RAIN: Risk Analysis of Infraestructure Networks.

THE EFFECT OF EXTREME RAIN ON CRITICAL INFRAESTRUCTURES.

THE CASE OF TOUS DAM (VALENCIA, SPAIN)

FEBRUARY 27, 2015

DRAGADOS

TECHNICAL AND R&D DIRECTORATE
HYDRAULIC WORKS SERVICE

DRAGADOS

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1. INTRODUCTION

- According to ICOLD (International Commission on Large Dams):

-Large dam if H>15 m or
-5<H<15 m and 3.000.000 m3 storage capacity

- 1082 large dams in Spain (9th country in the world), most of them with more than 50 years.

- Interest in dam safety: Laws, recommendations, technical bibliography…

- Methodology for the evaluation of hydrologic risk on dams and prioritising of mitigation strategies (UPV).

Number of Dams by Country Members

Country	Nb
China	23 842
United States of America	9 265
India	5 102
Japan	3 116
Brazil	1 392
Korea (Rep. of)	1 305
Canada	1 166
South Africa	1 114
Spain	1 082
Turkey	976
Iran	800
France	713
United Kingdom	607
Mexico	572
Italy	542
Australia	507
Norway	335
Albania	308
Germany	308
Zimbabwe	254
Romania	246
Thailand	218
Portugal	217

1. INTRODUCTION

•Tous dam failure in the 20th October, 1982, was one of the most important socio-natural disasters in Spain during the 20th century.

LEVANTE
diario regional de valencia

LA RIADA CONTINUA

DESOLACION Y RUINA

Cuatro muertos en Carcagente y seis en Cullera
• • •
Hay varios desaparecidos
• • •
Cincuenta y seis localidades sin teléfono
• • •
Importante colaboración de las fuerzas armadas
• • •
De toda España comienzan a llegar ayudas
• • •
Seguirá lloviendo, pero en la zona Norte
• • •
El riesgo pasa ahora a la cuenca del Turia

Los Reyes podrían visitar la zona afectada

ZONA CATASTROFICA
Hoy, Consejo de Ministros

2. REGULATORY OVERVIEW

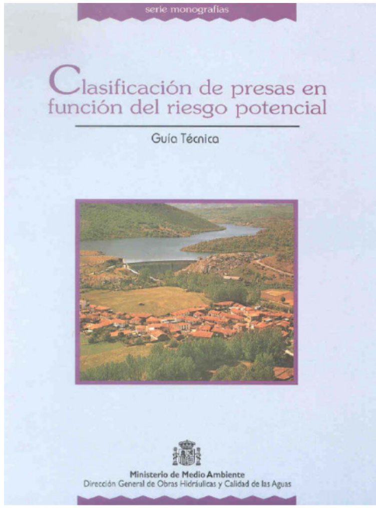
- 1995 “Basic Directive on Planning of Civil Protection against Flood Risk”.

- Potential Risk. Safety Emergency Plan for dams classified Category A and B.

  - Category A: Potential affection to urban areas, essential services or very important environmental and property damages.

  - Category B: Potential important environmental and property damages or affection to a reduced number of homes.

  - Category C: Potential minor environmental and property damages and incidental casualties.



- European Directive on Floods of 2007 and European Directive of Critical Infraestructures of 2008, introducing the necessity of Risk Analysis techniques.

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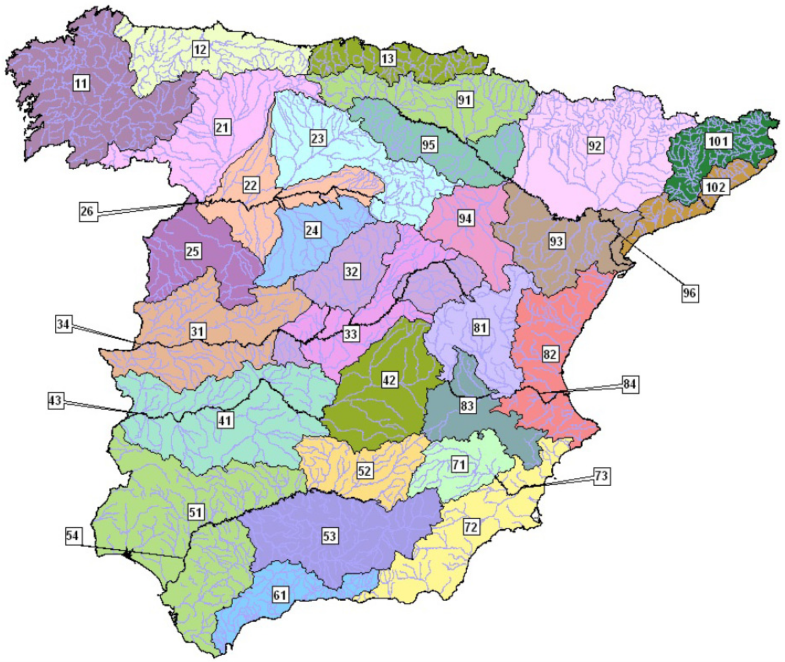
3. HIDROLOGICAL OVERVIEW

•CEDEX (Center for Studies and Experimentation for the Public Works Ministry, Spain) is developing Regional Stadistic Models to select the most appropriate frequency laws for determining the maximum flows during a rainfall.

•High number of regions to determine rainfall shows:

-The highly variable climatology in Spain.

-The necessity of an adequate river regulation and protection from devastating flash floods.



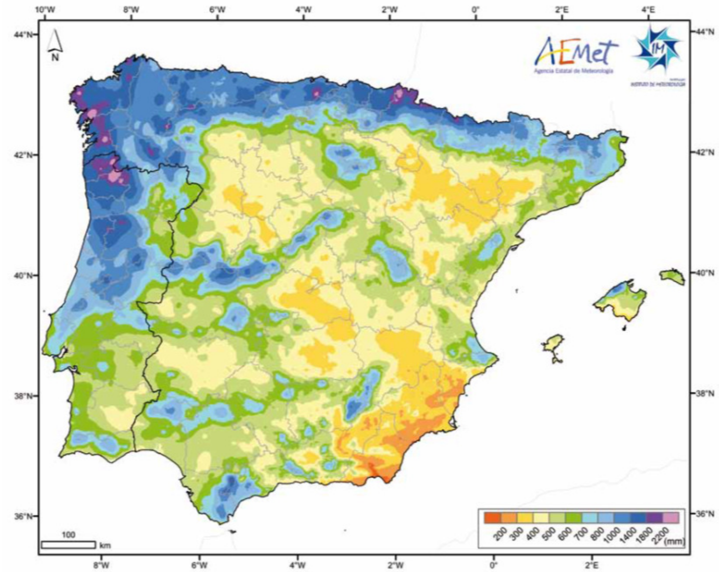
4. LOCAL CLIMATOLOGY

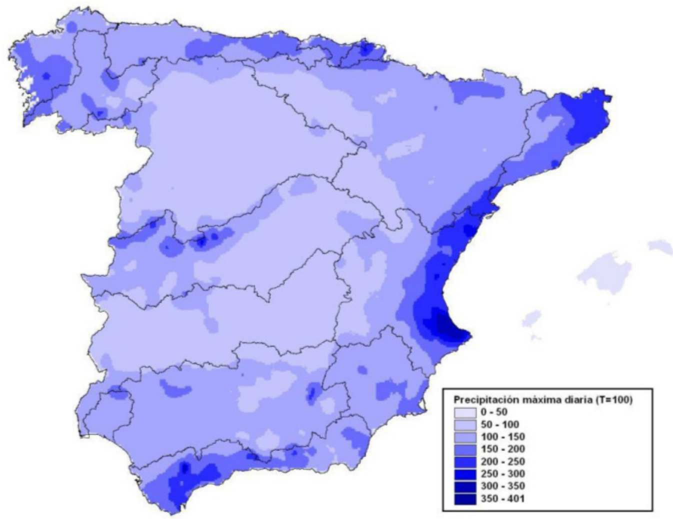
- Rainfall in Spain: big spatial variability.

  Highest values in annual average rainfall exceed 2200 mm in the North. The lowest in the southeast of Spain with 300 mm.

- The month with the most rainfall is December and the driest month is July.

- Maximum rainfall in one day 100 year return period.





4. LOCAL CLIMATOLOGY

- Effects of climate change in dams in Spain:

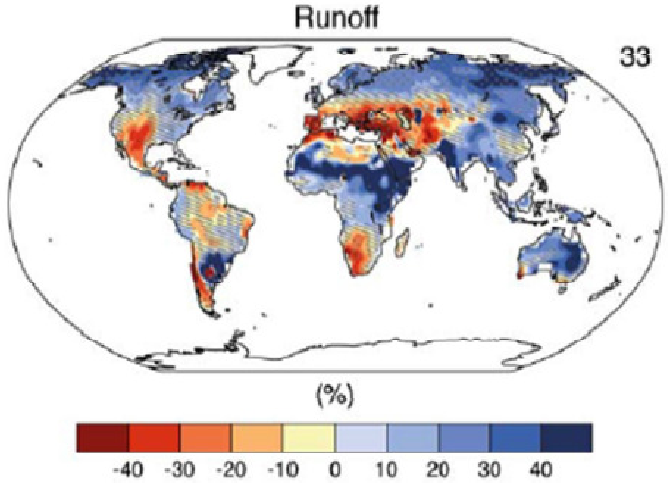
Important reduction on the average runoff

Increase in frequency and intensity of the extreme rainfall.

Increase in the frequency of flash floods.

Increase in average temperature.

Reduction in hydroelectricity generation in the Mediterranean coast countries.



Expected change in annual average rainfall by year 2081-2100

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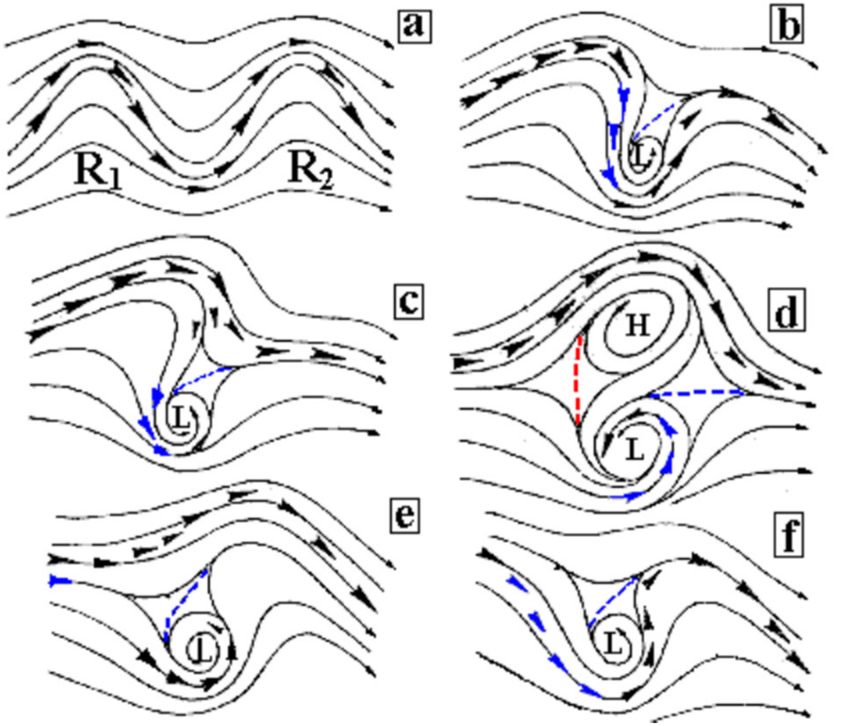
4. LOCAL CLIMATOLOGY

•Particular meteorological case in the Eastern coast of Spain: Gota Fría (Cut-off Low).

•Isolation of a small portion of cold air from the general circulation, reaching warmer environments.

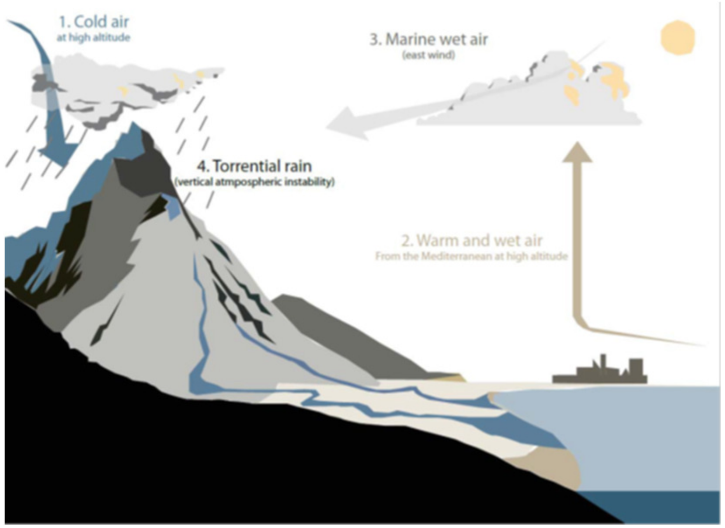
•Usually when jet stream is clearly wavy (near summer).

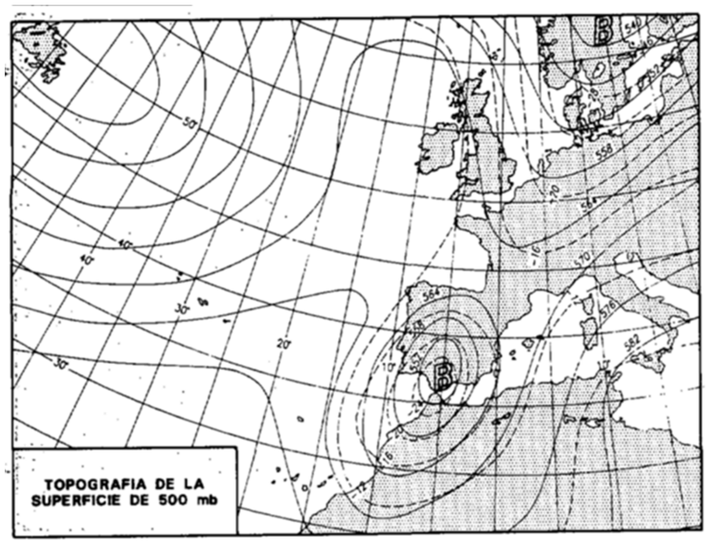


4. LOCAL CLIMATOLOGY

- In late summer and autumn, when the temperature in the Mediterranean sea is higher, warm and wet air from the sea ascend at high altitudes in the atmosphere. When it encounters the cold air core of the isolated Cut-off, the cold and the warm masses can generate an important vertical atmosphere instability causing torrential rains.

- Origin of the Tous Dam Failure.





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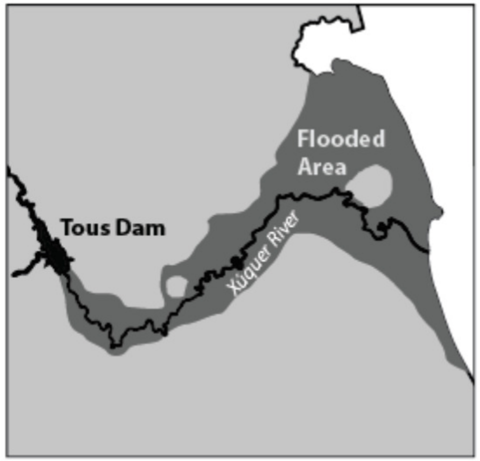
5. TOUS DAM FAILURE

•Tous dam was located in the eastern coast of Spain. This is one of the areas in the Western Mediterranean that is most prone to potentially catastrophic flash flood events due to its orography and the existence of Gota Fría phenomena.

•Tous Dam (1970s-1982) was a flood control structure located in the Júcar River basin, an area which covers some 21,600 km2 in the central part of the Mediterranean coast of Spain.



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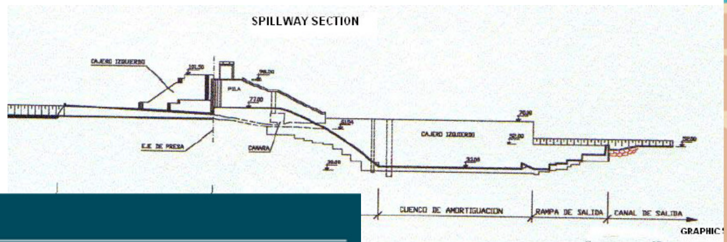
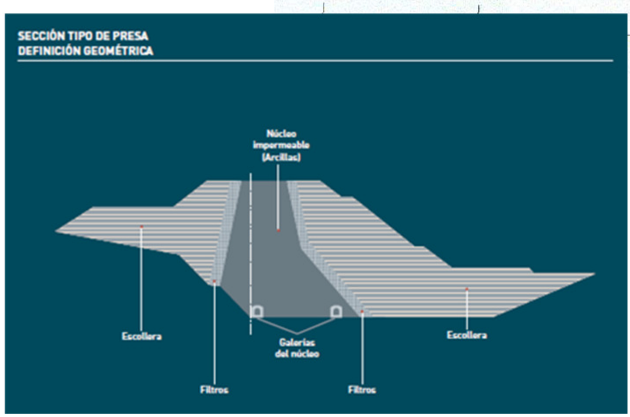
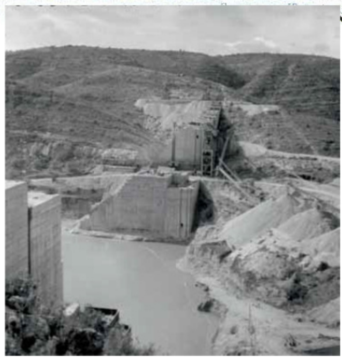
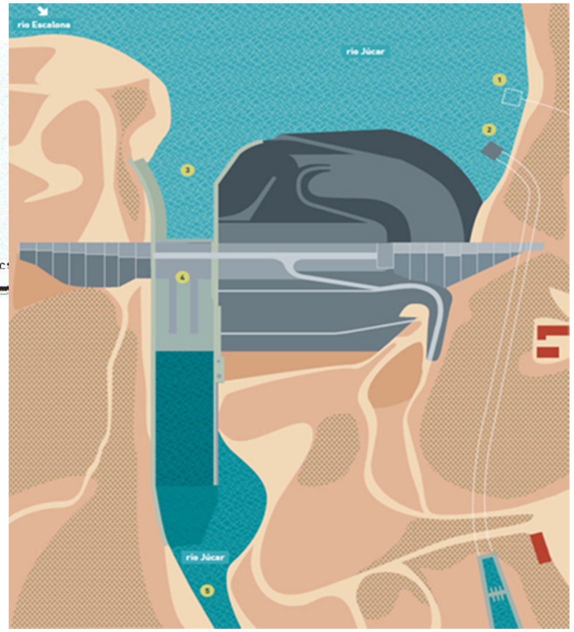
5. TOUS DAM FAILURE

- Because of a series of problems in the foundation, it was designed as a mixed dam, with the abutments made of concrete and the central part of the dam as rockfill dam with clay core.
- It's spillway was designed for a maximum flow of 6968 m3/s, corresponding to 500 years return period, widely higher than registered flows to construction date. Spillway was controlled by three radial gates of 15 m.



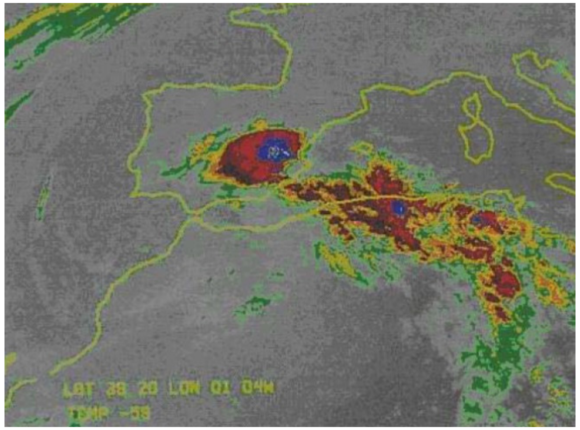






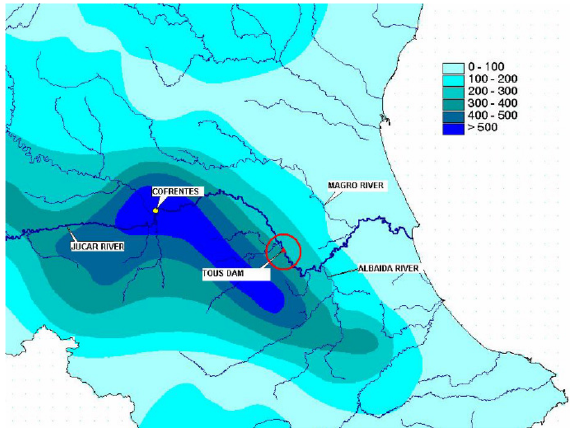
5. TOUS DAM FAILURE

•In 19th October 1982, a big storm developed in the central part of Jucar river basin. The intensity of the rainfall was exceptional, surpassing 500 mm in a zone where never had been registered rainfalls higher than 100 mm.



•Due to intensity of the storm, electrical power supply was interrupted, making impossible the opening of Tous dam spillway gates.

•Between the operating level and the dam crest, there was 14,50 m freeboard. Unable to open the gates, this freeboard was filled 10 hours after beginning the flood.



•During this time, incoming flood calculated had a pair of peaks over 6000 m3/s.

5. TOUS DAM FAILURE

- Since water level surpassed dam crest, erosion of the downstream slope of the dam begun, affecting only the rockfill and not the clay core.

- At 19:13 of 20th October, failure of the dam was complete, with a big noise produced with the sliding of the core and the fall of the spillway structure.

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5. TOUS DAM FAILURE

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- As a consequence of the dam failure, a big flow wave of 15000 m3/s demolished the downstream region.

- 300km2 of inhabited land, including many towns and villages were severely flooded, affecting some 200,000 people, of which 100,000 had to be evacuated. Fortunately, evacuation was made while dam was able to control the flow. In total, nearly 30 casualties and more than 330 million euros of economic losses.

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6. NEW TOUS DAM

•New Tous Dam, constructed by DRAGADOS, following new criteria:

-No spillway gates and with capacity for the Probable Maximum Flood of 20.000 m3/s (vs old Tous 6.968 m3/s).

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6. NEW TOUS DAM

-110 m high (vs old Tous 80 m)

-340 hm3 reservoir capacity (4.7 times bigger than old Tous dam)

7. MITIGATION STRATEGIES

•Revision of dams design criteria. Potential risk: new design return periods.

DAM CATEGORY	PROJECT DESIGN FLOW	EXTREME DESIGN FLOW
A	1000	5000-10000
B	500	1000-5000
C	100	100-500

•Automatic System of Hydrologic Information (in Spanish, SAIH) to automatically manage the information of flows and rainfalls inside the same river basin.

7. MITIGATION STRATEGIES

- Criteria in dam designing taking into account the risk: what can happen, how likely is to happen and what are the consequences.

- Risk Analysis to prioritize new constructions or modifications to older dams in use.

LOADS

[1] Hydrological study
[2] Seismic study
[3] Study of pool levels
[4] Study of gate performance
[5] Study of flood routing

SYSTEM RESPONSE

[6] Study of failure mechanisms
[7] Study of failure probabilities

CONSEQUENCES

[8] Study of dam-break hydrograph
[9] Study of consequences

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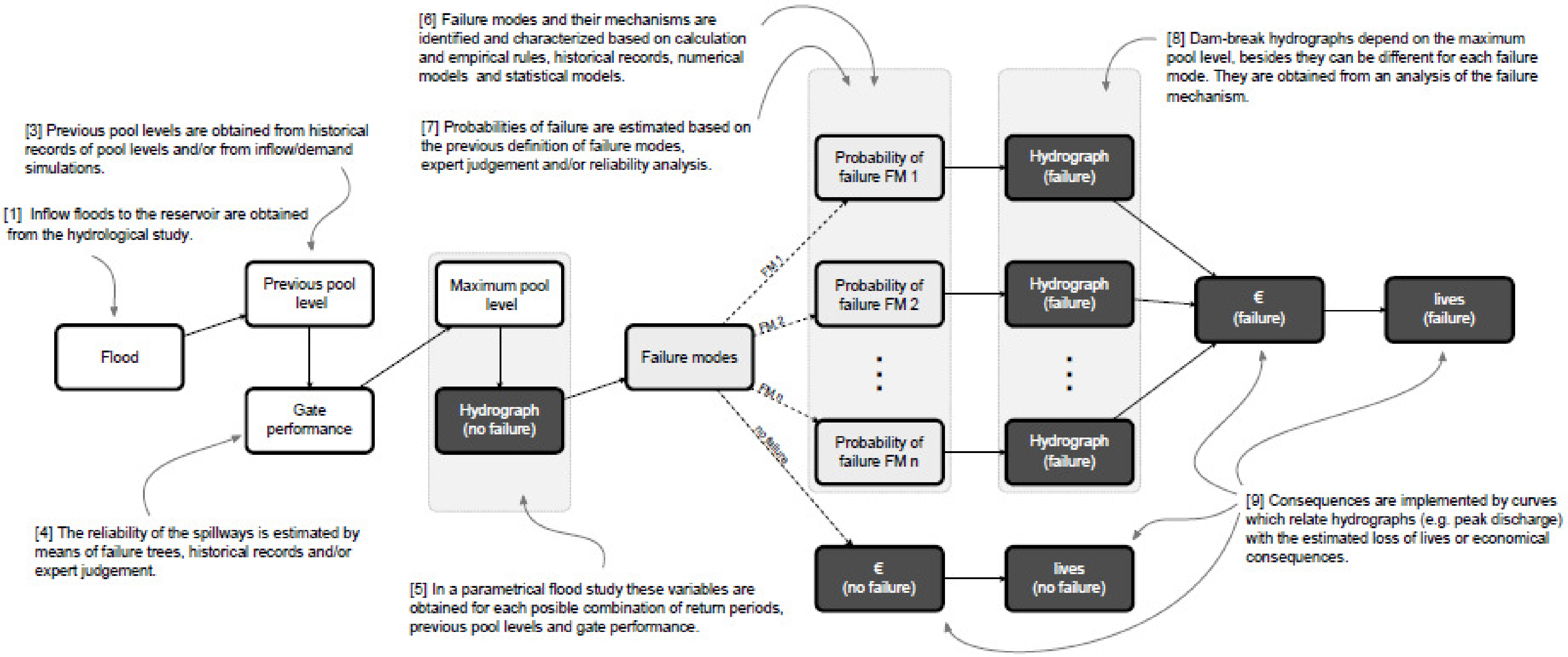
7. MITIGATION STRATEGIES

- Risk model: identify failure modes, event tree, different scenarios…



7. MITIGATION STRATEGIES

- Dam risks related to flood and rainfall: improve the capacity of the outlet works

- Augmenting spillway capacity. Labyrinth & Piano-key spillways.

- Protection of the downstream dam slope (only in low height dams) or modifications in the spillway stilling basin to reduce the energy of the flood downstream.

7. MITIGATION STRATEGIES

- NO use of gates in embankment dams spillways (although is not explicitly forbidden by any law).
- Managing of the structures to reduce risks.
- In some old dams, reducing the normal operation level, to have a greater freeboard.
- Usage of bottom outlet sporadically in order to clean the downstream riverbed, improving it's capacity against future flood events.

Thanks for your attention

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