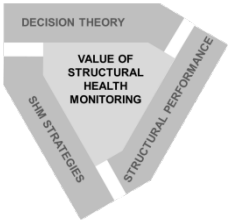
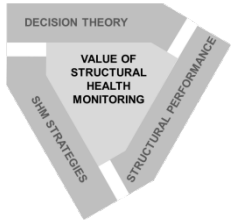
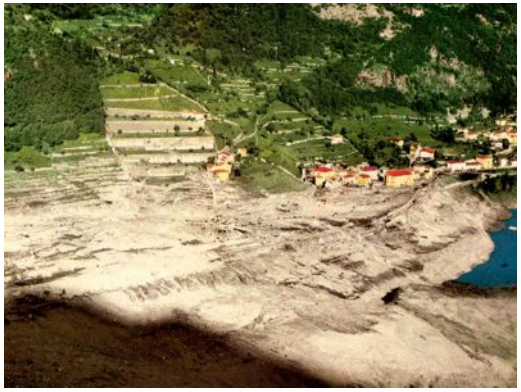



# MONITORING AND STRUCTURAL SAFETY ASSESSMENT OF CONCRETE DAMS

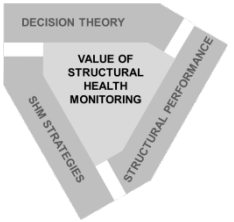
António Tavares de Castro, LNEC
Ilídio Ferreira, EDP
Juan Mata, LNEC




# Motivation for the monitoring of dams



- Large number of dams in operation
- Occurrence of some important accidents with tragic consequences
- Some incidents requiring difficult and expensive repair works
- Ageing of dams in operation
- Concern regarding environmental issues and socio-economic problems
- Development of the science and technology – materials, construction techniques, information technologies



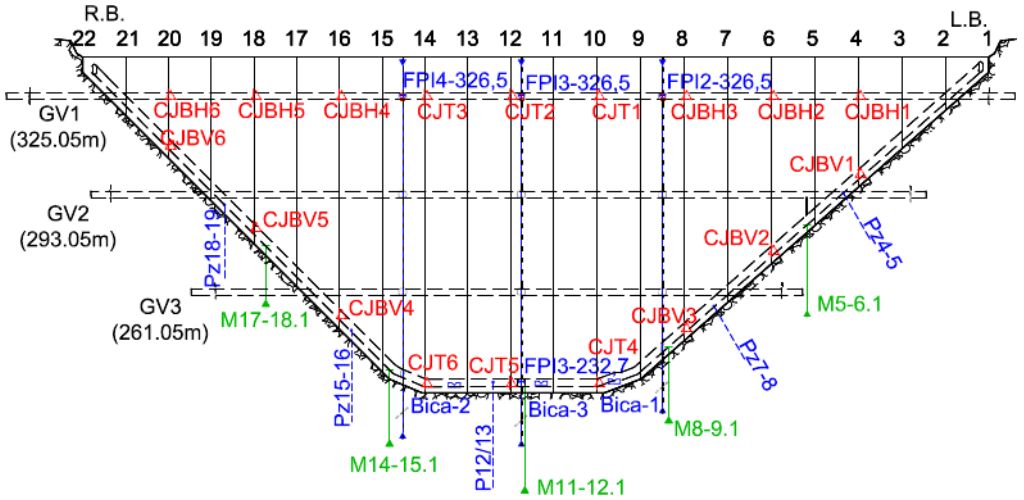

# Portuguese legislation concerning safety of dams

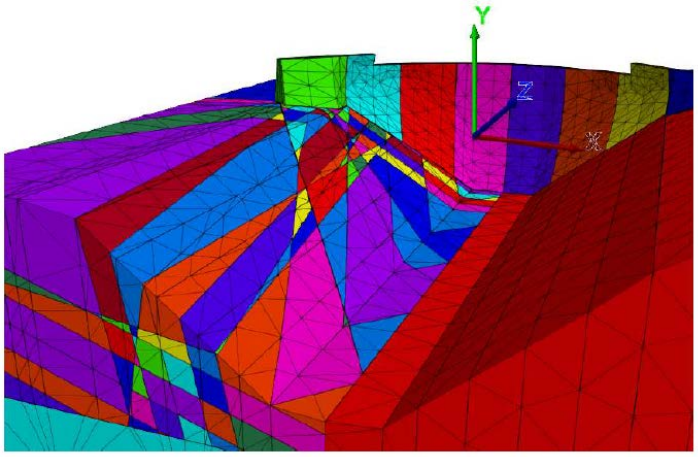
- Regulation for Safety of Dams
  - First version published in January 1990, revised in October 2007
  - Applies to:
    - About 100 dams with H>30 m, most concrete dams owned by EDP
    - 160 dams with 15<H<30 m high
    - 450 dams with H<15 m.
    - 80% earth fill dams; 18% concrete and masonry dams; 2% rock fill dams
  - Main entities
    - **Dam owner** (EDP, Municipalities, Irrigation Associations), with the technical support of the designer, contractor and other consultants and experts
    - **Portuguese Authority for Dams** (Portuguese Environment Agency – APA)
    - **LNEC**
    - **National Civil Defence Service**
    - **Dam Safety Commission**
- Codices of Practice for design, construction and observation and inspections of dams

# Safety control of dams

Reality

Monitored




Predicted

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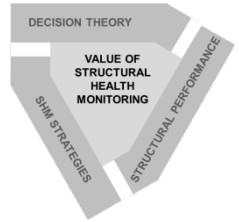
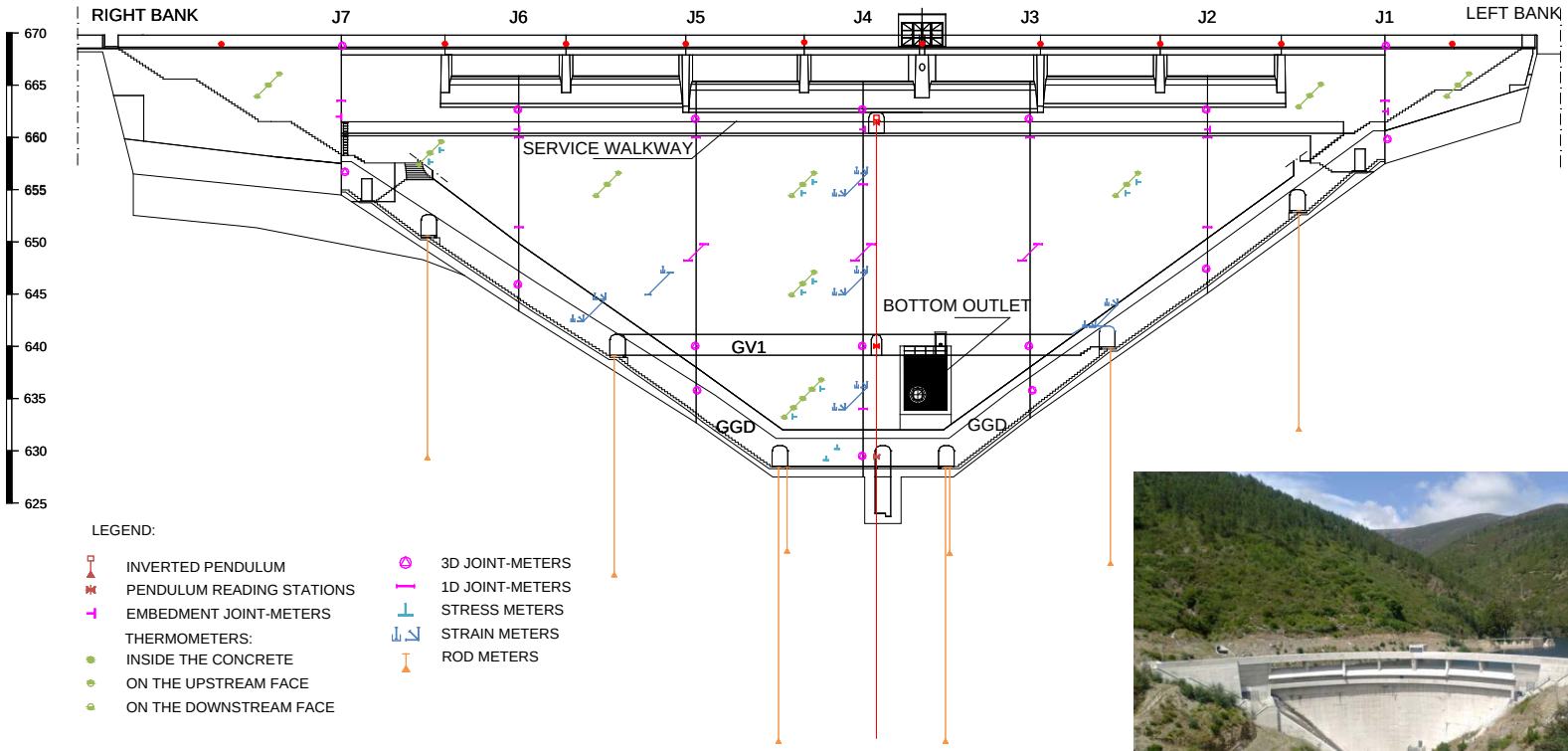
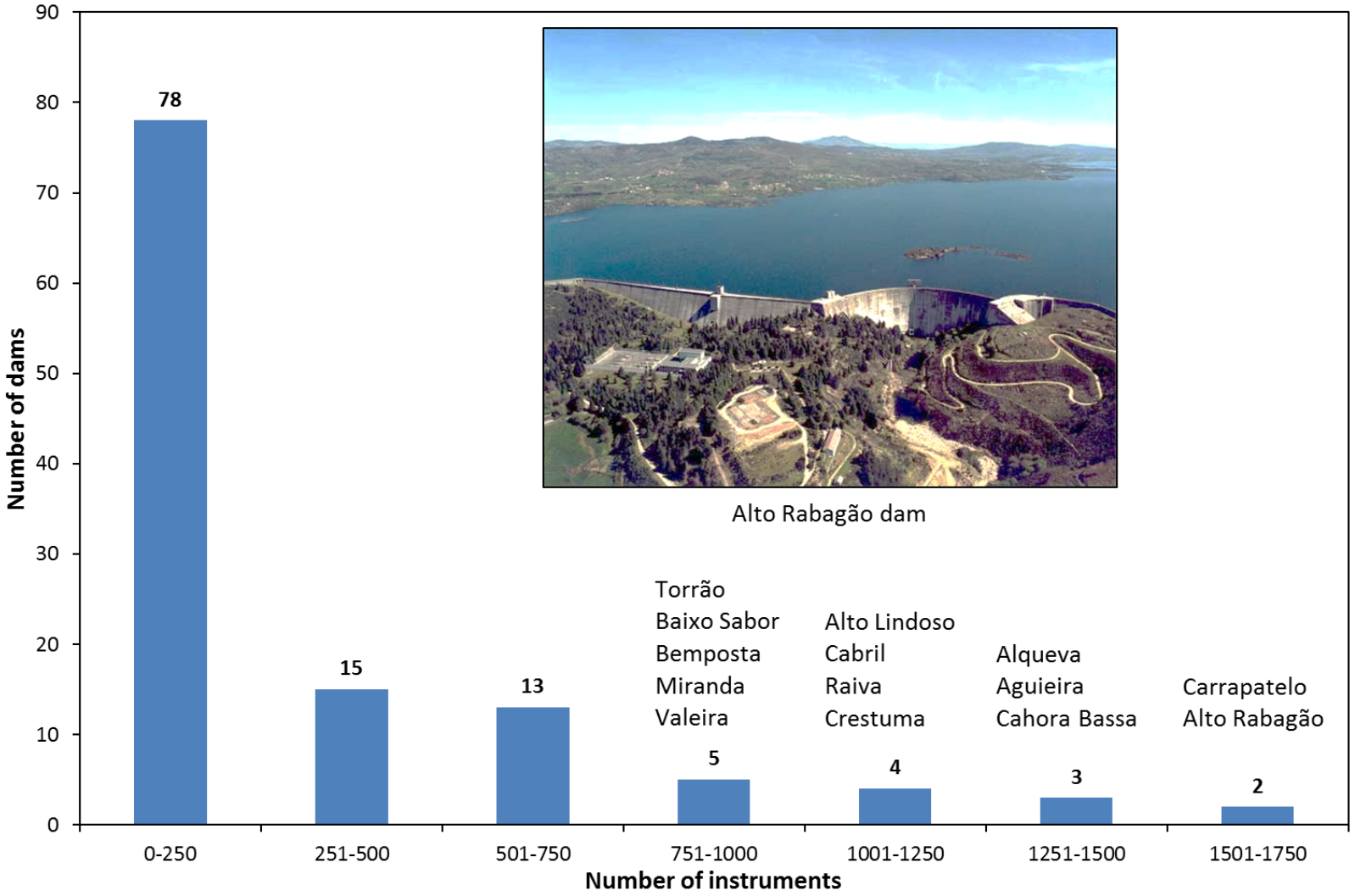


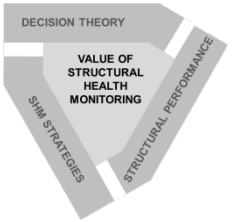

# Monitoring of concrete dams




Monitoring system of Alto Ceira II dam

# Number of instruments by dam (Portugal)






# Structural behaviour of a damaged concrete dam

## Alto Ceira dam

- Concrete arch with 37 m high
- Thickness between 4,5 m (base) and 1,5 m (crest)
- Construction in 1949

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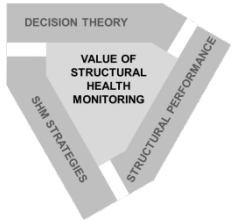


# BARRAGEM DO ALTO CEIRA

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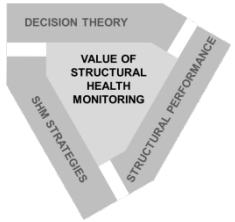
Energias de Portugal, EDP, Portugal

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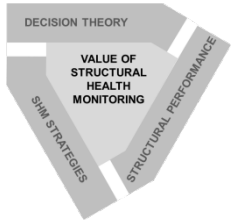
Energias de Portugal, EDP, Portugal




# BARRAGEM DO ALTO CEIRA

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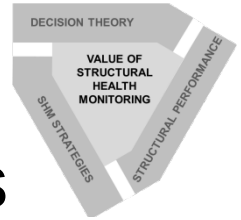
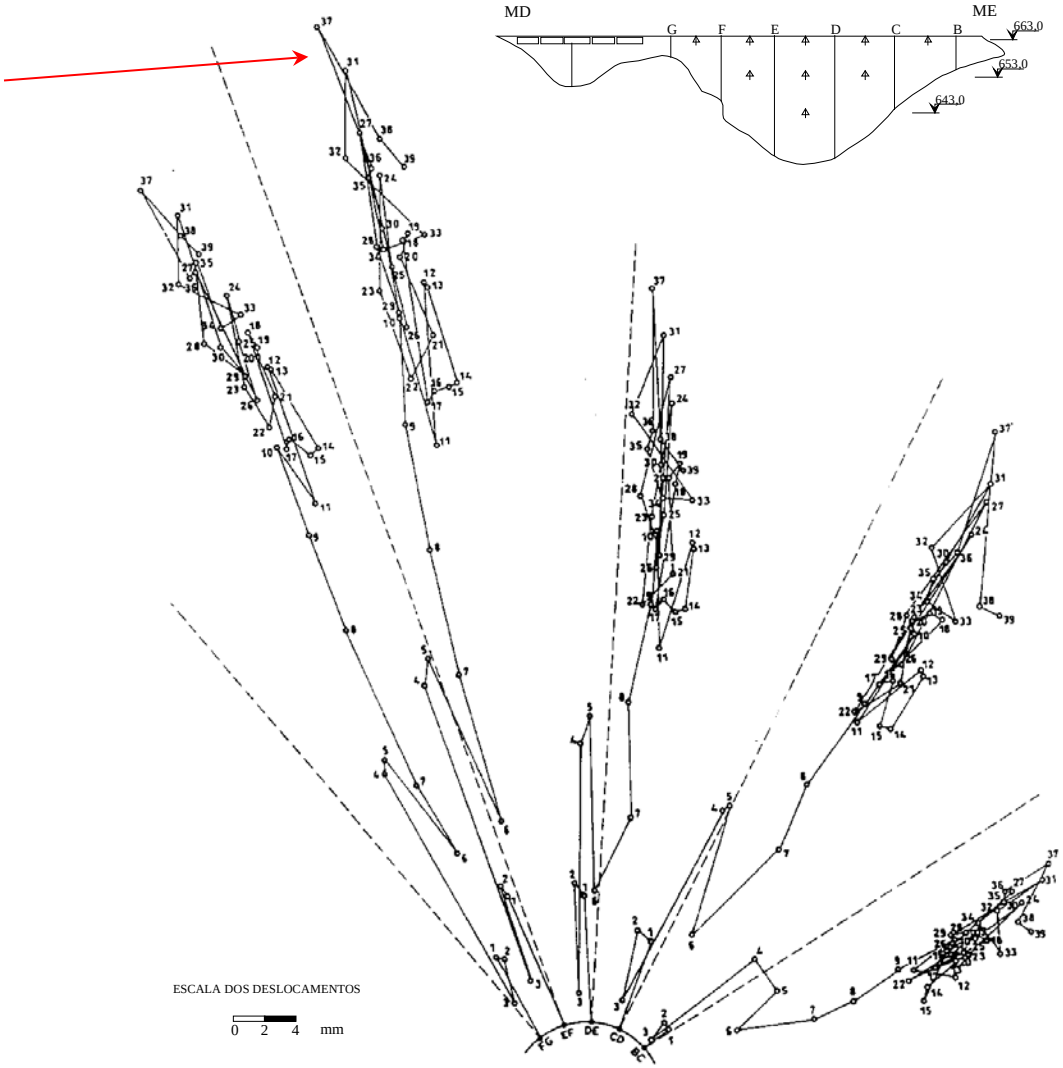
Energias de Portugal, EDP, Portugal




# Time evolution of horizontal displacements

Time rate of upstream displacements: ≈1 mm/year

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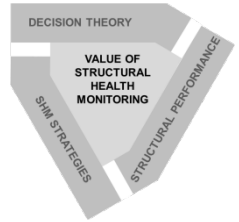
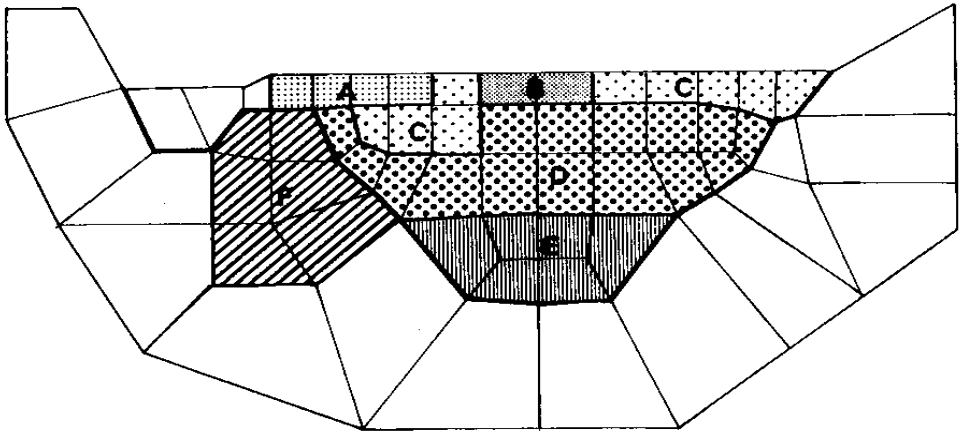
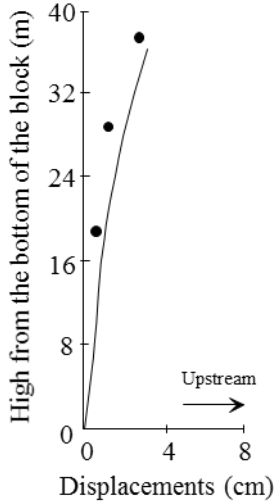
Energias de Portugal, EDP, Portugal



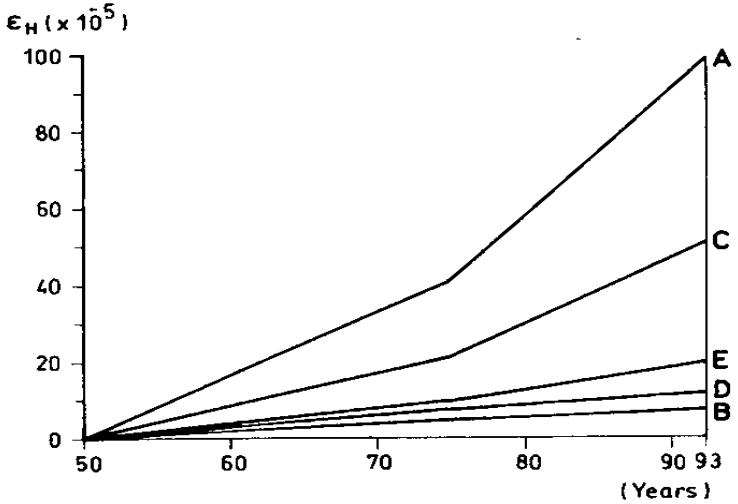

# Numerical studies (decade of 90')



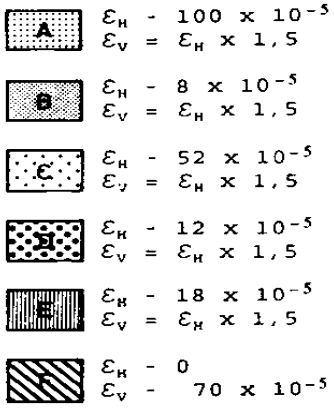

Central cantilever



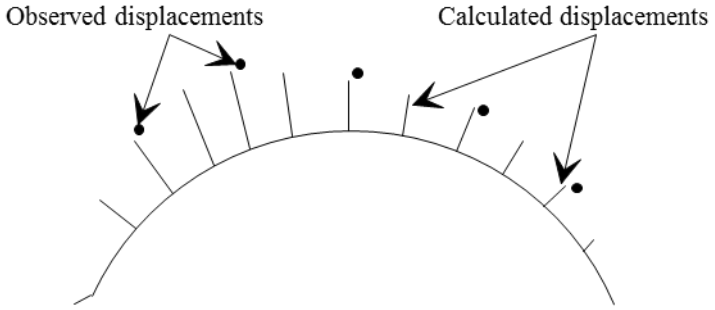

Swelling

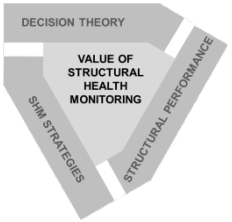



Maximum swelling values (1950-93)
H – Horizontal; V- Vertical




Crest arch






# ALTO CEIRA DAM
## Final remarks

- The dam was very damaged, with significant cracking
- Important swelling process
- The dam was demolished and substituted by a new one
- **Continuous assessment of the dam safety condition**
- **Extension of the dam lifetime**

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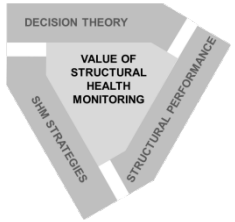
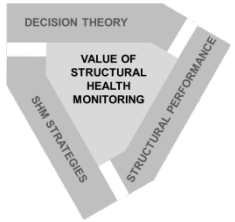



# Vajont dam

Vajont dam before the accident


Google maps, 2016

- 262 m high concrete arch
- Italy, 100 km north from Venice
- Built between 1957 and 1960
- Very serious accident in October 1963 (≈2000 death)




# Vajont dam accident

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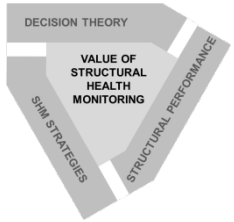
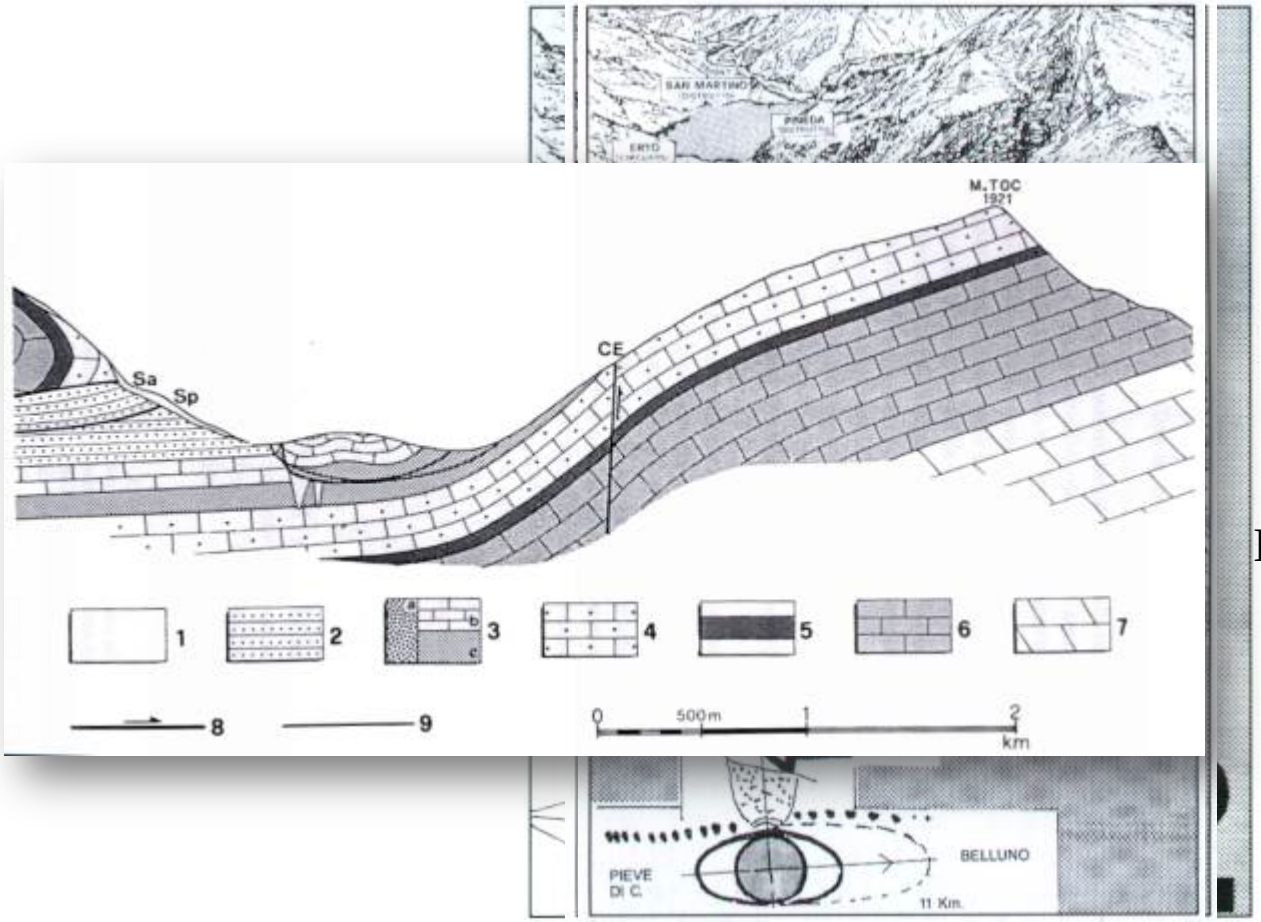



# Vajont dam: October 1963 accident




Marl and limestone formations

Layers of claystone, acting as sliding planes

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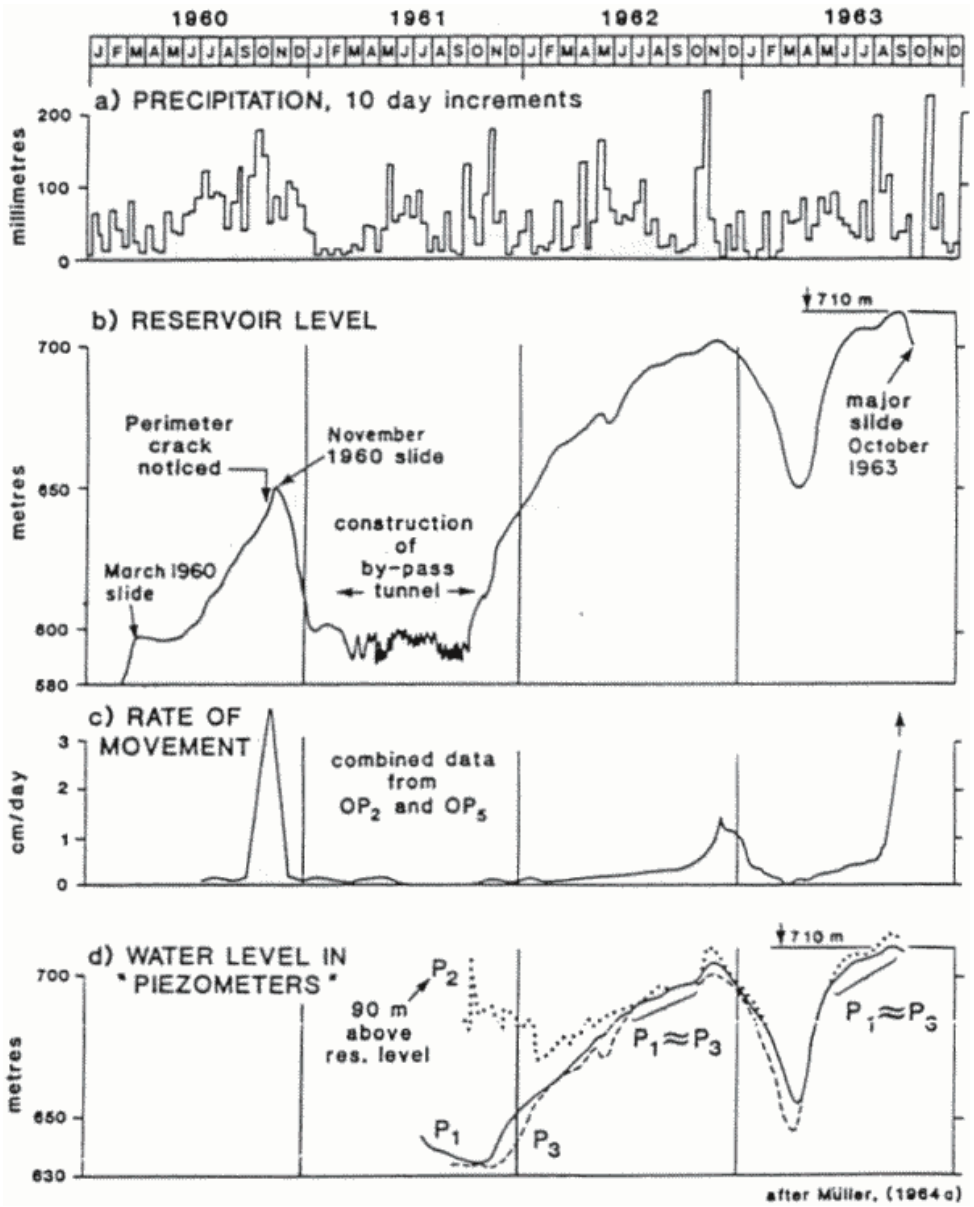
# COST TU1402: Quantifying the Value of Structural Health Monitoring

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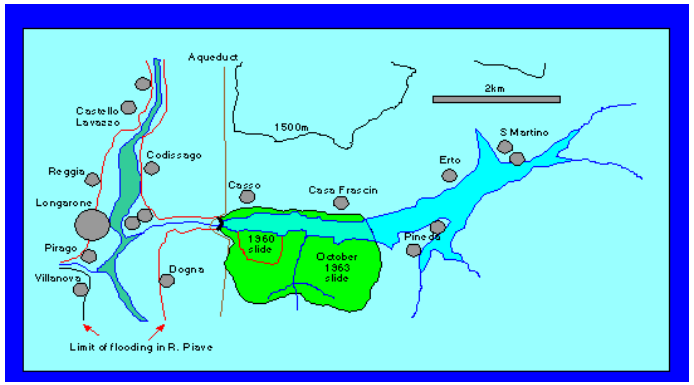
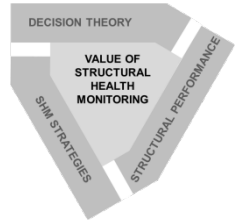
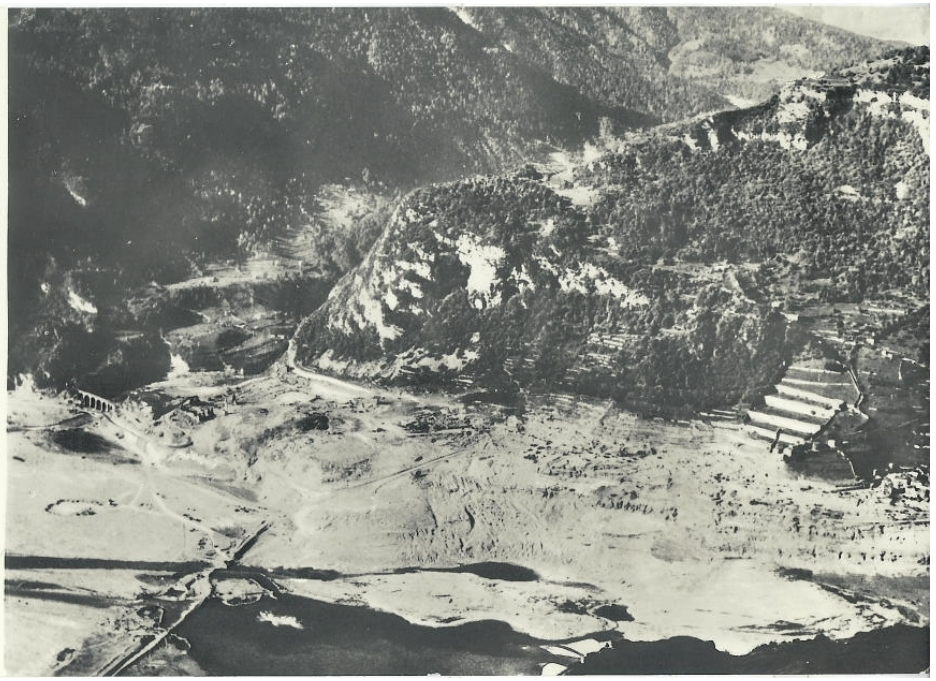
# Vajont dam
## 4 November 1960 landslide




# Longarone
# Before and after Vajont accident



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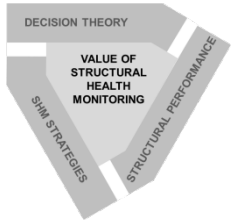


# Longarone
# Before and after Vajont accident

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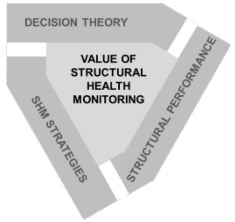
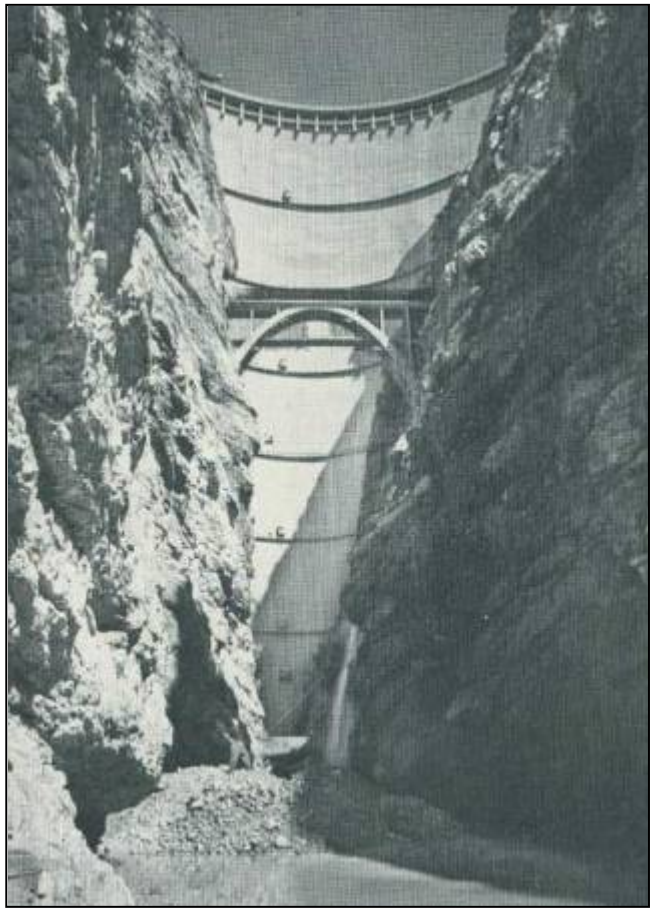
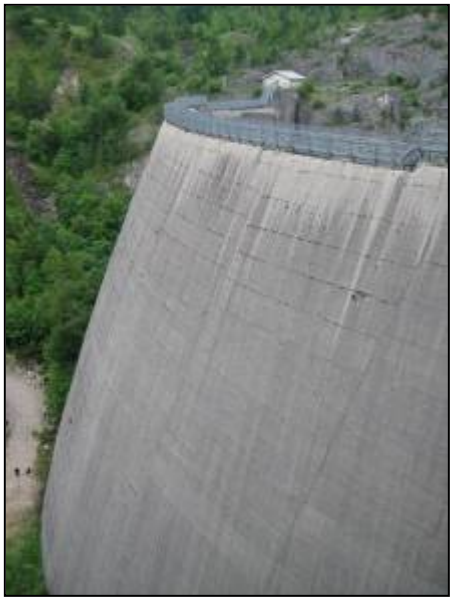
# COST TU1402: Quantifying the Value of Structural Health Monitoring




## Vajont dam
## Before and after the accident





**http:\\www.vajont.net**

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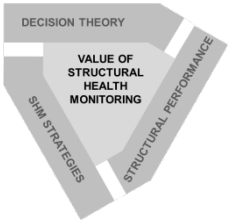
Energias de Portugal, EDP, Portugal




# Vajont dam accident

## Final remarks

- Safety control must be extended to all structures (dam body, foundation, reservoir slopes, etc.)

- Monitoring must result in analysis and interpretation of the data and, in case of abnormal behaviour, in proper and timely decisions

- Value of SHM vs. Cost of not monitoring

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