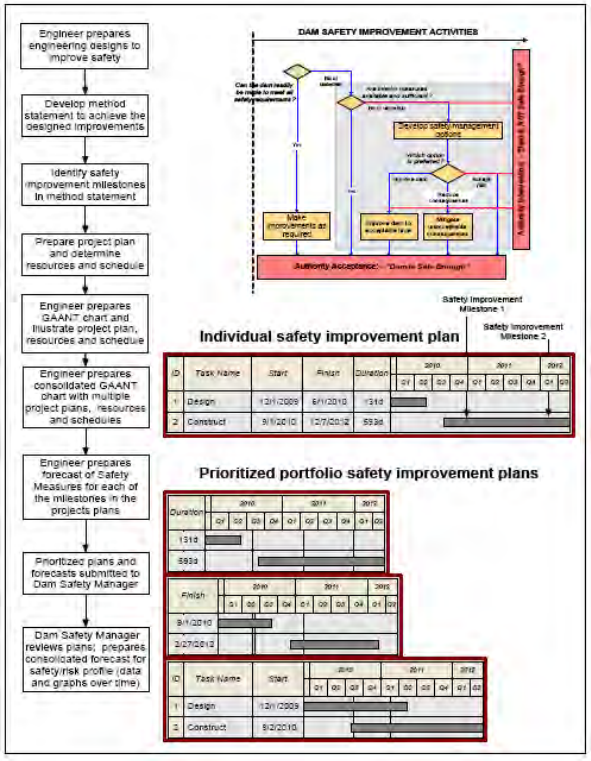
Asset management implications for Dam Safety

- Guiding Principles and Policies
- Requirements and Information Inputs
  - new needs, new information, feedback
- Analysis
  - Options
- Priorities
- Optimize across BU Hydro
  - Dam Safety is highest priority
  - Risk provides a common language
- Pre-study
- Implement

Vattenfall's Dam Safety Program







ICOLD Bulletin on Dam Safety Management, 2011

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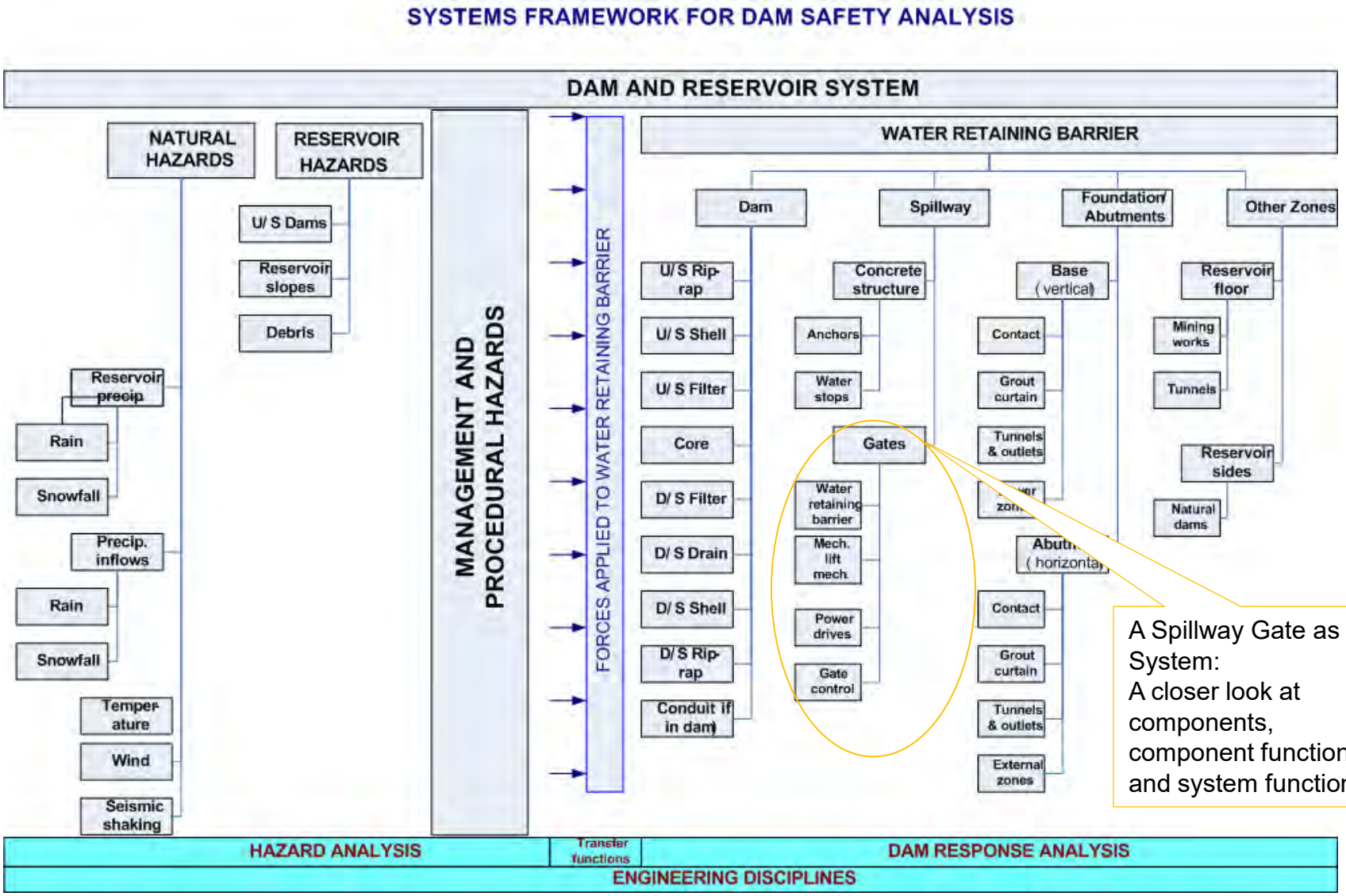
Dams as systems

- A dam is a system that:
  - Safely retains the stored volume of water and passes all flows through and around the dam in a controlled way
    - This is the “function” of the dam

- Overall, we want to know if a dam is functioning properly
  - This means that all sub-systems and components that are critical to system function must function properly

- Need to inspect all critical sub-systems and components for adequacy of functions
  - Need to make a judgement about how close any component is to complete functional performance

Framework for dam safety analysis – ``*Enterprise Architect*``



A Spillway Gate as a System:
A closer look at components, component functions and system functions

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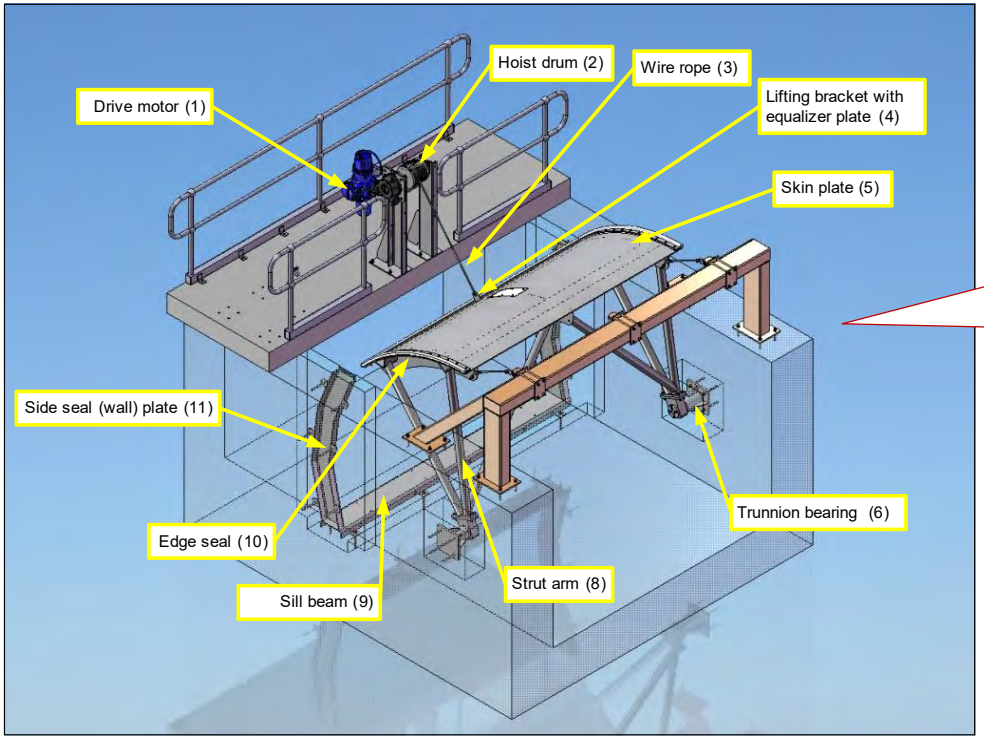
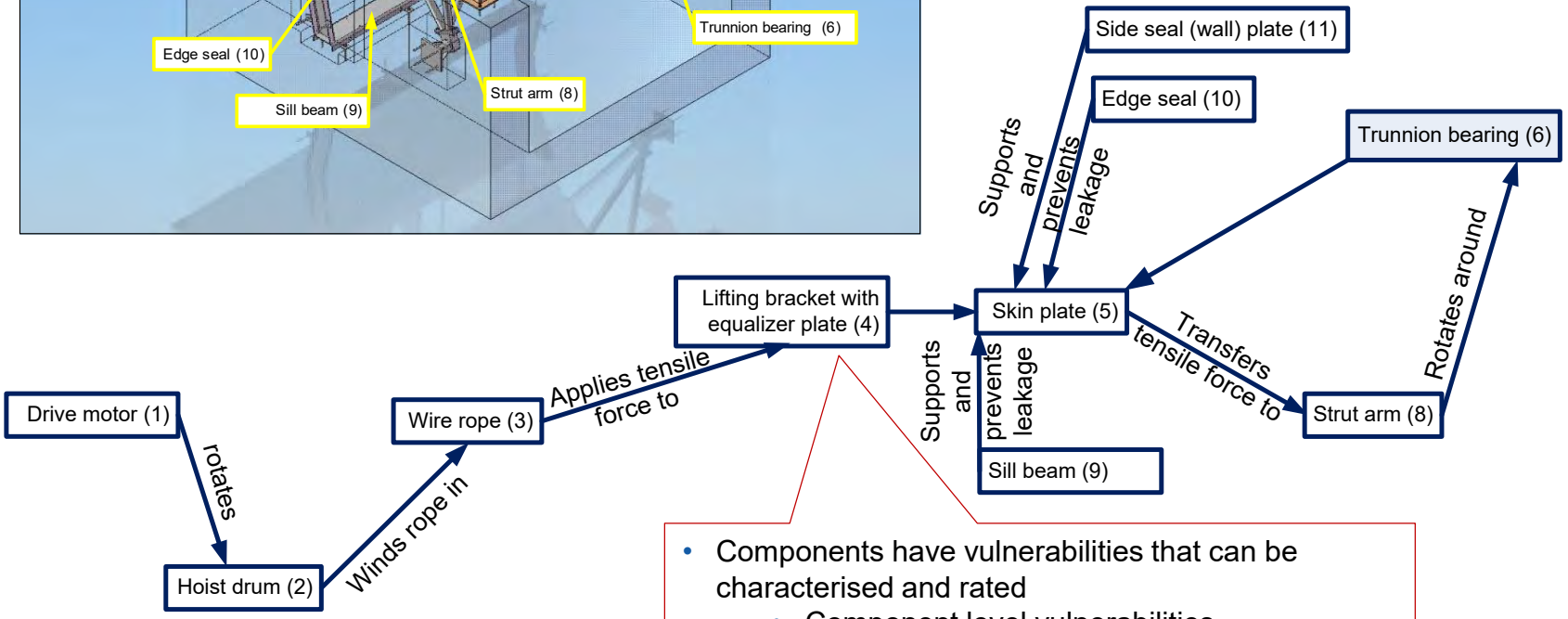
Functional analysis diagram (from Hartford et al., 2016)



- Gate system has functions to remain closed except when it is opened to pass flows.
- Gate system has components which also have functions
- Components function together to provide system function



- Components have vulnerabilities that can be characterised and rated
  - Component level vulnerabilities

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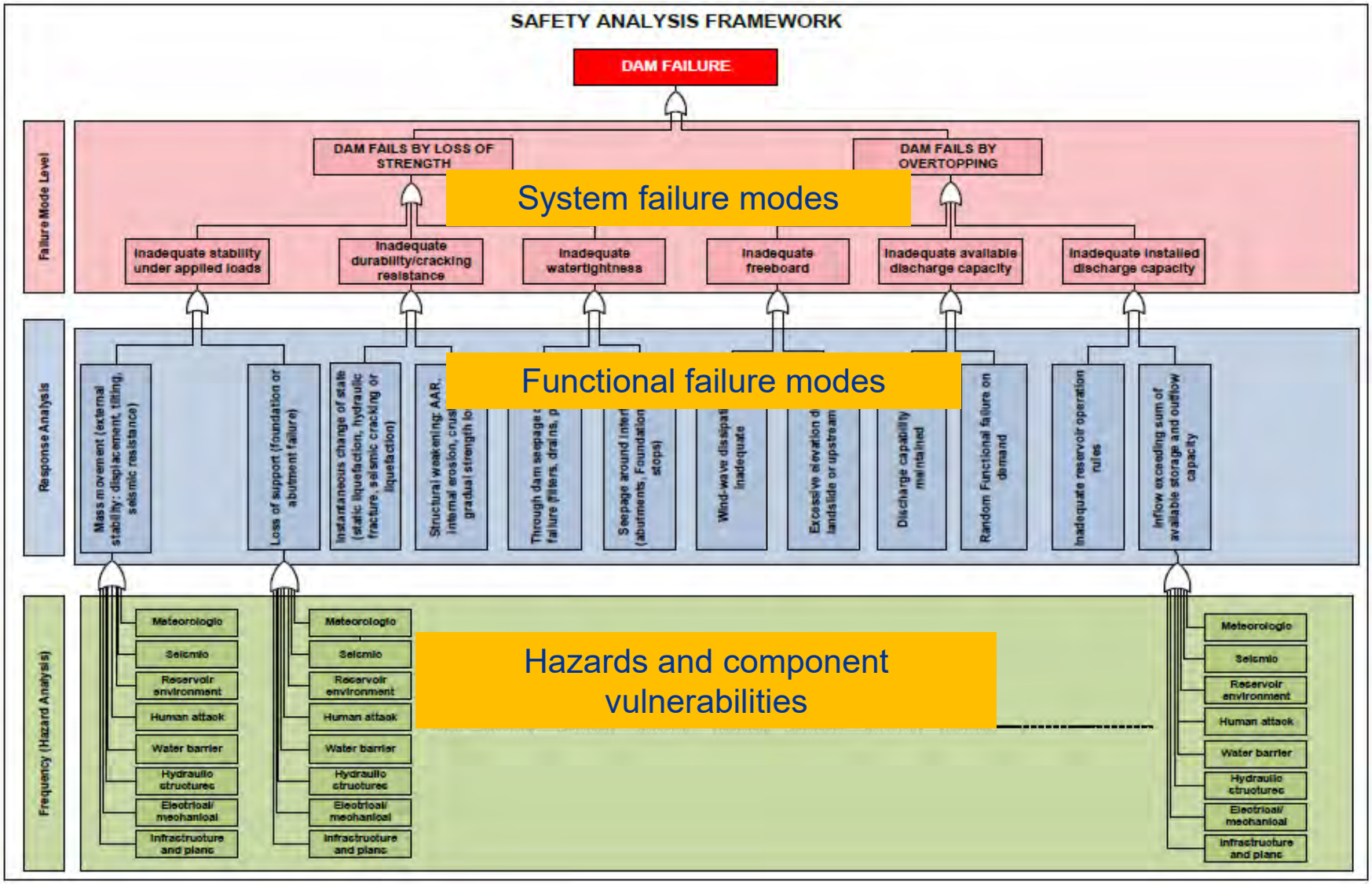
Fault tree Model of Hazards and Failure Modes, ICOLD B154



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Dam Safety –
Vulnerability index and the functioning of that system

Confidentiality - Medium (C2)

the “Setting”

- **”No or uncertain ...”**
  - Implies an actual or a potential Dam Safety Deficiency.
- **... many Facilities**
  - Implies that Deficiencies are Identified more or less Continuously ...
  - ... and it is not Possible to Fix everything Immediately.
- **This Calls for a Systematic Approach ...**
  - In what order should we prioritise Fixes?
- **... and Resources**
  - Is the rate of Fixing matching the rate of Identification?

the Vulnerability Index

- The Vulnerability Index is a mimic of the failure probability.
- The concept is useful since the theory of the dam safety science is not developed enough to allow us to calculate and use failure probabilities.

- The Vulnerability Index is used for
  - understanding the importance of a safety deficiency,
  - supporting in prioritisation,
  - providing basis for displaying continuous improvement,
  - providing basis for analysis of resource needs, and
  - being of use in showing due diligence (skälig aktsamhet), should we need to defense ourselves to a crime that is one of strict liability (which we have for dams).

Dam Safety Deficiencies and Vulnerability Index

- Vulnerabilities are Identified in Inspections and Reviews, carried out at specified intervals, and may also develop during Operation.

- Vulnerabilities are identified regarding
  - dams (water containment function)
  - spillway systems (water release function)
  - emergency preparedness (routines, material & equipment)
  - surveillance (routines & instrumentation)
  - competence
  - routines & methods (operation, maintenance & modifications)
  - information & documentation.

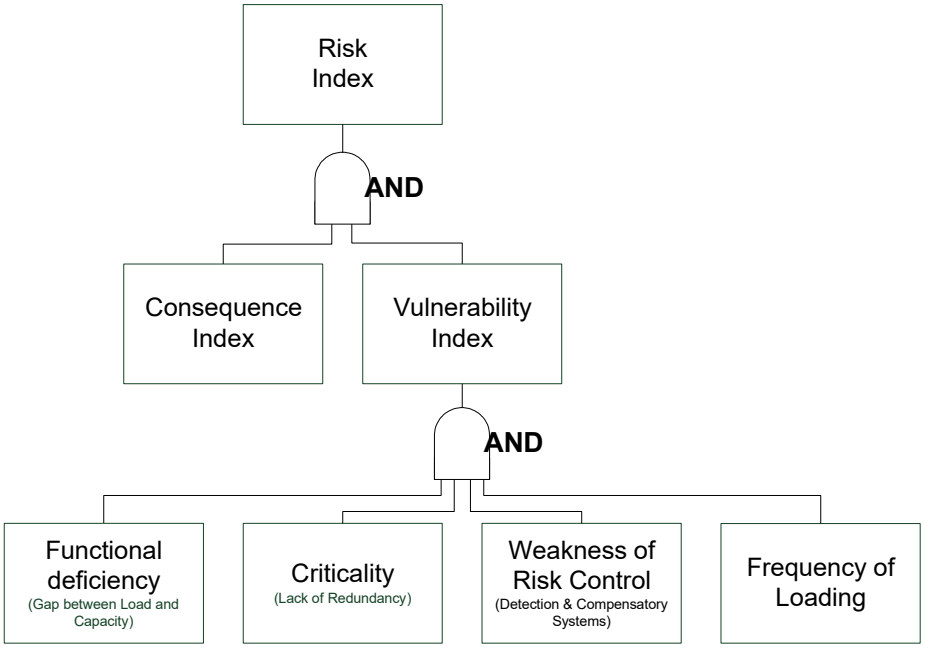
- A vulnerability index is assessed for each identified dam safety deficiency.
- The Vulnerability indices are simply added to each other to give the overall vulnerability for a dam, dams in a consequence category, or portfolio of dams, (or any other grouping).

Vulnerability Index – What is Assessed for a Deficiency ?

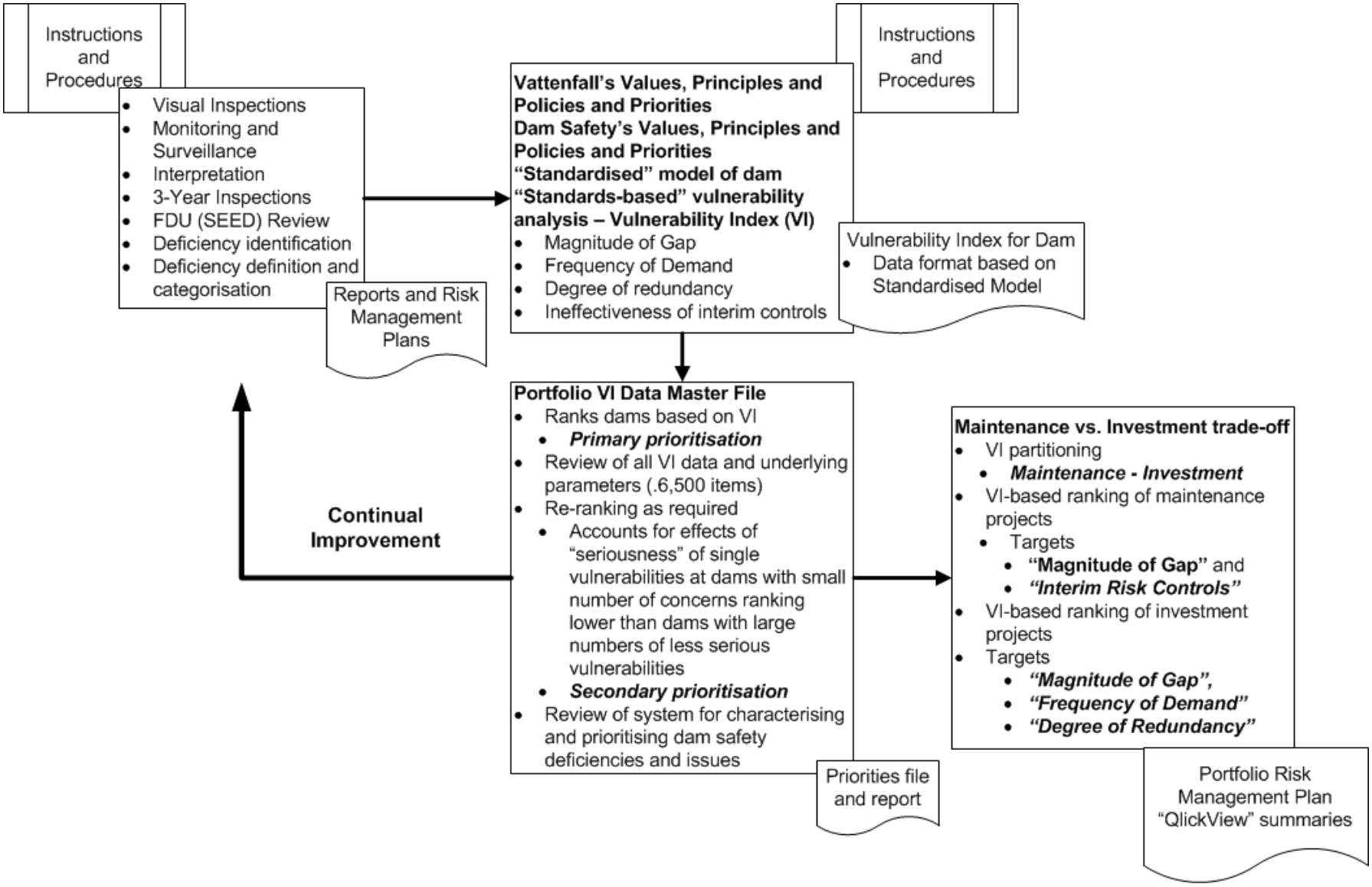
The Assessment factors are

- functional deficiency
  - what is the gap between the performance we have compared to what we should have?
- criticality of the function
  - how critical is the function with regard to redundancy?
- weakness of risk control for the function
  - are we lacking ability to detect malfunction and compensatory systems
- frequency of demand of the function
  - how often may the loading be larger than the remaining function
- the scale is 0 – 1 for all factors
  - 1 means no function, highest criticality, no risk control and continuous loading
  - 1 is max for a single deficiency,
  - 0 in functional deficiency = no deficiency.

Risk & Vulnerability Index and underlying assessment factors



CHARACTERISATION AND PRIORITISATION OF DAM SAFETY DEFICIENCIES AND ISSUES



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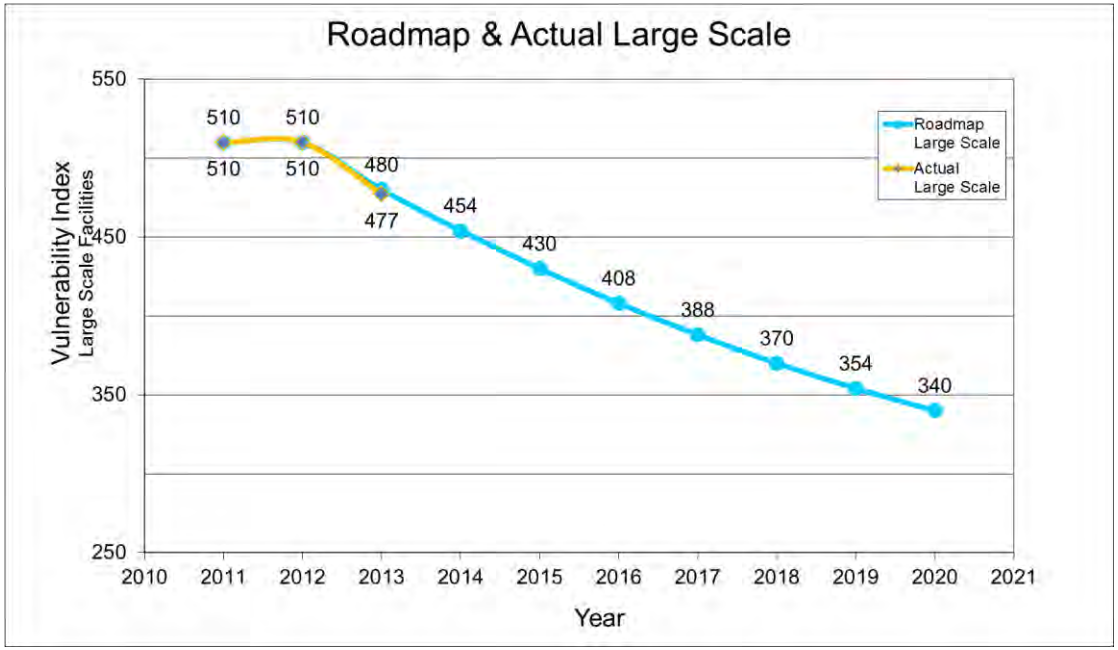
Portfolio Vulnerability Index - PVI

- The PVI should not be used to define a final target for the dam safety work or for other qualitative statements such as “safe enough”.

- The PVI normally increases through Inspections and Reviews as Dam Safety Deficiencies are discovered or re-evaluated.

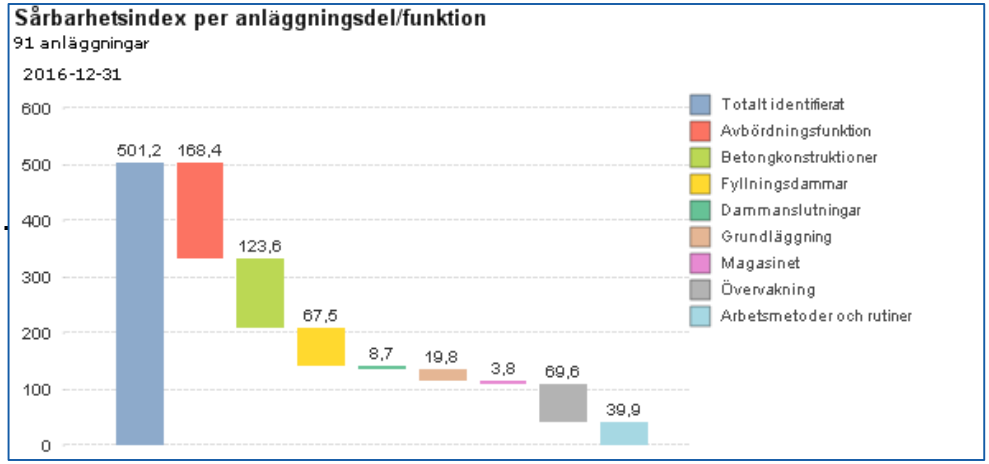
- The PVI is decreased by maintenance or modifications of the dam, or other improvements.

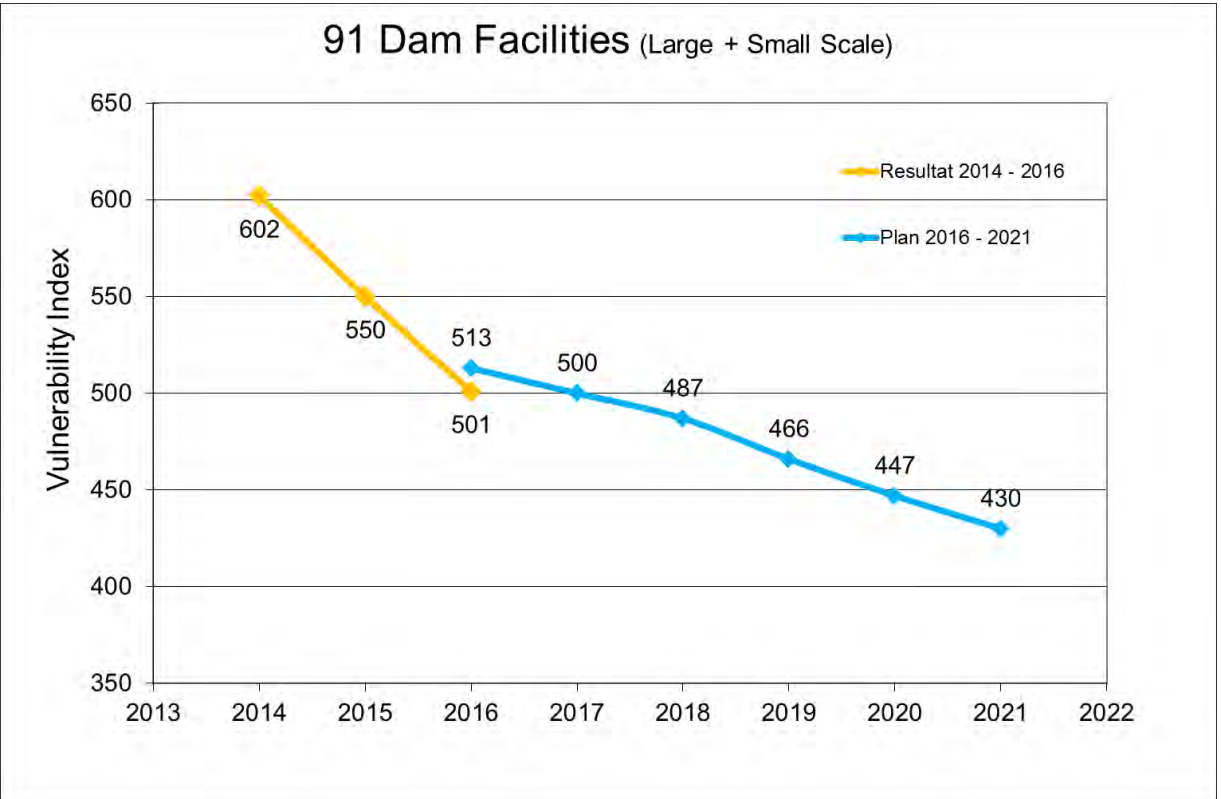
- In 2011 the goal was – based on reasoning – set to reduce the Large Scale PVI from 510 to 340 at the end 2020.



PVI Roadmap – Large and Small Scale Sweden (excl. VB Kraft)

- 2014 the goal was broadened to include Large & Small Facilities.
- 2016 the goal for PVI was revised.





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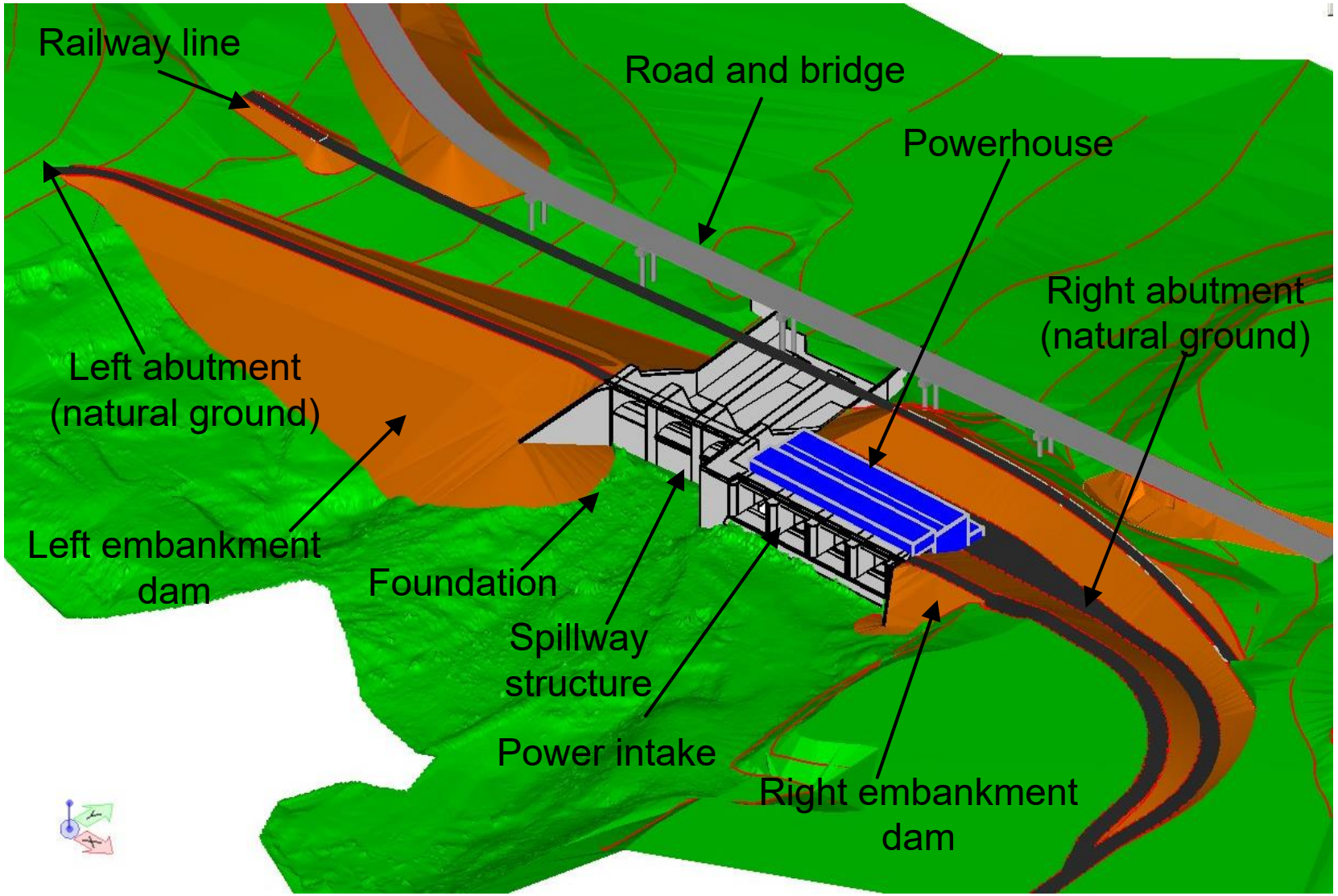
Example - Bergeforsen New Spillway

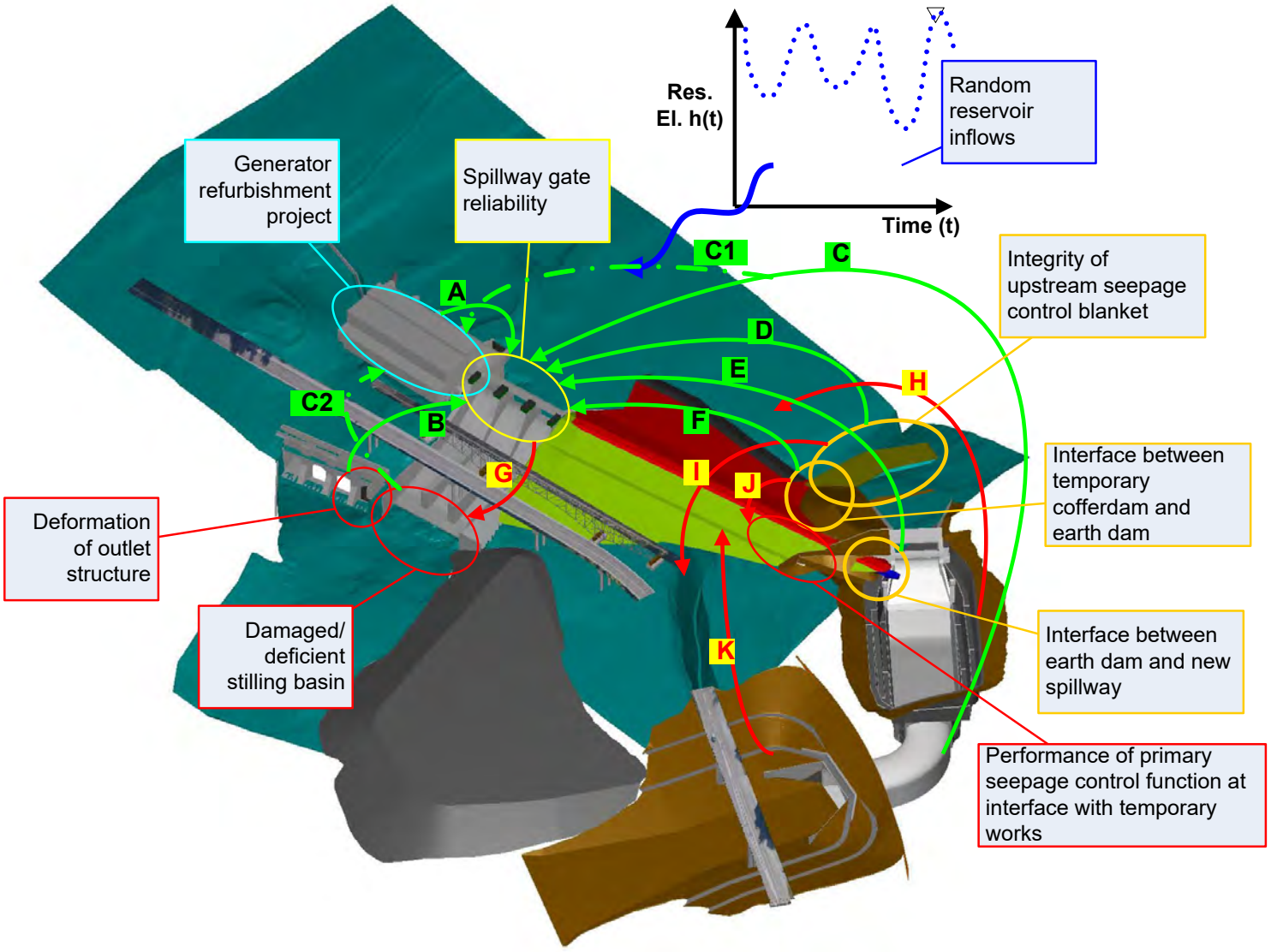
Reducing vulnerability to overtopping - Bergeforsen



Vulnerability reduction options analysis

Policy or Principle/Engineering Principle/ Safety & Reliability/RIDAS/Other Guideline	Option 1 (C)	Option 2 (B)	Option 3 (A)
Policy			
• Minimise risk to people and the environment	×	×	×
• Minimise risk to people and the environment to a practicable and affordable level	×	×	✓
• Acceptable risk management solution for catastrophic loss risk	×	×	✓
• Accepted by the public	?	?	✓
• Readily accepted by the authorities	?	?	⇧
Principle – Business Operations (Bergeforsen Kraft AB, based on E.On and Vattenfall)			
• Risk-informed dam safety decisions in terms of modern risk assessment practice for dams	×	×	✓
Engineering Principle			
• *Changes improve overall functionality when practicable (no adverse effects allowed)*	×	?	✓
• *Passive Operation with no active management controls to ensure function*	×	×	×
• *Active Operation with no active management controls to ensure function*	×	×	✓
• *Functionality not conditional on active management controls over a hazard*	×	×	✓
• *Conventional Engineering Solution*	×	×	✓
Safety and Reliability Principle			
• Redundancy	×	✓	✓
• Diversity	×	×	×
• Segregation	×	✓	✓
• Defence in Depth	×	×	✓
• Fault Tolerant	×	⇩	⇳
• Fail to a Safe Condition	×	⇩	⇘
Engineering Guidelines			
• Service function (normal + moderate floods) separate from auxiliary function (design flood)	×	✓	✓
• Service function compliments other hydraulic functions and auxiliary function	×	?	✓
• Auxiliary capacity based on economics with possible reduction in auxiliary functionality only	?	✓	✓

Managing the hydraulic function risk during improvement



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