



Indian Committee on Large Dams  
Young Engineers Forum

# INTERNATIONAL DAM SAFETY CONFERENCE



Central Water Commission

## MANAGING DAM SAFETY RISKS OVER TIME INCLUDING CLIMATE CHANGE

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Risk Analysis

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**HYDRO**  
EXPLOITATION

10-12 October 2022 at Jaipur, Rajasthan (India)



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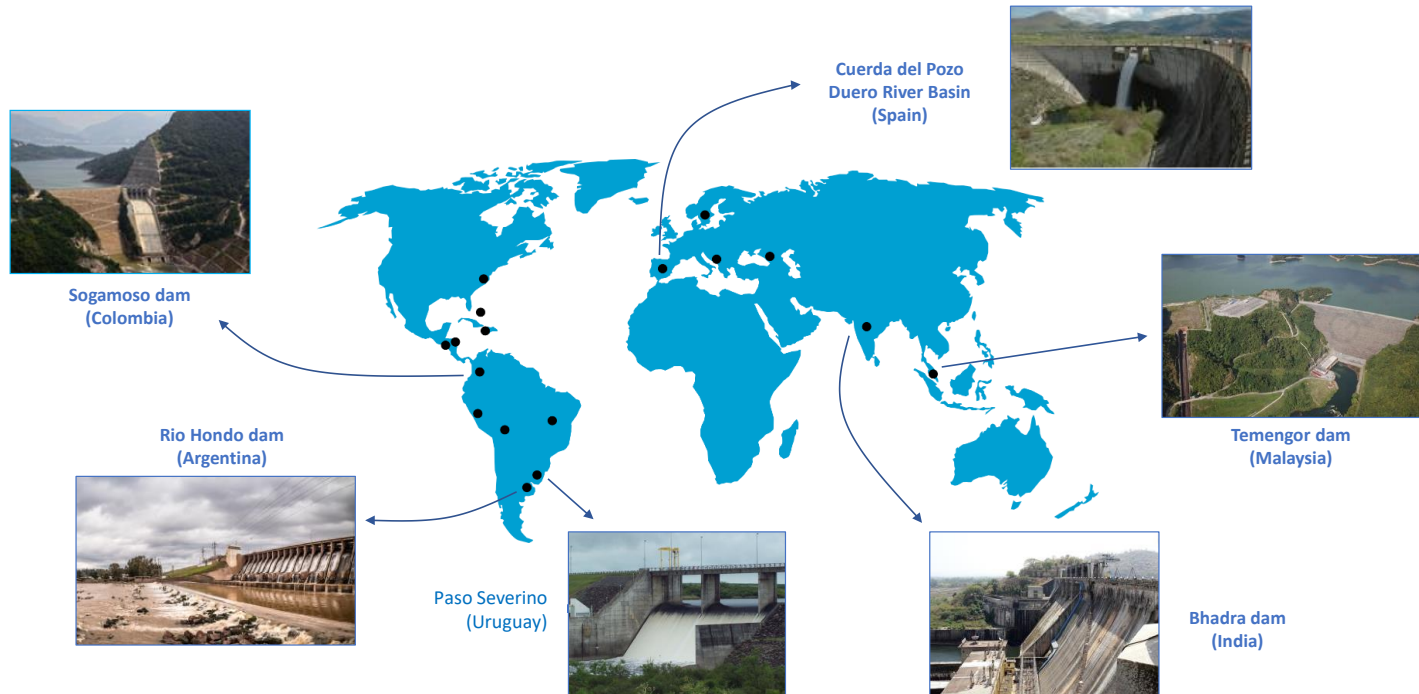
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## iPresas Risk Analysis

iPresas provides **consulting and training** services for public and private entities promoting and supporting **risk-informed dam safety management**.

One of the world leaders in this topic, with risk analysis of **more than 60 dams** worldwide.

iPresas is a technology-based **spin-off company** of the Polytechnic University of Valencia (UPV)



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## What is risk?

Risk is the combination of three concepts (Kaplan, 1997):

- What can happen
- How likely it is
- What the consequences are

**Risk = Probability x Consequences**

**Failure probability:**

- Failure mode
- Load scenario

**Individual risk**

- Social: **Social risk**
- Economic: **Economic risk**
- Environmental
- Cultural

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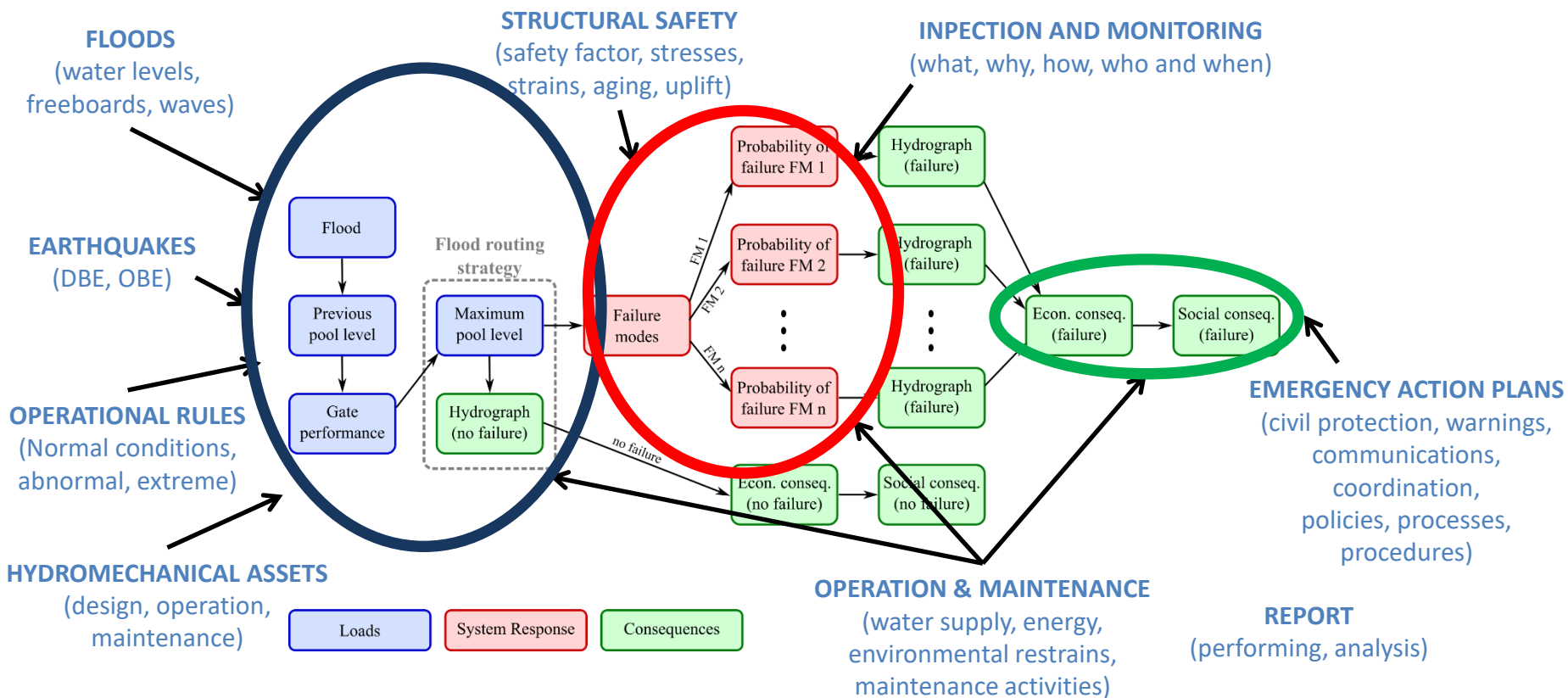
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## Quantitative risk model



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## Risk analysis and climate change

- **Risk Analysis** is a suitable methodology to inform dam safety management in a justifiable, objective and clear way.
- However, dam risks changes along **time** due to:
  - **Climate change**
  - Increasing exposure of people and economic assets
  - Changes in the water resources management system
  - Degradation of the dam and gates equipment



### *'Expect More': Climate Change Raises Risk of Dam Failures*

Engineers say most dams in the United States, designed decades ago, are unsuited to a warmer world and stronger storms.



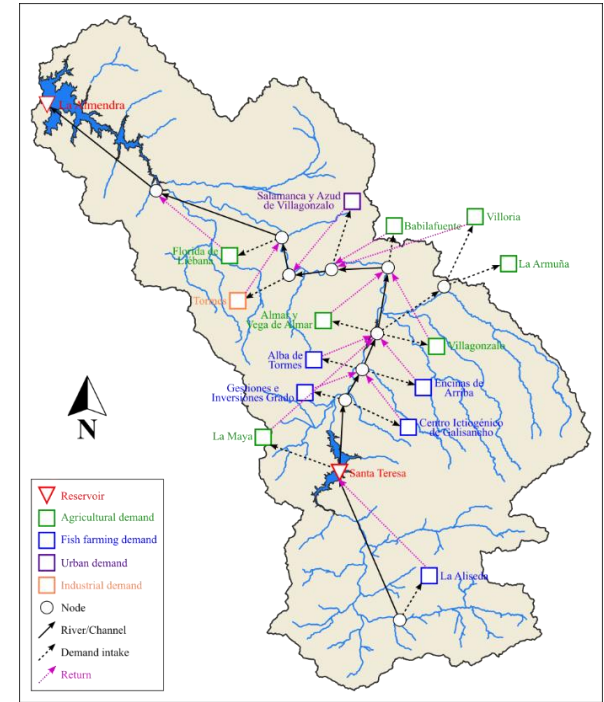
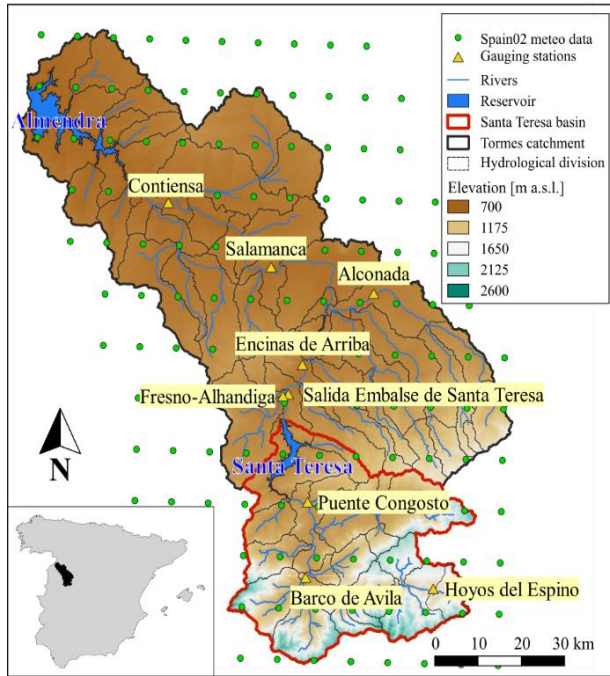
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## Case study: Santa Teresa Dam



More info:

Fluixá-Sanmartín, J., Morales-Torres, A., Escuder-Bueno, I., and Paredes-Arquiola, J. (2019). **Quantification of climate change impact on dam failure risk under hydrological scenarios: a case study from a Spanish dam.** *Nat. Hazards Earth Syst. Sci.*

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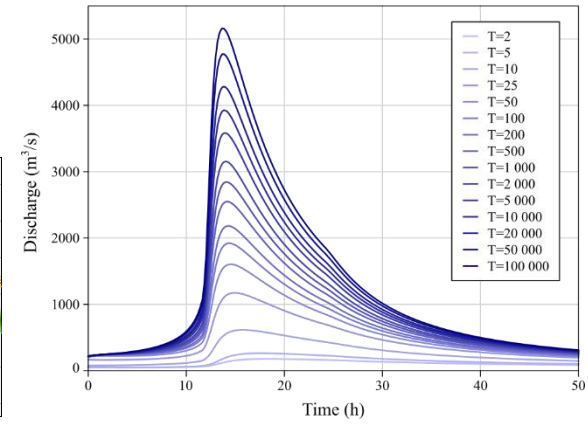
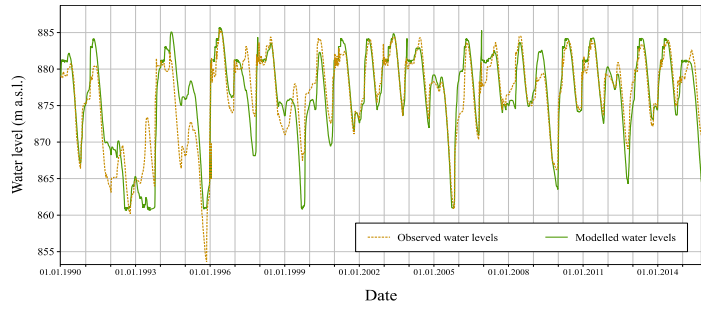
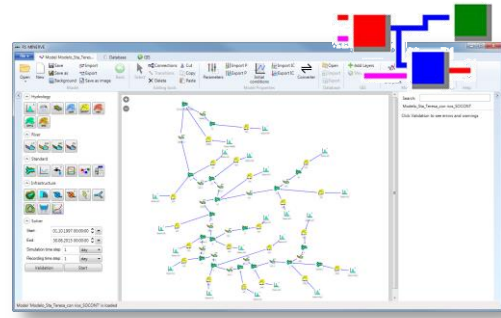
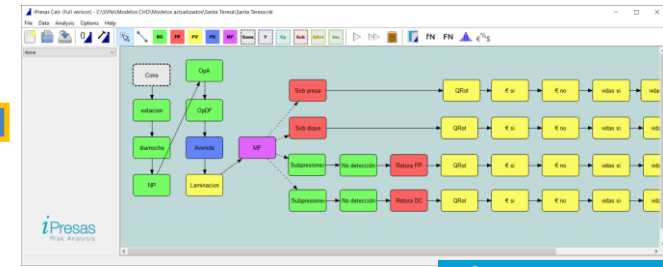
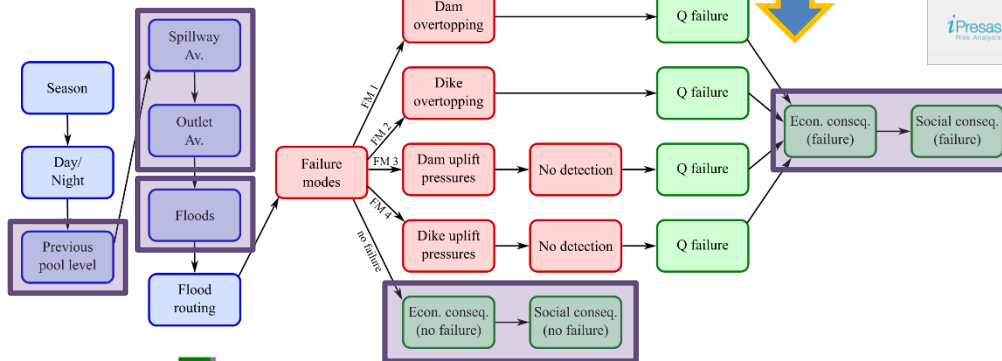


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## Case study: Quantification of CC impacts on risk

- Multi-model approach





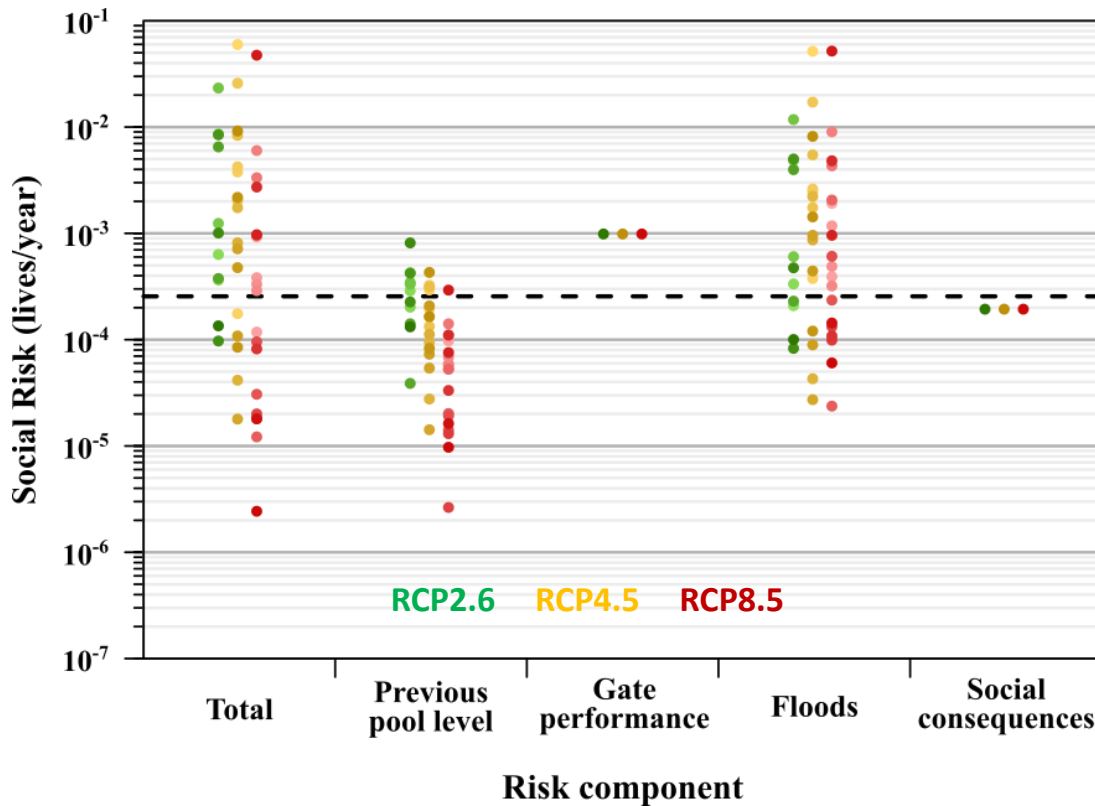
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## Case study: Quantification of CC impacts on risk



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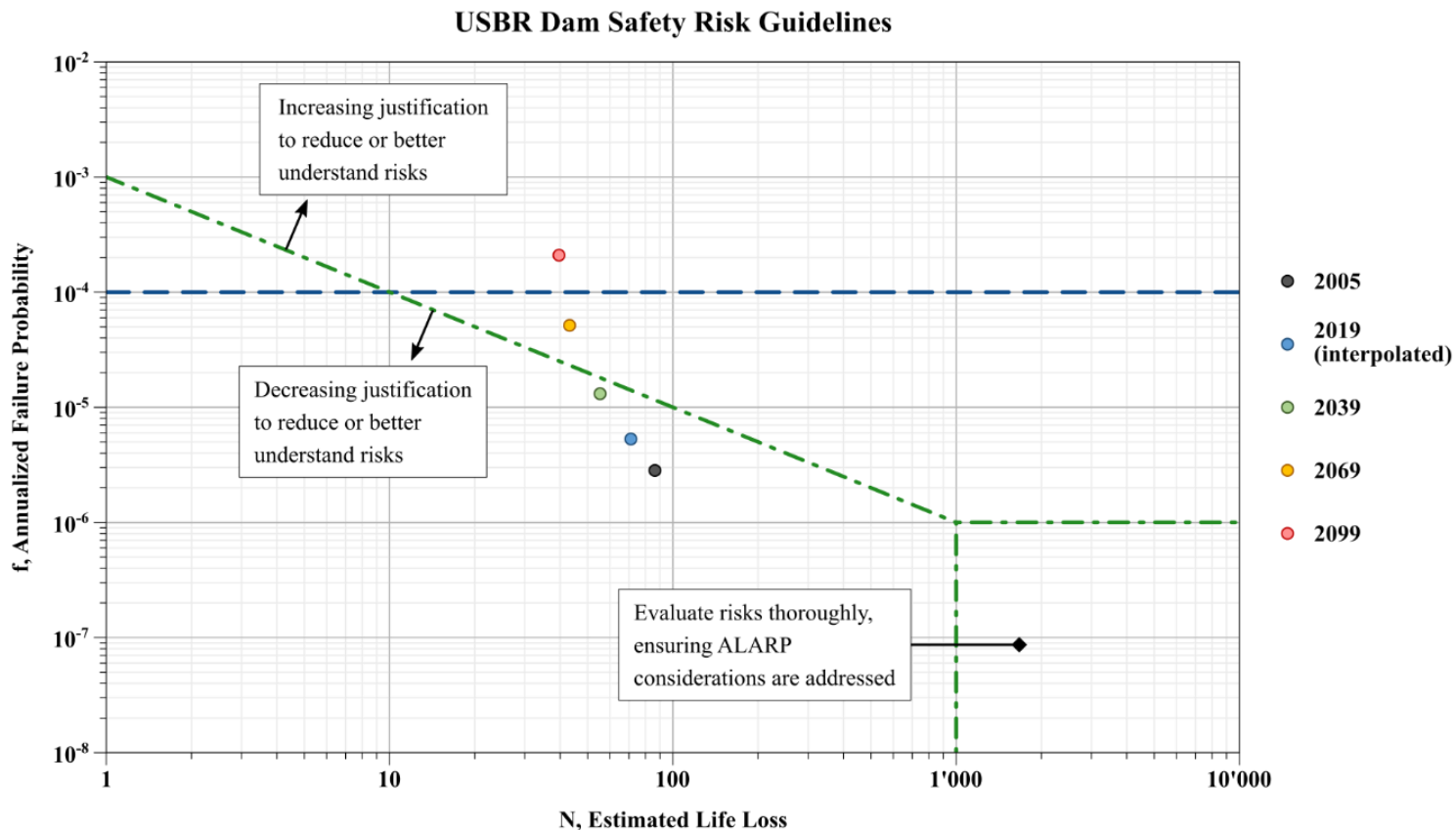
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## Case study: Risk assessment



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## Case study: Risk reduction measures

- A. Implementation of an **Emergency Action Plan**: reduces the social consequences of the dam failure. ↓  $R_s$
- B. Construction of a **continuous concrete parapet** of 1.5 m a lo along the dam and the auxiliary saddle dam. ↓  $p_{\text{overtopping}} \& R$
- C. Lowering 1.5 m the **spillway's crest level**: increases the discharge capacity through each gate  $403 \text{ m}^3/\text{s} \rightarrow 588 \text{ m}^3/\text{s}$ . ↓  $p_{\text{failure}} \& R$
- D. Establishment of an **enhanced maintenance program** for spillway gates: increase their reliability. ↓  $p_{\text{failure}} \& R$

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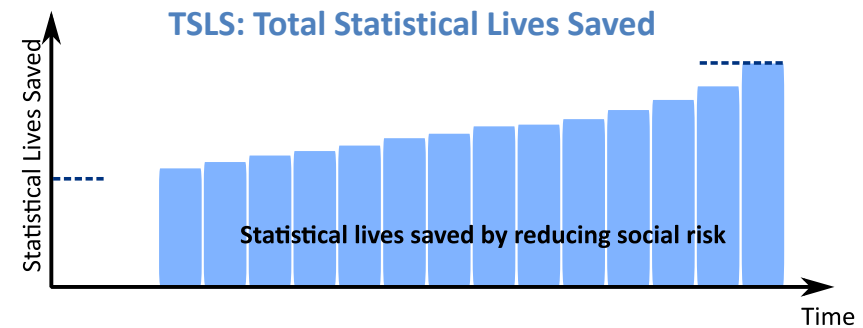
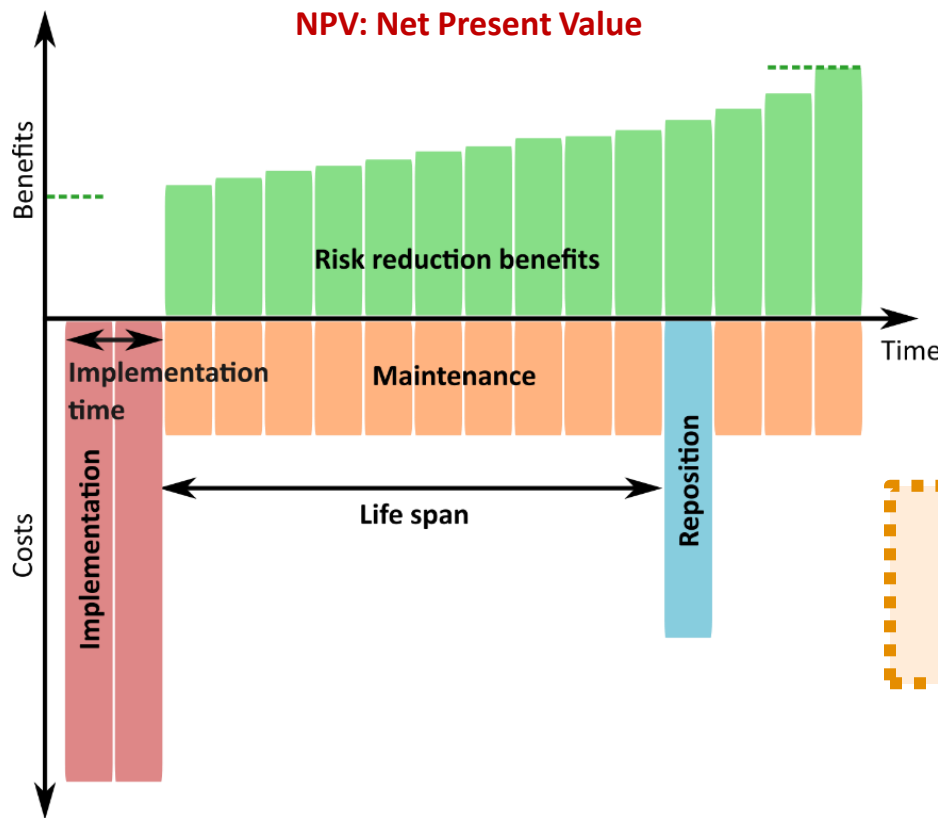
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## Implementing risk reduction actions along time



**ACSL: Adjusted Cost per Statistical Live Saved**

$$ACSL = \frac{NPV (M\text{€})}{TSL (lives)}$$



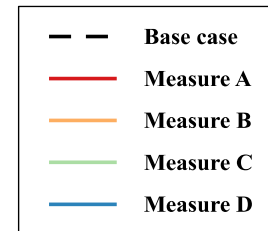
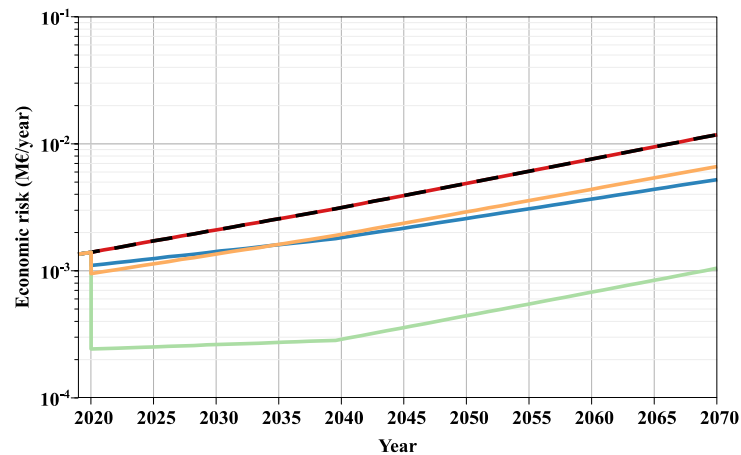
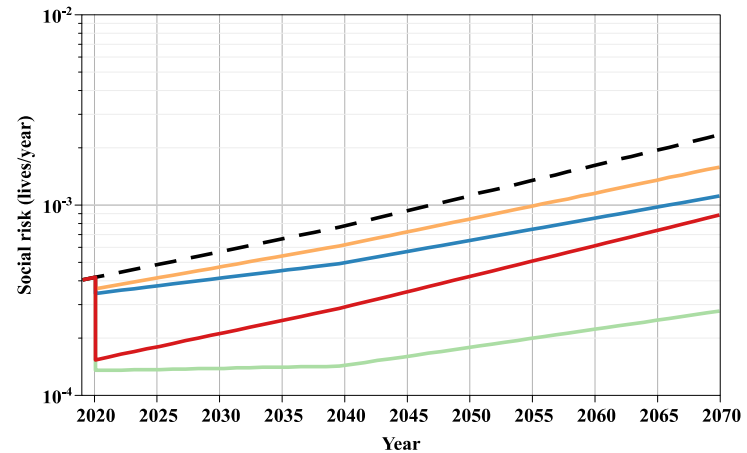
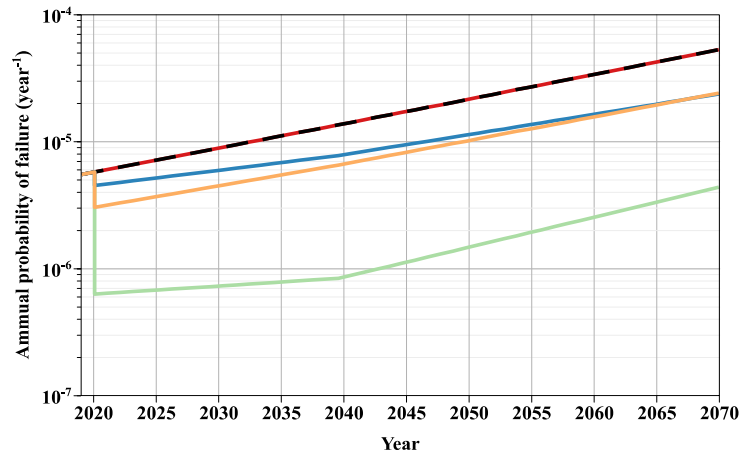
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## Case study: Effect of risk reduction measures



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## Case study: Prioritization of measures

Measure	Priority (considering CC)	Priority (without considering CC)
A: Emergency Action Plan	2	1
B: Concrete parapet wall	1	2
C: Increase spillway capacity	3	3
D: Gates maintenance plan	4	4

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## More information

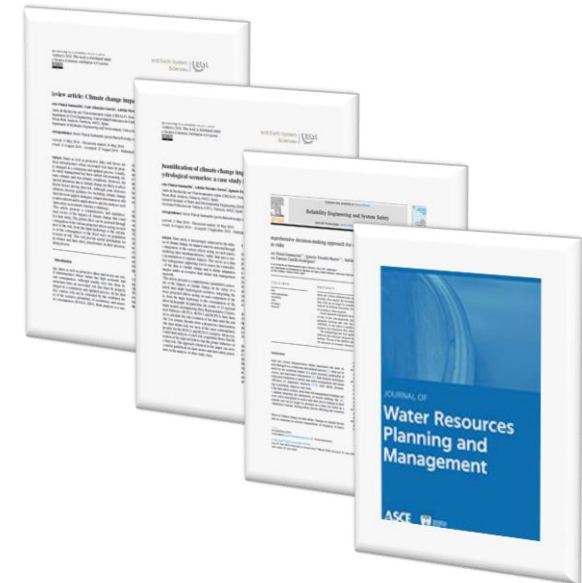
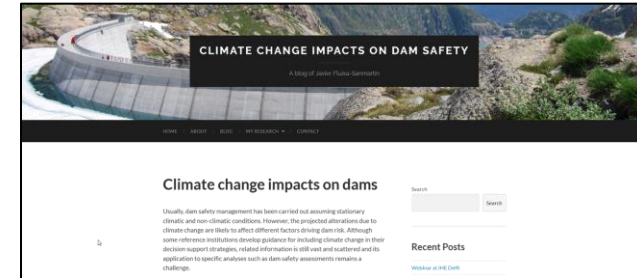
- **Website:**

[www.climatechangedamsafety.com](http://www.climatechangedamsafety.com)

[www.ipresas.com](http://www.ipresas.com)

- **Publications:**

- Fluixá-Sanmartín, J., Altarejos-García, L., Morales-Torres, A., and Escuder-Bueno, I. (2018). **Review article: Climate change impacts on dam safety.** *Nat. Hazards Earth Syst. Sci.*
- Fluixá-Sanmartín, J., Morales-Torres, A., Escuder-Bueno, I., and Paredes-Arquiola, J. (2019). **Quantification of climate change impact on dam failure risk under hydrological scenarios: a case study from a Spanish dam.** *Nat. Hazards Earth Syst. Sci.*
- Fluixá-Sanmartín, J., Escuder-Bueno, I., Morales-Torres, A., and Castillo-Rodríguez, J. T. (2020). **Comprehensive decision-making approach for managing time dependent dam risks.** *Reliability Engineering & System Safety.*
- Fluixá-Sanmartín, J., Escuder-Bueno, I., Morales-Torres, A., and Castillo-Rodríguez, J. T. (2021). **Accounting for climate change uncertainty in long-term dam risk management.** *J. Water Resour. Plan. Manag.*



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## Natural and Infrastructure Risk Manager

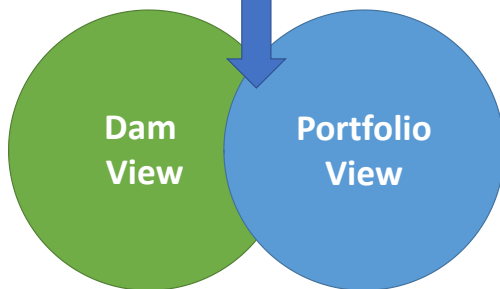


RELEASED IN 2022

Natural and Infrastructure  
Risk Manager  
by iPresas  
Risk Analysis



Risk results with climate change



- ✓ Considering effect of **climate change** and risk variations along time.
- ✓ Risk results **updated** regularly based on dam monitoring, behavior and actions made.
- ✓ Automatically generated **reports**.
- ✓ **Prioritization** of investments along time to define the optimal moment to reduce risk.
- ✓ Integrated **portfolio management**.
- ✓ High **protection and confidentiality** of risk results.

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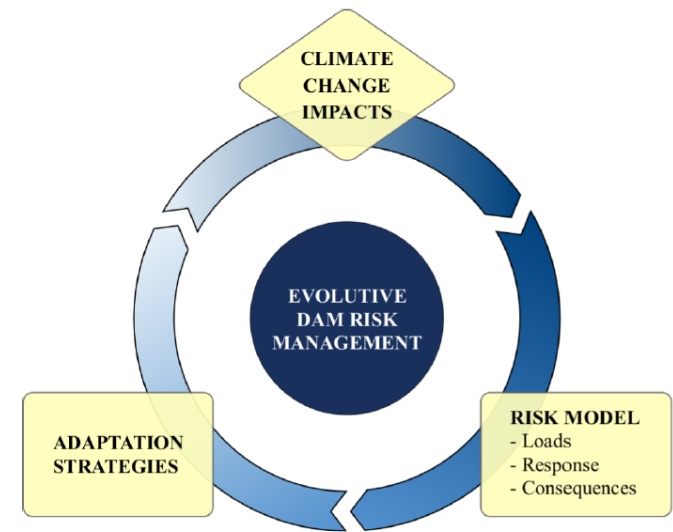
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## Conclusions

- In the future, dam risks may change due to **climate change** and population variations.
- Complex and interrelated impacts: **risk models** are a useful tool to **structure and quantify** these effects.
- The uncertainty associated with climate change **should not prevent decisions** from being made.
- This allows introducing climate change effect on risk-informed **dam safety management**.
- Modern tools will allow us to integrate climate change in **decision making**.



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# THANK YOU FOR YOUR ATTENTION!

Contact:  
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