ICOLD TCDS -
Technical Committe on Dam Surveillance

Sam Johansson

HydroResearch
SAM JOHANSSON AB

TCDS -
Technical Committe on Dam Surveillance

- 30 deltagare
  - Members
  - Co-opted, 5
  - Corresponding 1
  - Inactive 2
- 26 länder
- Två kvinnor
- Ca 5 st <40 år
- 2 ICOLD vice presidenter

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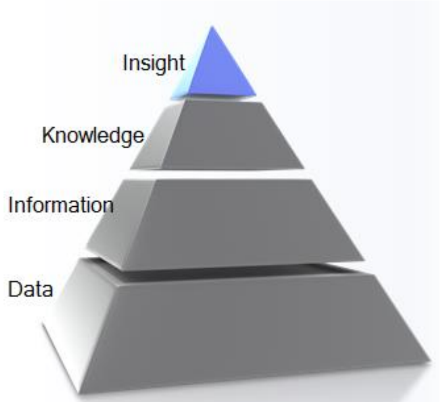
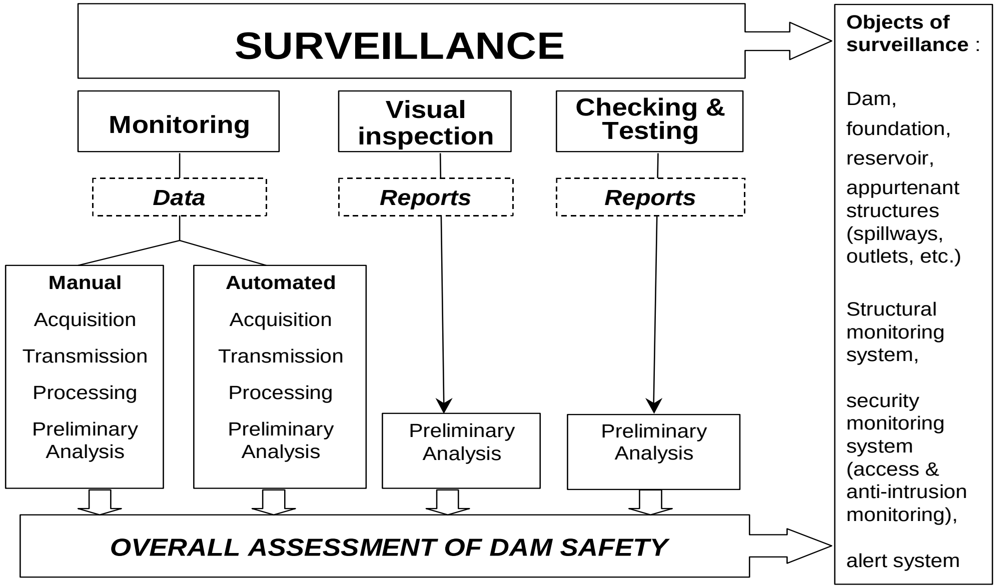
Terms of Reference:

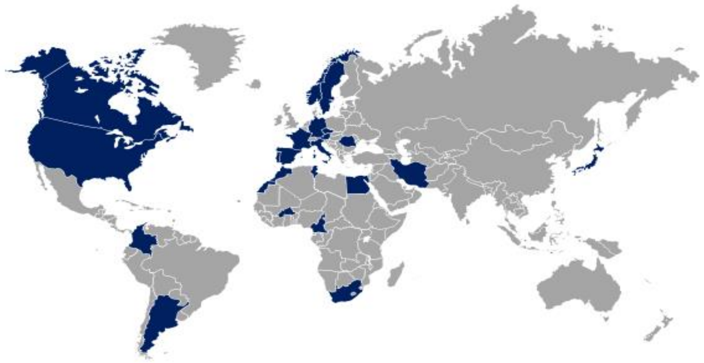
- *Methods for the improvement of the quality and reliability of information*
- *Data processing and representation techniques*
- *Effective Diagnostic analyses to determine behavior patterns*
- *Dedicated surveillance systems for the optimization of maintenance-, rehabilitation- and other life cycle costs*
- *Impact of surveillance (preventing dam incidents and dam failure by means of selected case histories*





TCDS – New bulletin ”Lessons learnt from case histories”

- *Nine benchmark histories in the main text*
  - Malpasset (importance of monitoring engineering geological aspects)
  - Vaiont (importance of monitoring reservoir slopes)
  - Zeuzier (the unbelievable effect of pore pressure relief)
  - Teton (value of diligent visual observations)
  - Dnieprostroi, Möhne and Eder (explosive loads during World War II)
  - Folsom (gate failure, tested regularly but not all the way through)
  - Cahora Bassa (the value of diligent installations on the life of instruments)
  - Zoeknog (failure, predicted by pore pressure gauges, but ignored)
  - Tous (backup systems failure)
- *71 other*
- *About 12 is clearly related to foundation*



Hazards or failure modes	Nº of cases	%
Seepage	25	23,8%
Erosion (foundation and dam body)	**15**	**14,3%**
Pore water pressures	8	7,6%
Hydraulic fracture	4	3,8%
Foundation rock deformation	**6**	**5,7%**
Settlements, deformations and movements of dam body	9	8,6%
Uplift	7	6,7%
Sliding of dam body	1	1,0%
Temperature load	1	1,0%
Ageing of concrete & cracking	6	5,7%
Sealing membranes (cracks & behaviour)	**6**	**5,7%**
Dam slope stability	4	3,8%
Downstream river erosion	1	1,0%
Reservoir slope sliding	2	1,9%
Earthquake	3	2,9%
Sedimentation	1	1,0%
Improvement of monitoring systems	3	2,9%
Diligent monitoring data analysis	3	2,9%

Content

3 Toolbox - Aims of benchmark case histories

“There are several aims with a set of benchmark case histories. The noble objectives are:

- Primarily, NOT to criticise but to learn from the facts (for example the design of the dam or monitoring system, or the decisions taken by operational staff etc,)
- Secondarily, to stress points in an unbiased and professional manner and not to point fingers

In this way, significant universal lessons can be learnt from these case histories and provide guidance on design aspects, construction and operation procedures.”

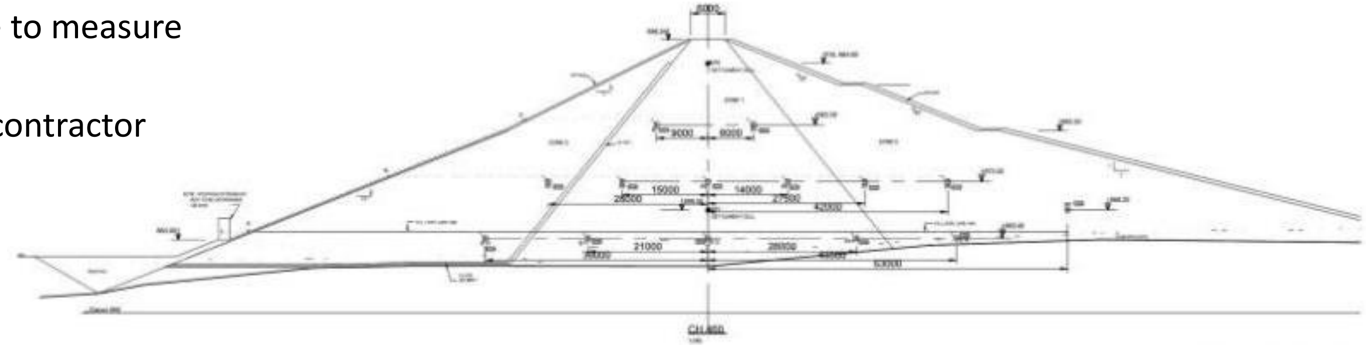
Zoeknog failure

HydroResearch

ABSTRACT Case history category: e. The installation of the instrumentation system of Zoeknog Dam was done meticulously by an experienced instrumentation expert. He monitored and evaluated the results during first filling (although it was not required from him). His alarm of a potential dam failure was ignored and the dam failed within 2 weeks of his first alarm.

- *TECHNICAL DETAILS*
  - Construction started during 1990 on the 40 m high dam (above lowest foundation level). It was designed as a zoned earthfill section with a central clay core and outer fill zones

- *SURVEILLANCE DETAILS*
  - **Piezometers** installed at two chainages (460 and 540) with three levels of instruments in each line to measure the phreatic line from upstream of the clay core to downstream of the chimney drain. Both lines were on the right bank, the first 30 metres from the outlet conduit and the second line of instruments 80 metres further
  - Three **settlement cells** were added to the second line to measure the settlement at foundation level.
  - The installation was done by an experienced private contractor



Zoeknog failure

HydroResearch

DESCRIPTION OF THE INCIDENT

On 12 January **Fil Filmalter** was in the **author's** office. The author told him that the Dam Safety Surveillance teams of DWS (headed by the author) is unfamiliar with the dam as it does not fall under his jurisdiction and referred him to the Dam Safety Office (the dam safety regulating authority) that was indirectly involved. Fil stepped into the passage and shouted in Afrikaans the equivalent of " I am telling you Zoeknog dam is going to fail and you don't want to do anything" and left; …

Early morning of 25 January the dam was breached with no lives lost and fortunately no significant damage to other infrastructure.

LESSONS LEARNT

The main lesson learned is **to act on warnings of diligent instrumentation personnel**. In the case of Zoeknog,Dam it would not have mattered. The obvious solution would have been to drain and breach the dam, remove all the earthfill and start again from foundation level.

SELECTED REFERENCES

DURLASSBODEN DAM

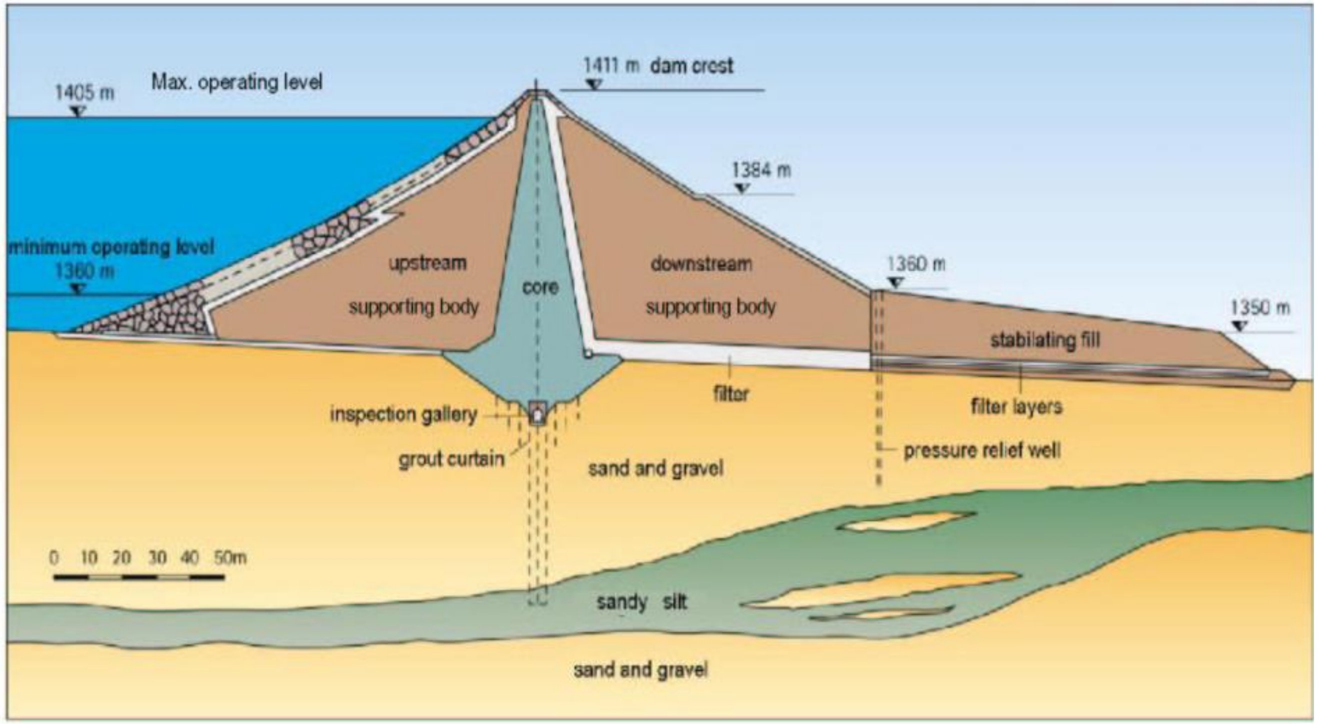
HydroResearch

Dam type: Embankment Dam with Earth core – 80 m high
Case history category: c, d
Main objective: Surveillance of the grout curtain
Main benefit: Good understanding of dam behaviour
Observations: Long term behaviour of the dam foundation

Durlassboden dam is an embankment dam with an earth core and is founded on erodible alluvial deposits with a maximum depth of 130 m. Due to economic and technical reasons the grout curtain was not carried out to the full depth of the alluvium, but only down to a silt layer at a depth of about 50 m. Therefore, water can pass through the "window" below the silt layer.

These boundary conditions required an **extensive monitoring** system that is based on **relief wells** at the downstream dam toe and in the dam foreland**, piezometers** in the dam foreland, piezometers upstream and downstream of the grout curtain

In 2010, after more than 40 years of operation the question appeared whether an upgrade of a part of the dam foreland or even of the grout curtain is necessary. To get the right answer to this question an intensive evaluation of the measured data was carried out. Having data over a period of more than 40 years trends either positive or negative should have been possible to identify. The evaluation showed clearly that there a no negative trends.



Lessons learnt

*The evaluation demonstrated the **satisfying long term performance of the dam and the grout curtain over the decades.*** Any necessary improvements may be based on current and future readings.

El CHOCON DAM - INTERNAL EROSION in rock-core contact

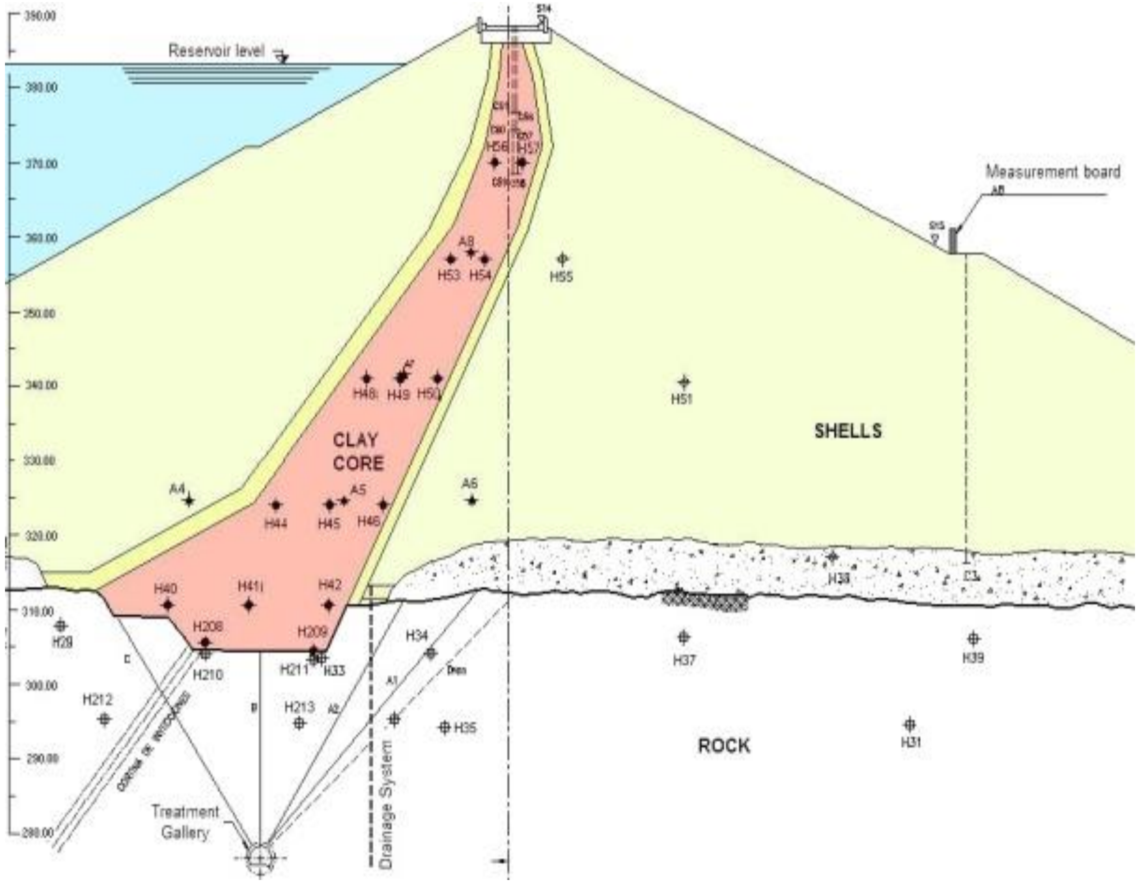
HydroResearch

Dam type: Embankment dam with clay core - 86m high.
Case history category: e, c, d
Main objective: Early detection of failure mechanisms
Main benefit: Correct and on time remedial action
Observations: Early detection of potential erosion and assessment of remedial works

A continuous **increase of piezometric levels** in the rock-core contact on right abutment was observed, leading to design remedial works: **grouting** program was considered necessary at both the right and left banks and through the complete foundation in order to reduce the potential of **clay core piping through open rock joints**.

Lessons learnt

The design for dam safety-monitoring, have reliable and well located instruments at the rock contact. **Piezometric measurements in the contact core-foundation permit to detect the increase of pressure and alarm Engineers.**



SYLVENSTEIN DAM - RETROFITTING

HydroResearch

Dam type: Embankment dam with clay core – 48 m high

Case history category: d, e

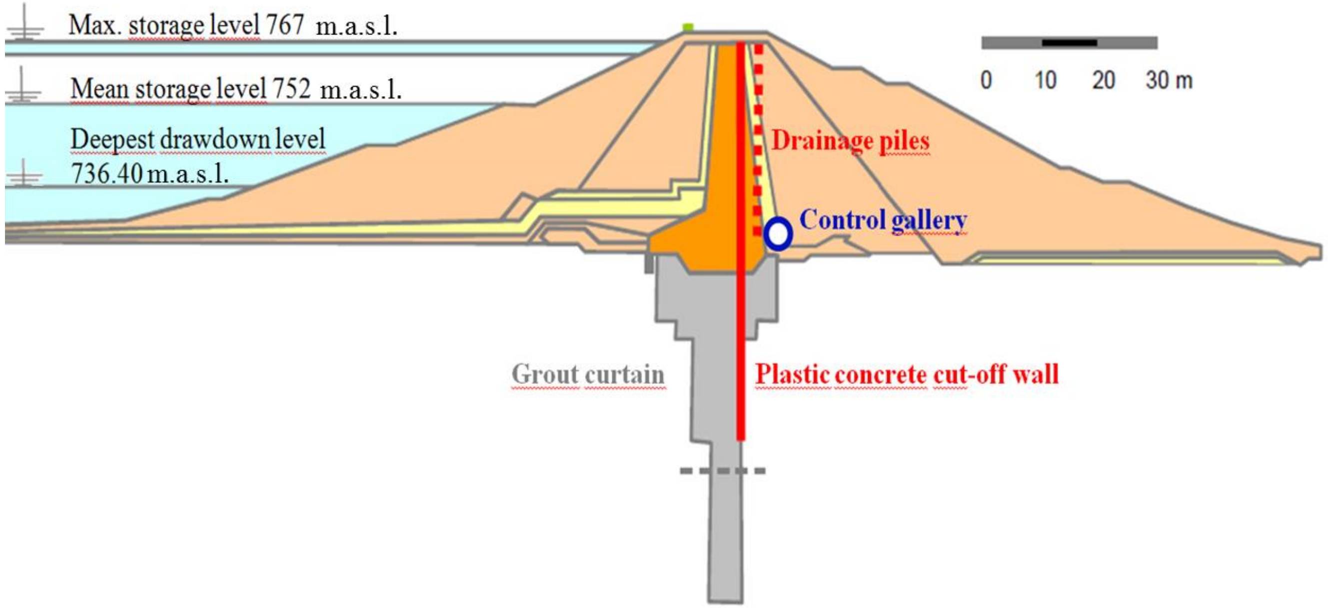
Main objective: Improvement of the sealing system and the seepage flow measurement

Main benefit: Improvement of the dam safety standard

Observations: Innovative methods (deep cut-off wall, additional control gallery)

The dam and subsoil of the Sylvenstein Reservoir were equipped with a new efficient cut-off wall and a reliable seepage water measurement system after operating for more than 50 years. This was the first time in Germany that a 70 m deep diaphragm wall (two-phase plastic concrete cut-off wall), which also cut into rock foundation on either side of the wall, was installed while the dam was still in operation. Monitoring the new sealing system is possible with the drainage piles and an accessible control gallery, which was pressed from the compact rock through the whole dam into the opposite abutment – without hindering the standard operations of the dam, a constructionally brilliant feat that was realized for the first time worldwide.

These boundary conditions required an extensive monitoring system that is based on relief wells at the downstream dam toe and in the dam foreland, piezometers in the dam foreland, piezometers upstream and downstream of the grout curtain.



Lessons learnt

- *Bringing a **50-year-old sealing system up to date** (clay core/grout curtain in overburden) by **adding a cut-off wall** to the dam and the foundation (overburden /rock) is possible by using adequate construction methods and machinery (e.g. hydro-cutters).*
- **Improving the dam monitoring** *and the seepage flow measurement system by adding drainage piles (vertical measure) and a completely new control gallery (horizontal measure) is possible. (Remark: Adding new control galleries should not be considered as a mandatory measure within the scope of embankment dam upgrading projects!)*

Oued El Makhazine DAM – CUTOFF WALL WRONG

HydroResearch

Dam type: Embankment dam with clay core - 67m high, 530m crest length.

Case history category: b, c, d

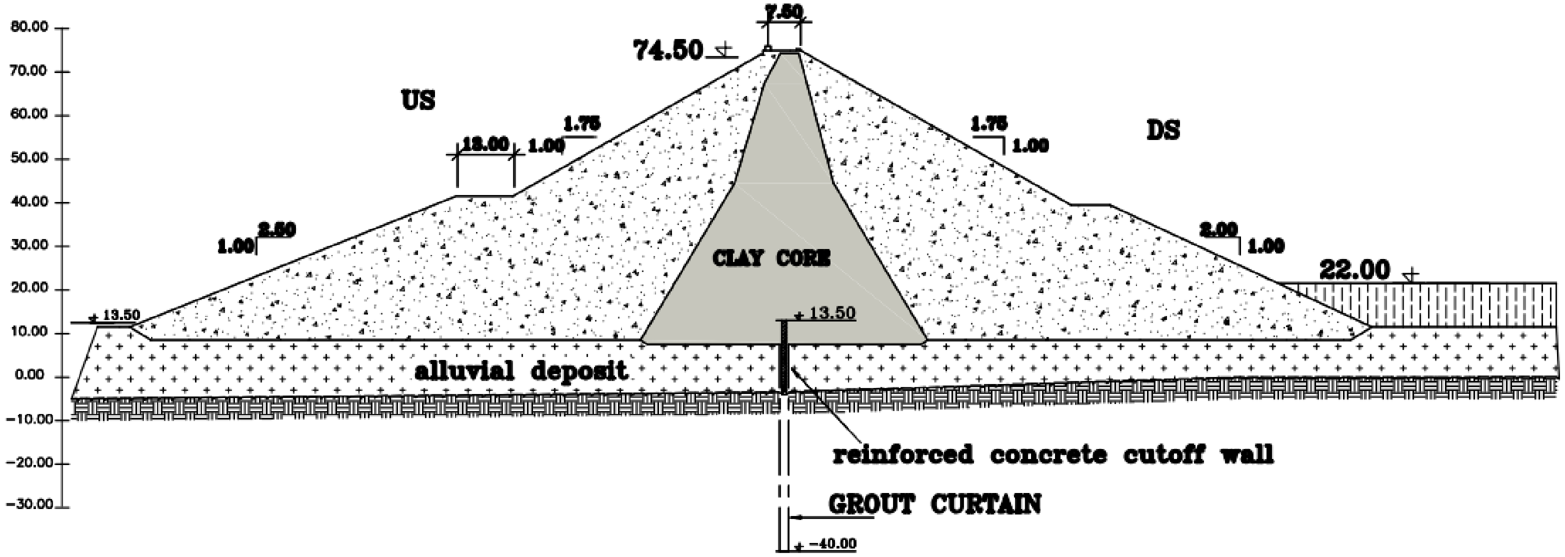
Main objective: Early detection of failure mechanisms

Main benefit: Correct and on time remedial action

Observations: Early detection of potential erosion and assessment of remedial works

Since the **first impoundment** of the reservoir occurred in 1979, the **pore pressure** in the alluvial deposit was gradually **increasing downstream** of the cutoff wall, while it was **decreasing upstream**. This was attributed to the continuous deterioration of the cutoff wall.

The safety of the dam was jeopardized in 1995 when the piezometric level reached, almost the downstream toe of the dam with a reservoir **10m below the normal storage elevation**. An extensive drainage system including relief wells and deep drainage trenches allowed for the total control of the seepage along with a decrease of the piezometric level at the toe of the dam.



Lessons learnt

The design for dam safety-monitoring have a robust, reliable and well located instruments in the alluvial foundation downstream and upstream of the cutoff wall. The close follow up and interpretation of the readings based on statistical modelling analysis, permit to detect the increase of pressure and alarm Engineers.

STORFINNFORSEN POWER STATION - EMBANKMENT DAM IMPROVEMENT INITIATED BY JUST A SMALL CHANGE IN MEASUREMENTS DATA

HydroResearch

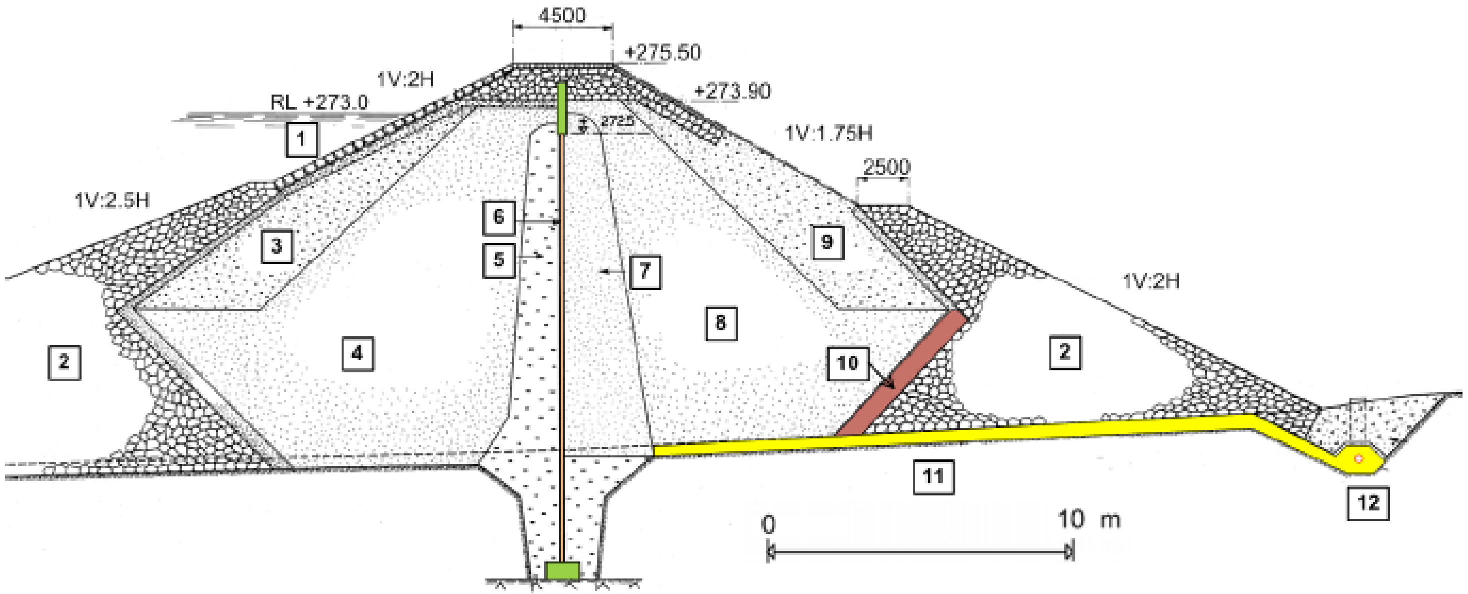
Dam type: Embankment dam with glacial till core and timber sheet pile - 23m high

Case history category: b, c, d, e

Main objective: Early detection of potential failure mechanisms

Main benefit: Correct and on time remedial action

Observations: Early detection of potential timber deterioration and assessment of remedial works



Total leakage has been small with minor variations (1 to 1.5 l/s) over the years. The readings from the four standpipes have generally indicated constant pressure until 2007, when a **slight increase (some 9 mm/year)** became evident.

Lessons learnt

This case shows that also **small changes may be important, and *evaluation of data must be set in the context of the construction of the dam*.** The small measured change in pressure, together with a not so god original design, was in this case enough to start further investigations. They showed high pore pressure in support fill and that the pressure in the filter layer below the downstream support fill has increased slightly over the last five years or so, indicating possible deterioration in the sealing function of the timber sheet piling.

This potential weakness was taken care of by installing a toe berm and additional drainage in the downstream part. The monitoring system was also upgraded with more sensors for automatic measurements to better understand and detect potential future deterioration of the sealing zone.

General remarks

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- Monitoring is an interdependent chain of activities. No matter how well an instrumentation system has been designed and installed, their purpose will be nullified if they are not well maintained, observed and the results evaluated regularly.
- Similarly, visual inspections and surveillance related analyses not performed and documented by diligent and experienced persons may be of limited value.
- <u>Quantity</u> of data can be very useful to determine short-term behaviour, but huge quantities of data should not be mistaken as a measure of the quality of surveillance. Massive sets of data and un-interpreted line graphs may provide a false sense confidence that good surveillance practices are being followed.
- <u>Quality</u> data, quality data processing, and quality evaluation and dissemination of information should rather be the measure of the <u>quality</u> of the dam surveillance practice.