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European Working Group

INTERNAL EROSION AND FILTERS : UPDATE AND NEW TECHNICAL BULLETINS

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Update and new ICOLD bulletins

- Update of bulletin on filters
- Update of bulletin on geotextiles

and

- A bulletin on risk assesment of internal erosion
- A bulletin on methods of detection

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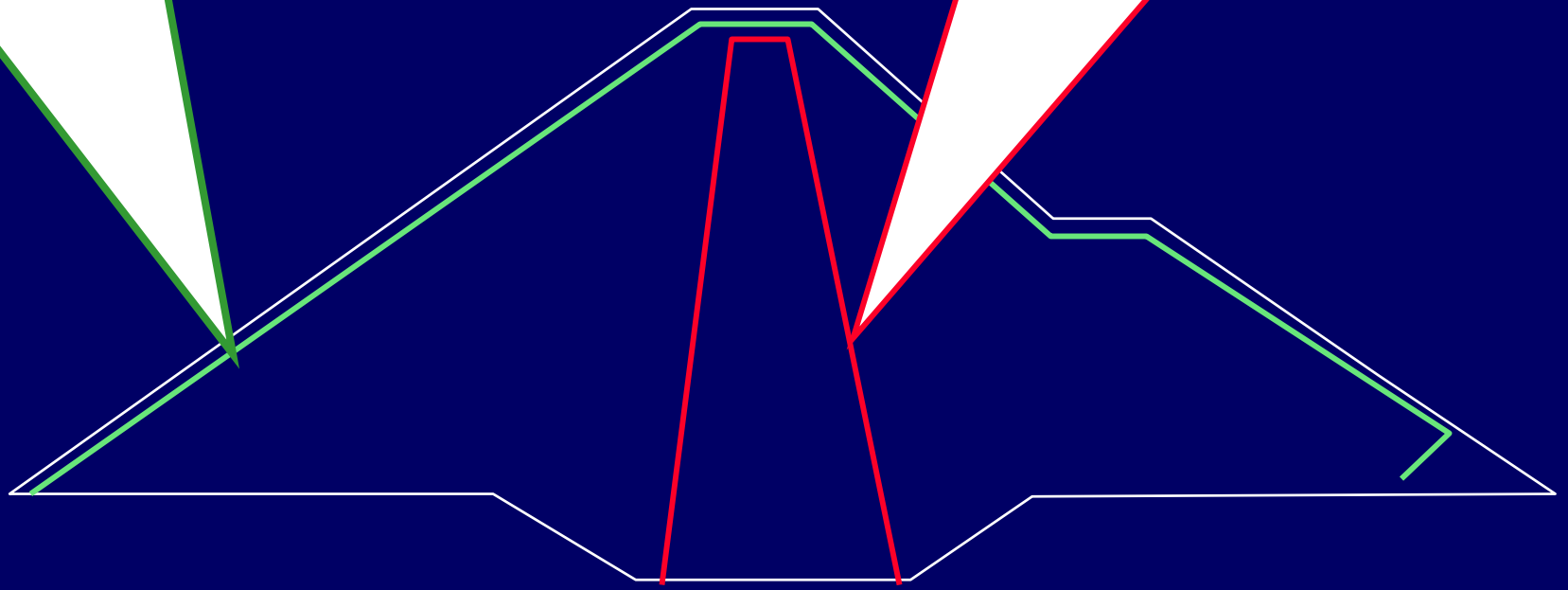
Why an update of the bulletins on granular and geotextile filters?

- A more integrated approach
- A better understanding of material behaviour
- New research results

Two kinds of filter destination

•low retention requirement
•High pore pressure requirement

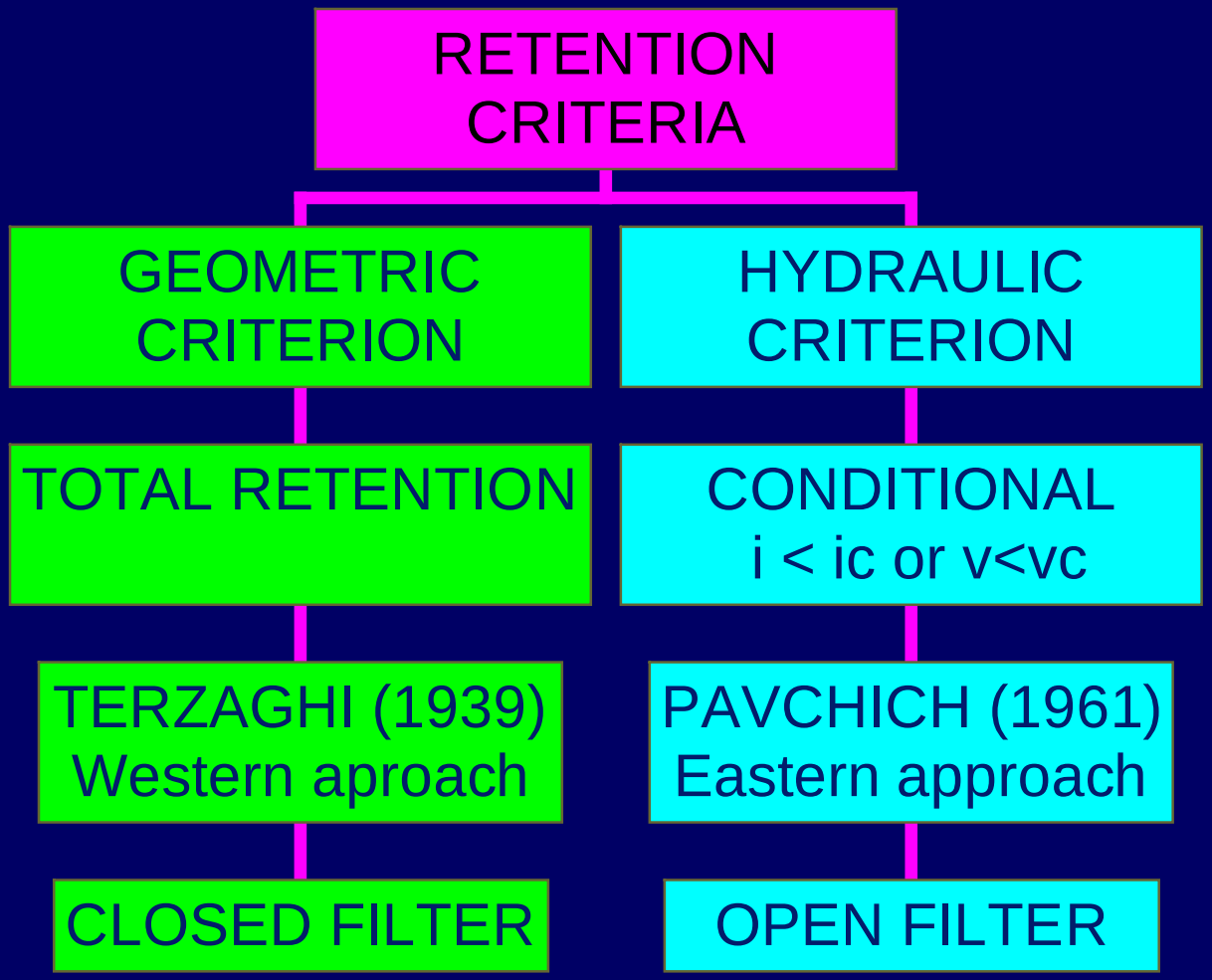
•High retention requirement
•Low pore pressure requirement



Critical Filter : with large concern on dam safety

No critical Filter with low concern on dam safety

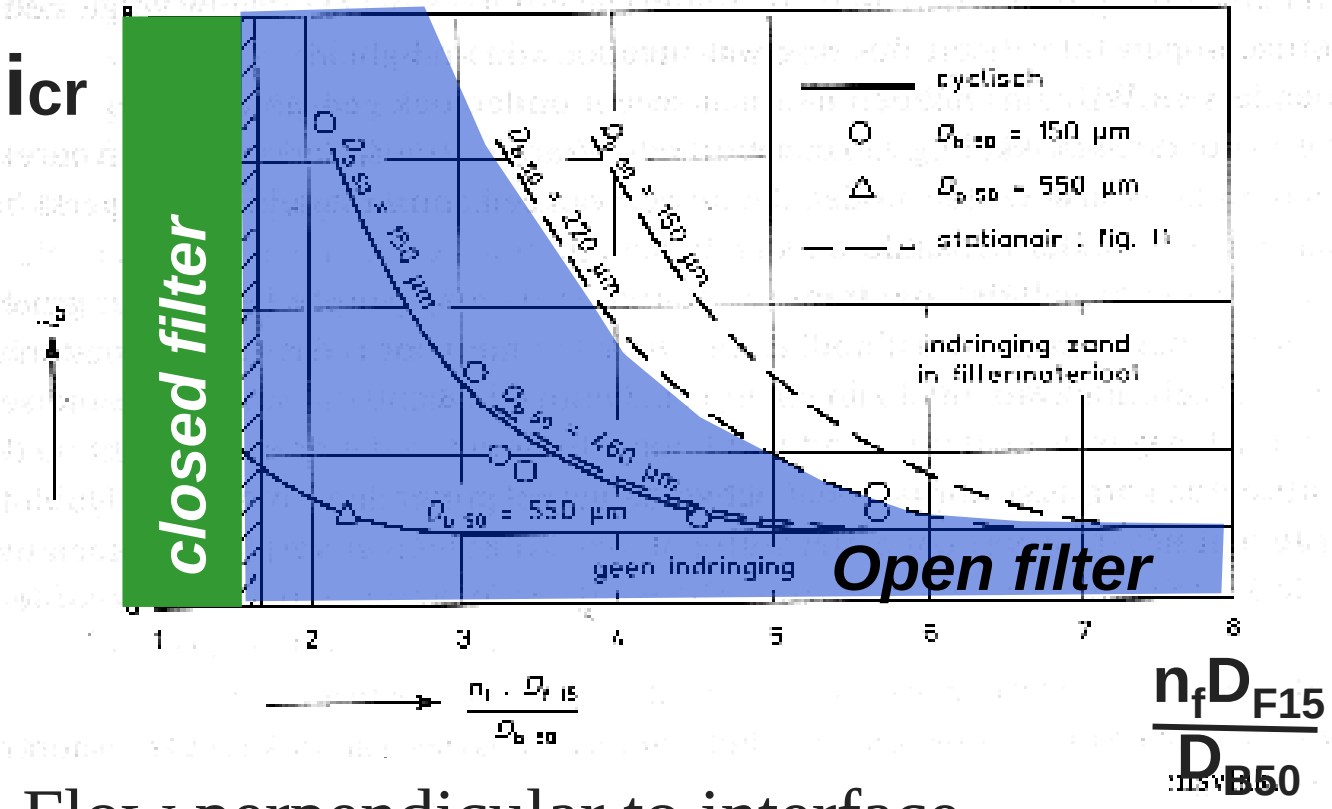
Two kinds of Retention Criteria



Open Filters from Bakker K.J. and CUR *(1994)*

Open filter : Retention depends on hydraulic gradient

Critical hydraulic Gradient Depends on the base soil gradation. Criterion linked to velocity and turbulence



Flow perpendicular to interface

New Retention criterion (Delgado)

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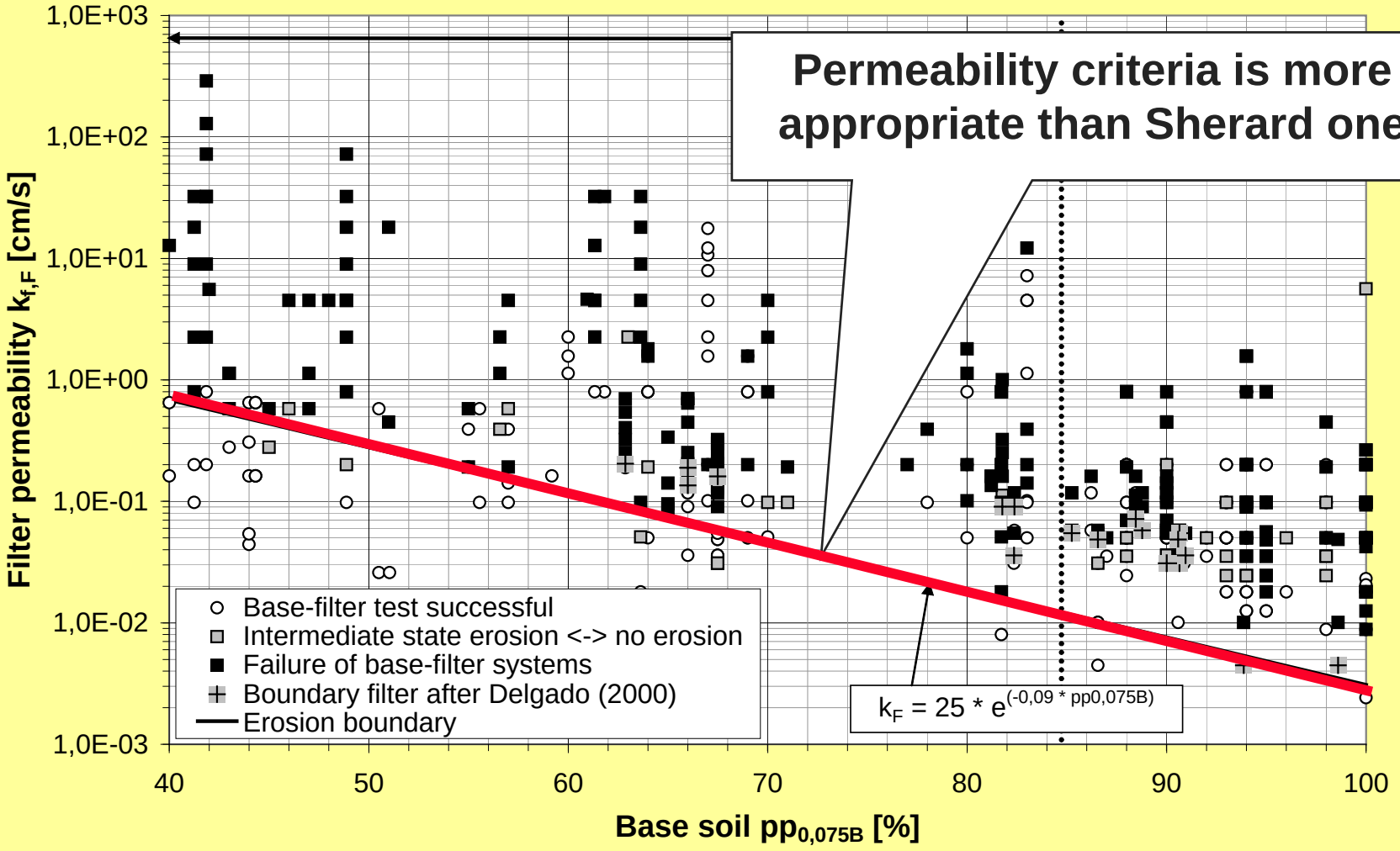

Other criteria from Giroud (2010)

CRITERIA	FILTER TYPE	CLOSED GRANULAR	OPEN GRANULAR	GEOTEXTILE
RETENTION	POROSITY		X	X
	THICKNESS		X	X
DRAINAGE	PRESSURE		X	X
	FLOW RATE	X	X	X

The advantage of the closed filter is simplicity…

Geotextile functional characteristics

- $d_{fines} \leq$ **Filtration Opening Size** $\leq d_{skeleton}$
- $T_{mini} \leq$ **Thickness** $\leq T_{maxi}$
- $K_{mini} \leq$ **Permeability**
- **Porosity / Opening area** $\geq n_{mini}$

Geotextile functional characteristics

- $d_{fines} \leq$ **Filtration Opening Size** $\leq d_{skeleton}$
- ~~$T_{mini} \leq$ Thickness $\leq T_{maxi}$~~ → $25 \leq m \leq 40$
- **Permeability** $\geq K_{mini}$

Homogeneity

Soil stability

Some recommandations on limits of the geotextiles use

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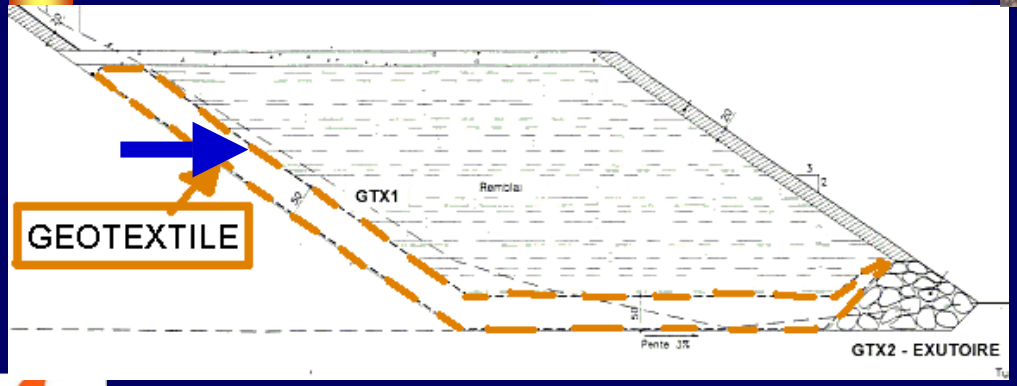
Torcy dam

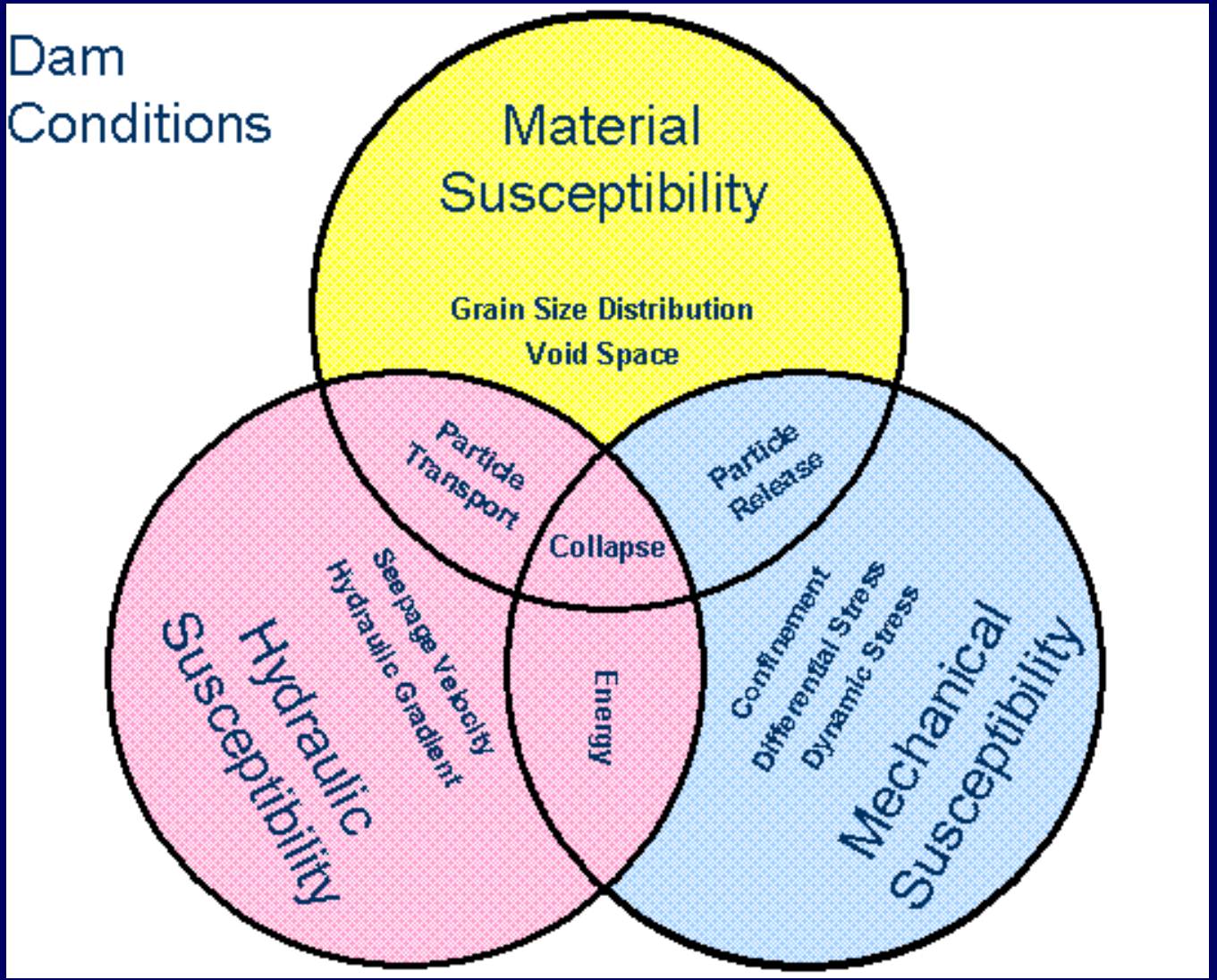
Root hole (Royet 1997)



Why a new bulletin on internal erosion ? (Foster 1999)

Failure mechanism	Erosion		sliding	
Mode of failure	External Erosion	Internal Erosion	Static shear	Seismic shear
% over the world	48%	46%	6%	
% over the world	94%		6%	

Rapid screening assessment



The 3 dam conditions (S. Garner 2009)

How deeply assess the vulnerability?

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What are the loading conditions ?

Where are the possible locations of initiation?

What are the possible mechanisms of initiating erosion?

What is the filter efficiency in controlling erosion?

What are the consequences of the on going erosion?

Are the consequences detected?

What are the solutions of quick and efficient repair?

What breach mechanism may develop?
What are the consequences & protective measures?

The framework (Fell & Fry 2007)

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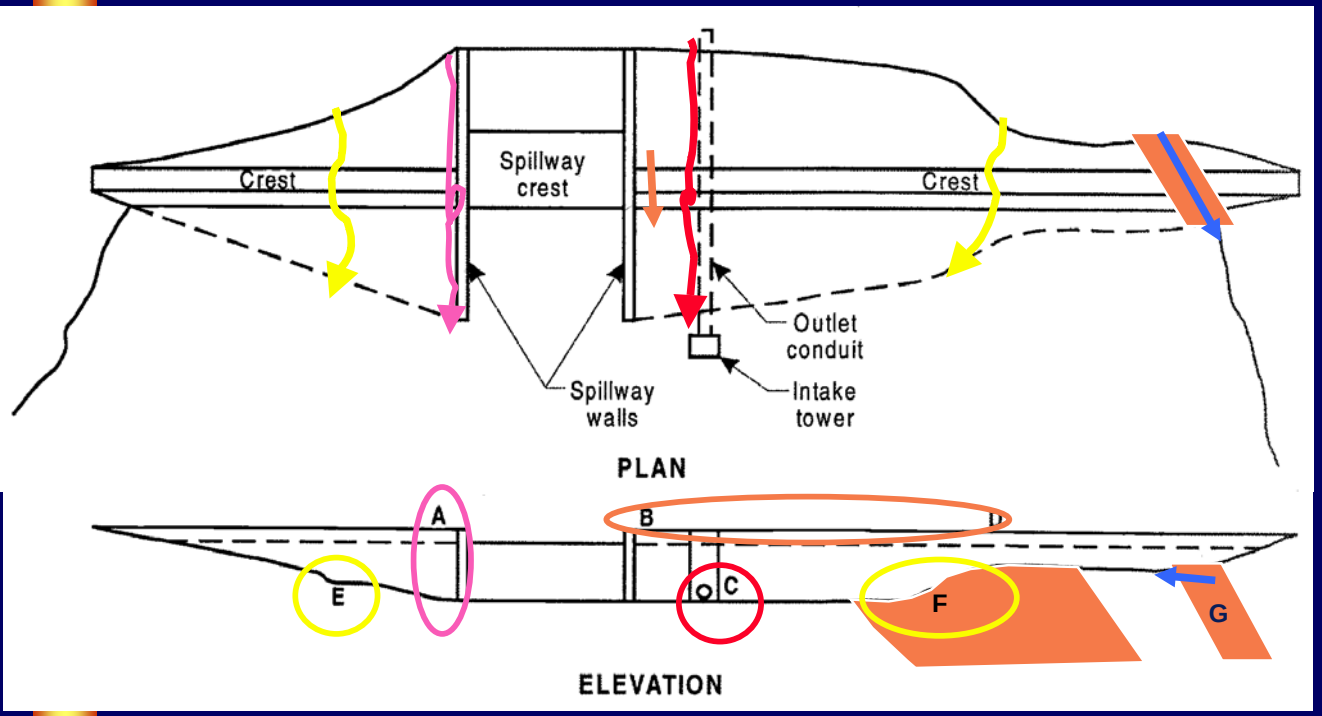
STEPS	QUESTIONS AND ANSWERS
1 Loading	HYDROSTATIC : Frequent water level, Rare flood, Safety flood SEISMIC : OBE and MDE
2 Location	EMBANKMENT : Upper, Lower, Conduit, Wall, FOUNDATION : Valley, Abutment, EMBANKMENT TO FOUNDATION
3 Initiation	BACKWARD EROSION, CONCENTRATED LEAK, CONTACT EROSION, SUFFUSION
4 Filtration	NO EROSION VAUGHAN, NO EROSION SHERARD, SOME EROSION, EXCESSIVE EROSION, CONTINUING EROSION
5 Progression	Rate of erosion? Will pipe stay open? Upstream and downstream flow limitation? Critical gradient or velocity reaches? Hold a roof?
6 Detection	Piping mode monitoring? Surveillance frequency? Continuous temperature measurement?
7 Intervention	Safety measures for piping mode? Personnel? Equipment? Materials? Weather? Flooding? Access? Training? Time to intervene?
8 Breach	GROSS ENLARGEMENT, LOSS OF FREEBOARD by CREST SETTLEMENT, SLOPE INSTABILITY, UNRAVELLING

Location of initiation : Where are the Failure paths?



LEGEND

A, B	Adjacent spillway walls.
C	Adjacent outlet conduit.
D,E	Related to irregularities in the foundation profile.
F	In the foundation
G	From embankment to foundation

Factors of initiation

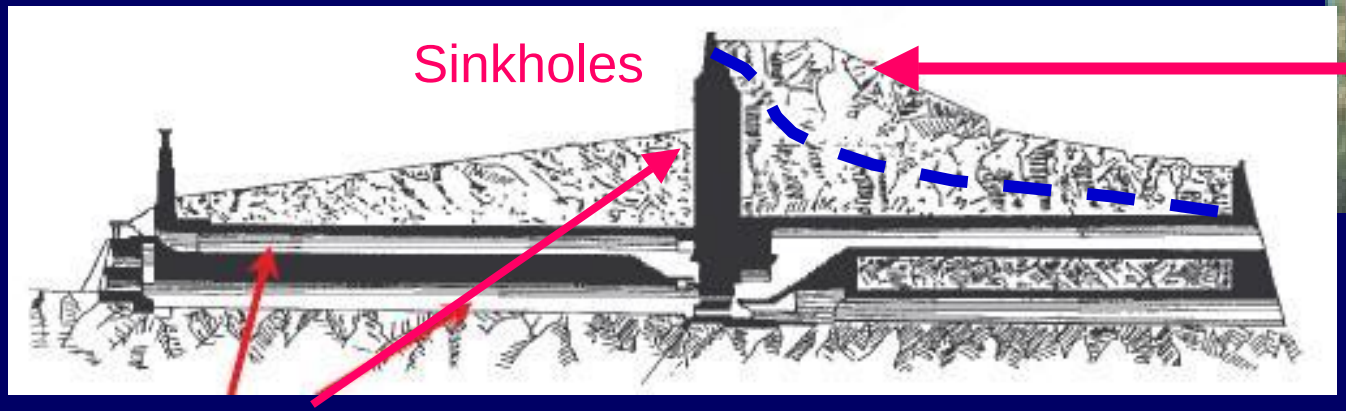
Poor Design

- No filter (old dams)
- Bad filters
- Embankment zoning
- High permeability zone

AGEING

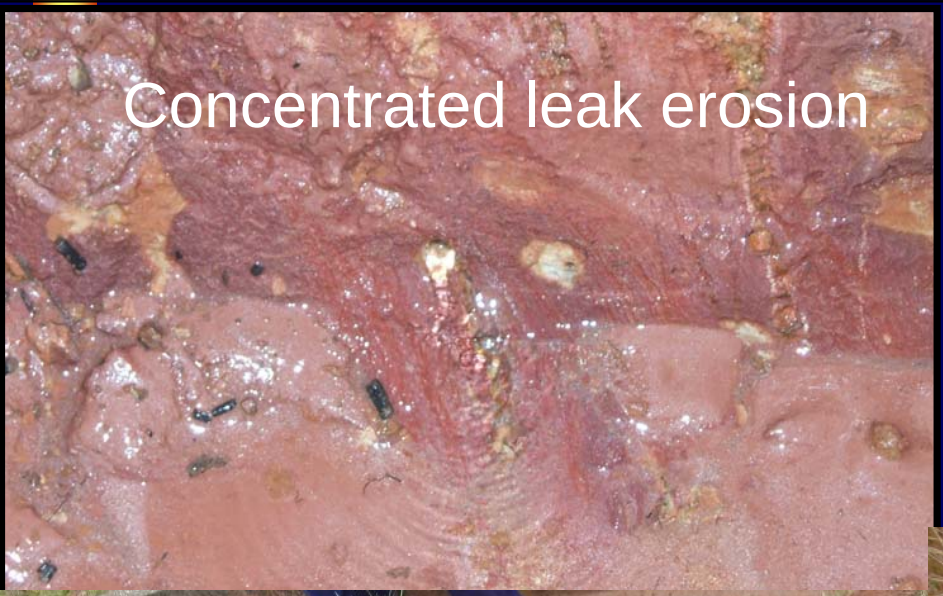
- Conduit leak
- Structure ageing
- Filter degradation
- Incomplete repair
- Differential settlement of the foundation
- Dessication cracking
- Animal holes
- Vegetation

St-Ferreol ageing (1675)



Leakeage 6l/s, sinkholes and sand and gravel deposit in the conduit (some m^3)

Filter weathering and clogging



Large leakage with clay deposit in collector

Initiation : definition

Internal erosion *o*ccurs when soil particles within a water retaining structure or its foundation, are carried downstream by seepage flow. Internal erosion can initiate by 4 types of initiation :

1 Concentrated Leak Erosion,

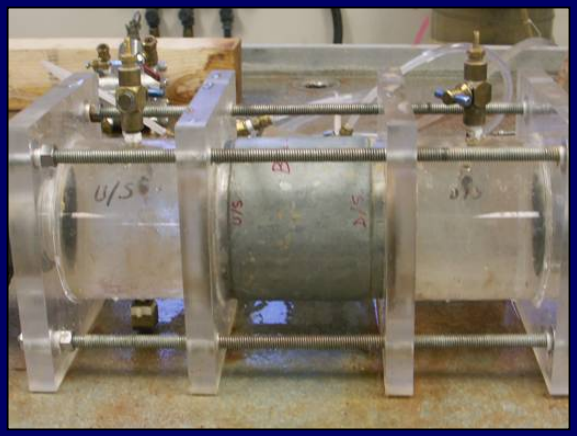
2 Backward Erosion,

3 Soils Contact Erosion,

4 Suffusion.

1 – crack or hole erosion

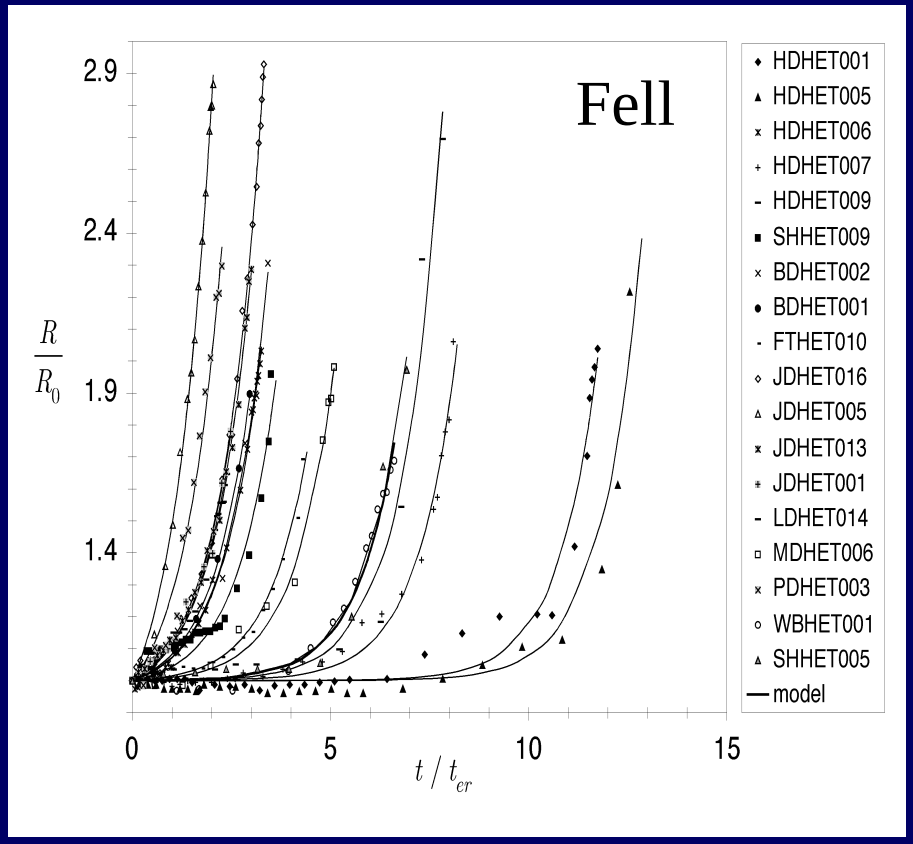
Clayey fill on clay foundation

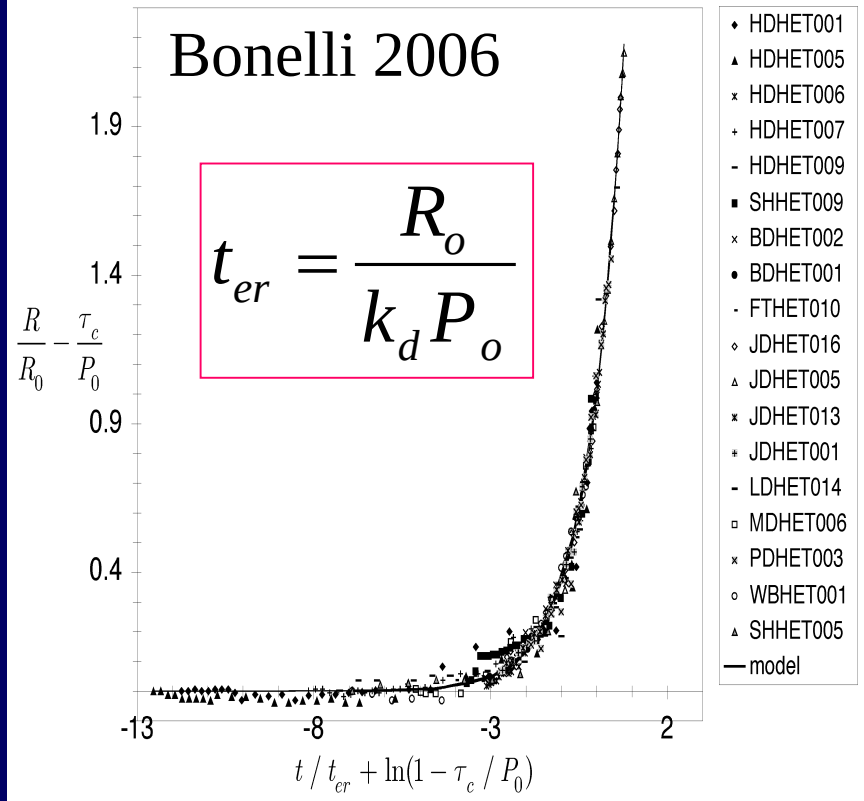


Test de HET (CEMAGREF LCPC)

etines téchnicos J-J Fry

1 – crack or hole erosion





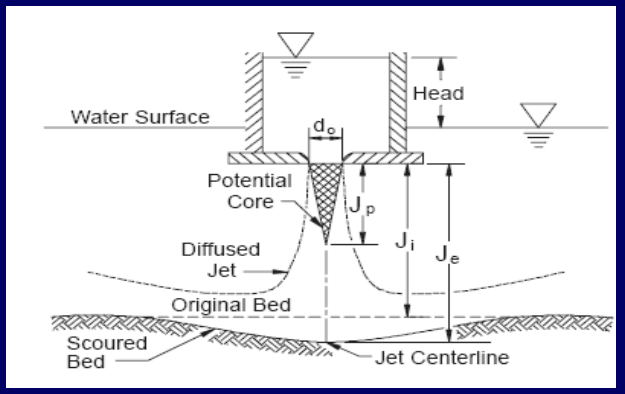
Only one relationship, but different time scales!

1 – crack or hole erosion

sandy clay or silt material

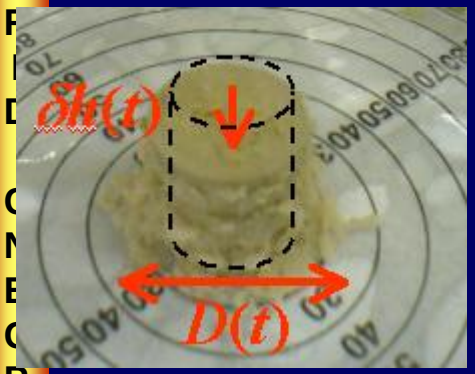
whether HET impossible

=> JET test



=> kd, τ_c

Dispersion (castle test)



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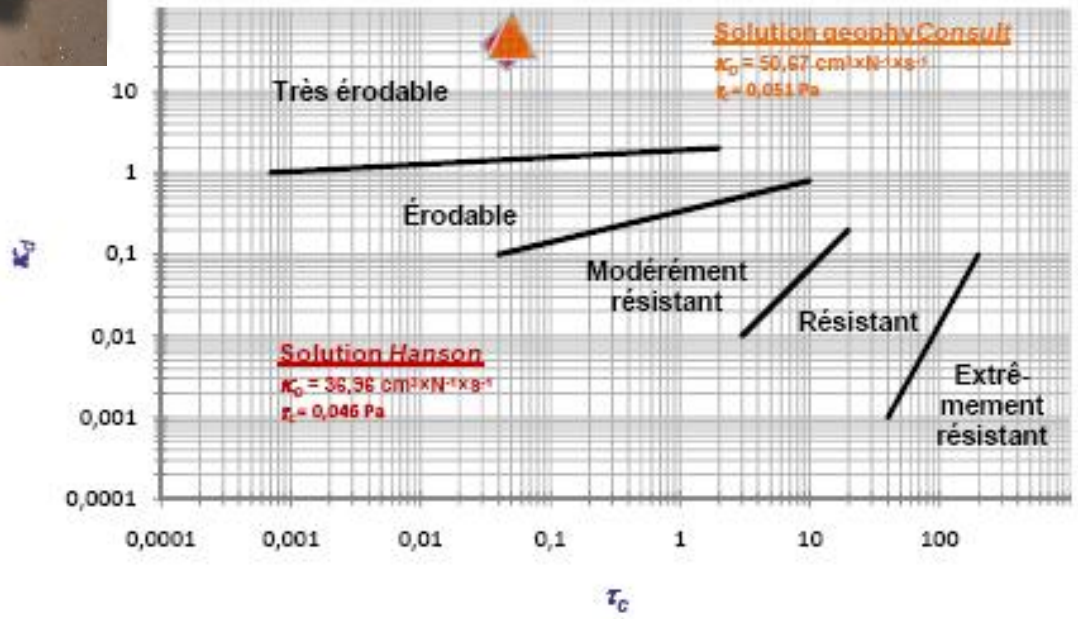
Erosion test used as an Index test

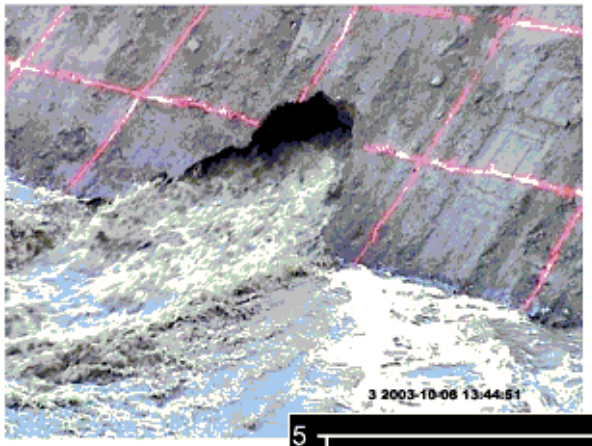
JET test result on residual soil :

= Very large erodibility

=> very urgent repair

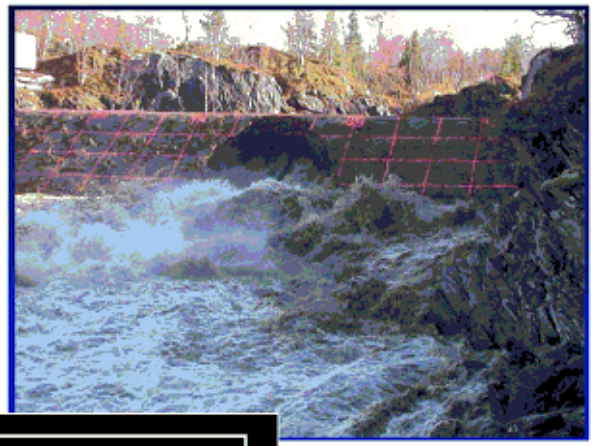


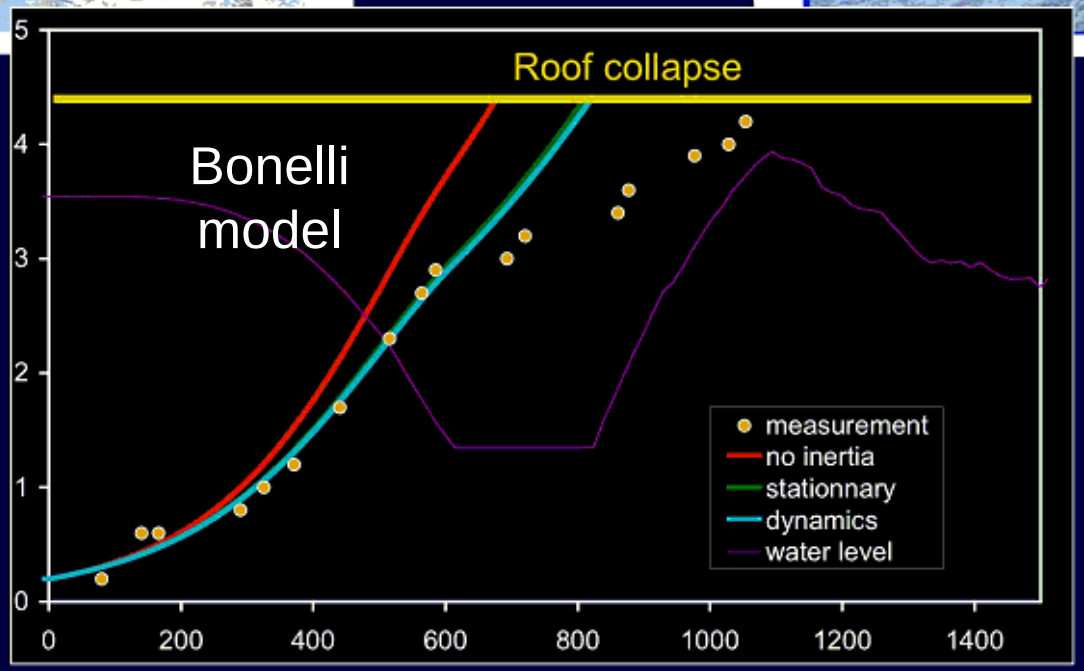
1 – crack or hole erosion : application of tests to piping



Norway
IMPACT
FP5 Project

Rossvatn
field tests





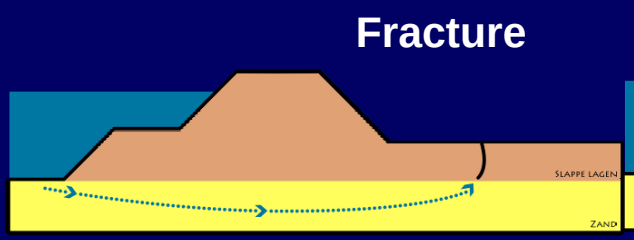
$\tau_c \approx 5$ Pa

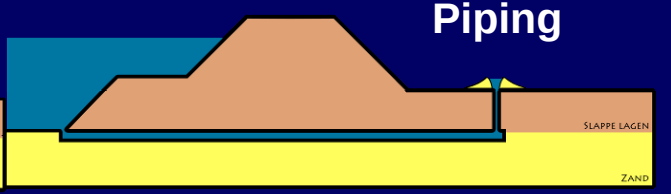
$k_{er} \approx 10^{-2}$ s/m

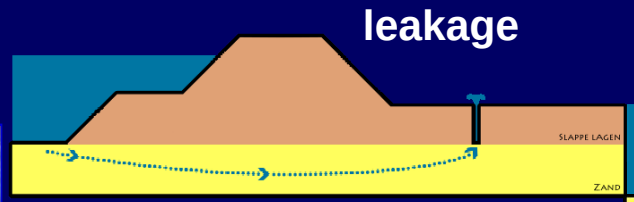
2 - Backward erosion

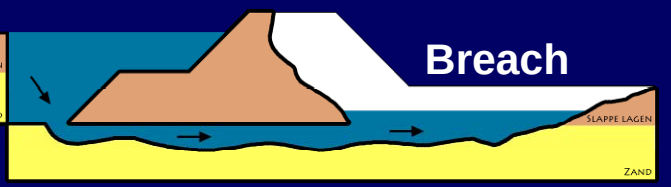
1

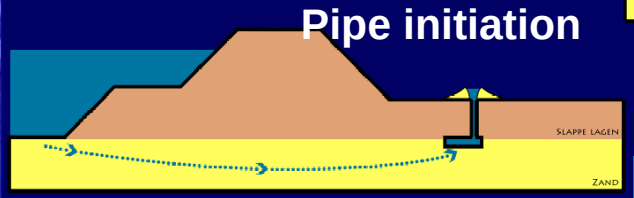
Clayey embankment on sandy foundation

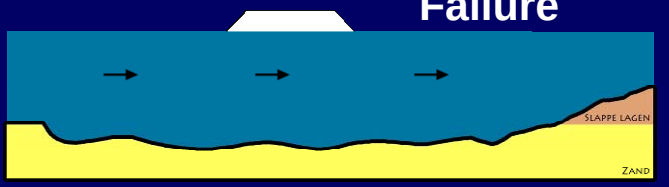


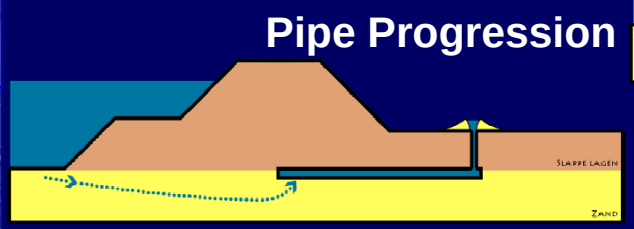












during floods the pipe increases up to failure

.D boletines téchnicos J-J Fry

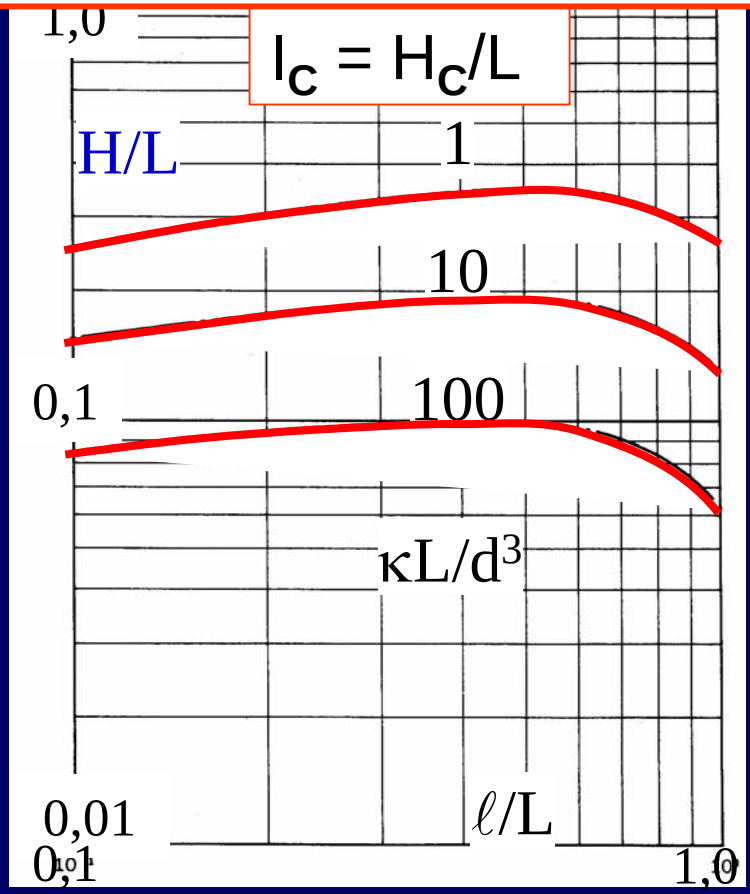
2 - Backward erosion

Clayey embankment on sandy foundation

$$\Delta H_c = \alpha \cdot c \cdot \frac{\gamma_p}{\gamma_w} \tan(\theta)(0.68 - 0.10\ln(c)) \cdot L$$

$$\alpha = \left(\frac{D}{L}\right)^{\left(\frac{0.28}{\left(\frac{D}{L}\right)^{2.8}-1}\right)}$$

$$c = \eta d_{70}\left(\frac{1}{\kappa L}\right)^{\frac{1}{3}}$$



Sellmeijer (1988)

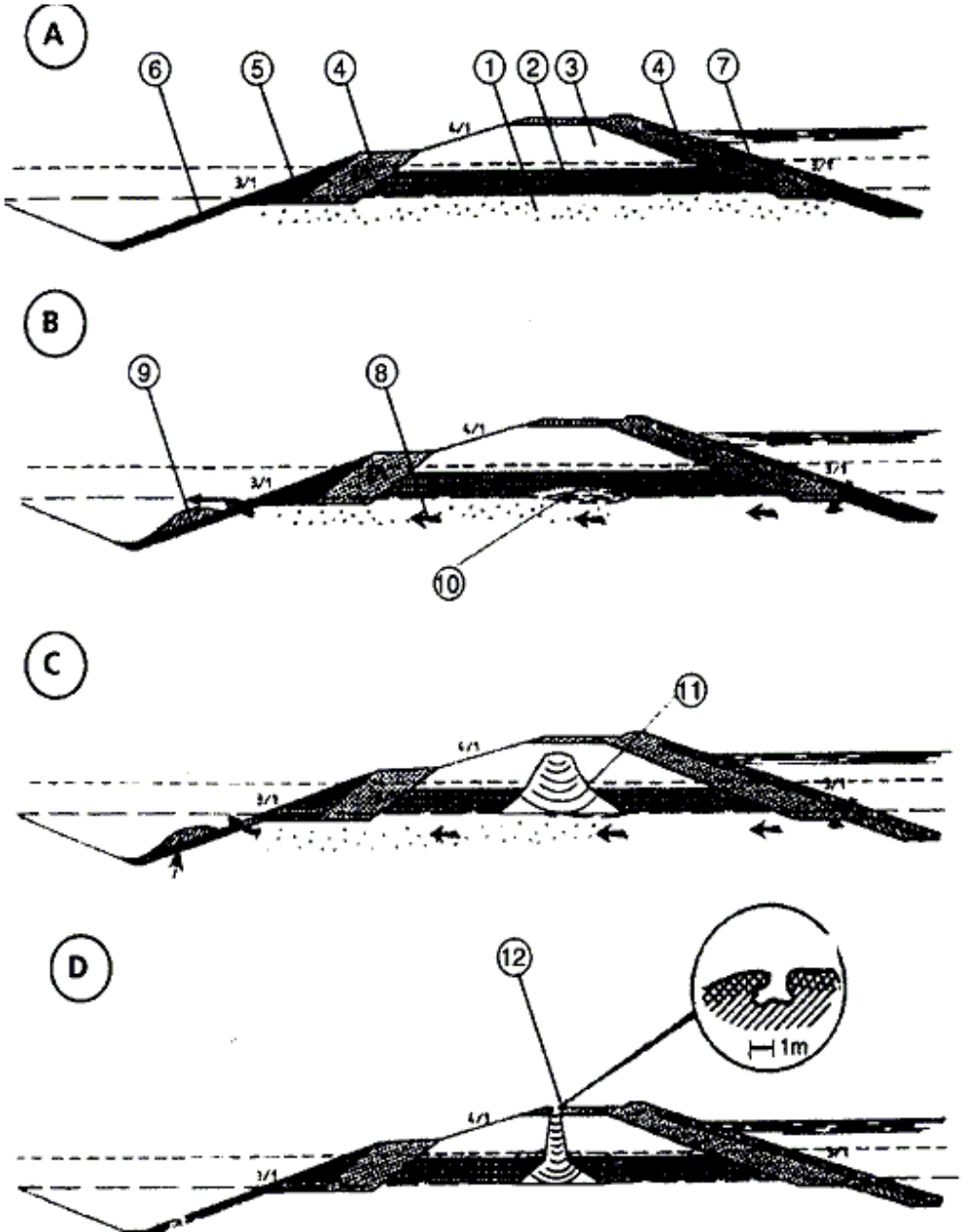
2 - Backward erosion in karstic foundation

1m water load caused the collapse of 3 sinkholes (15-25 m diameter) along a fault in the reservoir

El Gassanieh reservoir (2003) during an extreme flood

Embankment on gravely alluvium

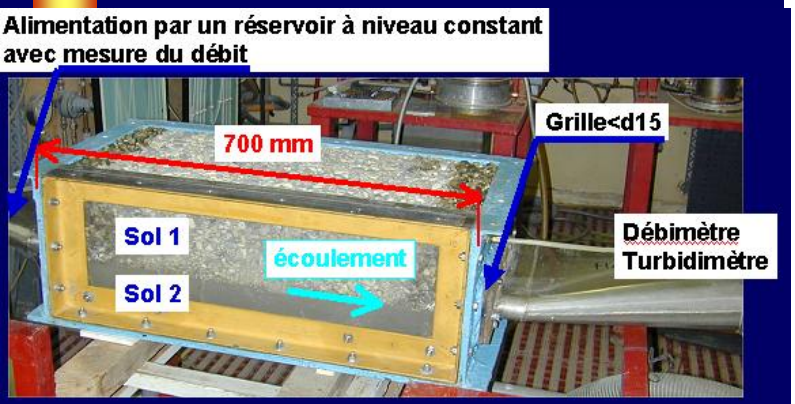
3 Contact erosion



Embankment on gravely alluvium

1 6 0 4

3 – Contact erosion

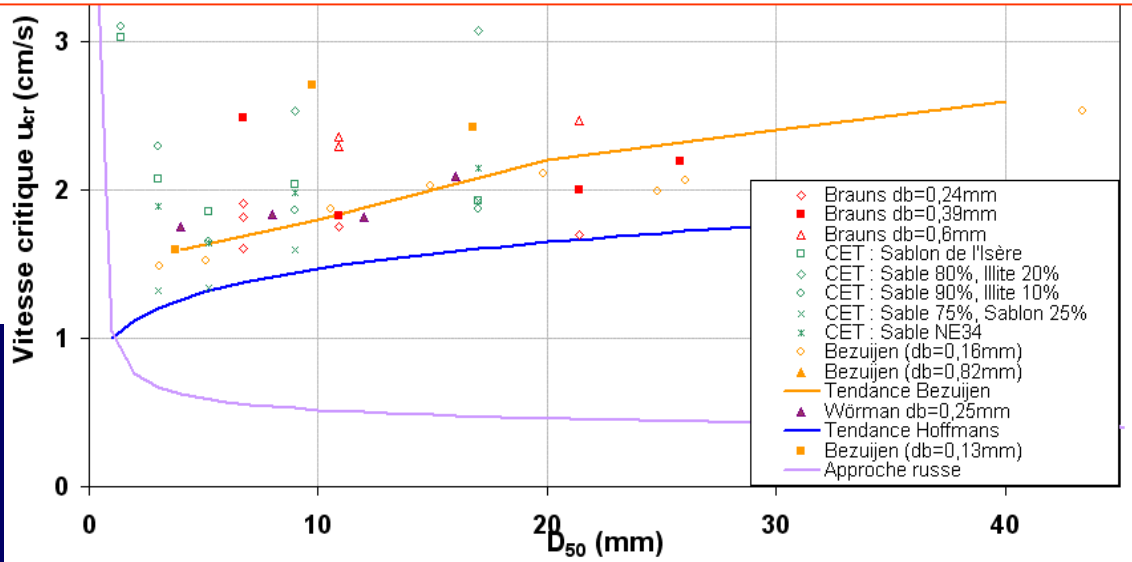


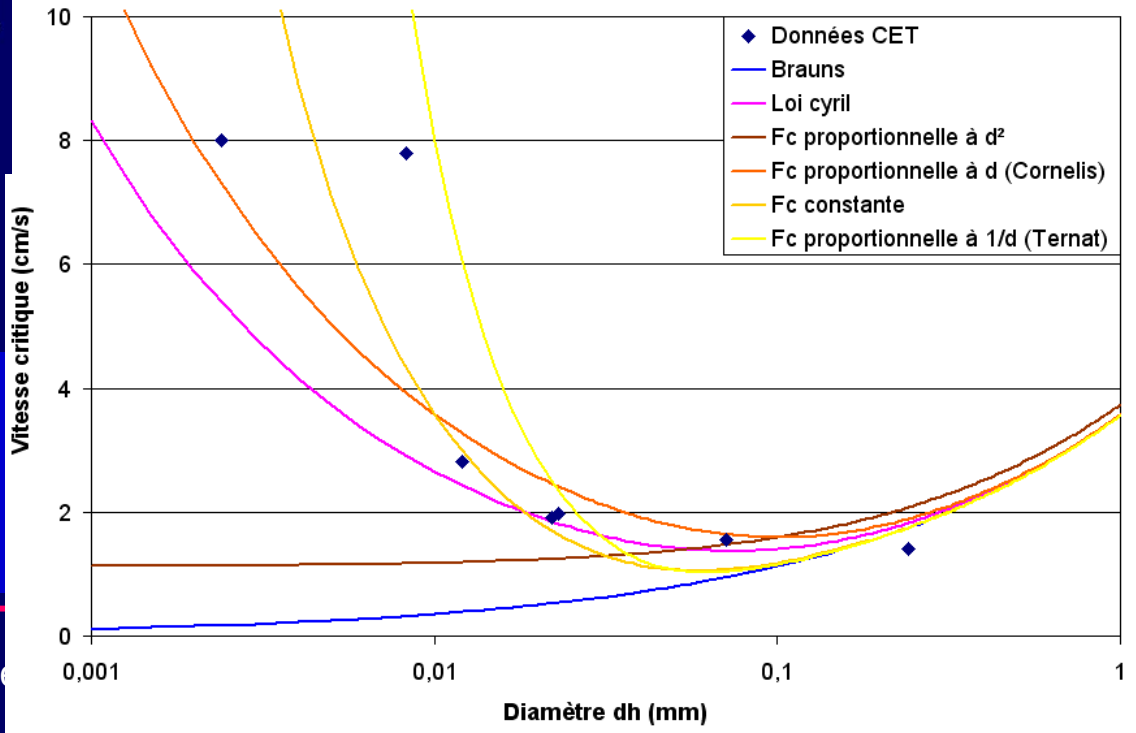
I D C N E G P

LTHE Y-H Faure, C. Guidoux, R. Beguin

No erosion with

v < #1cm/s





Embankment or foundation with unstable soil

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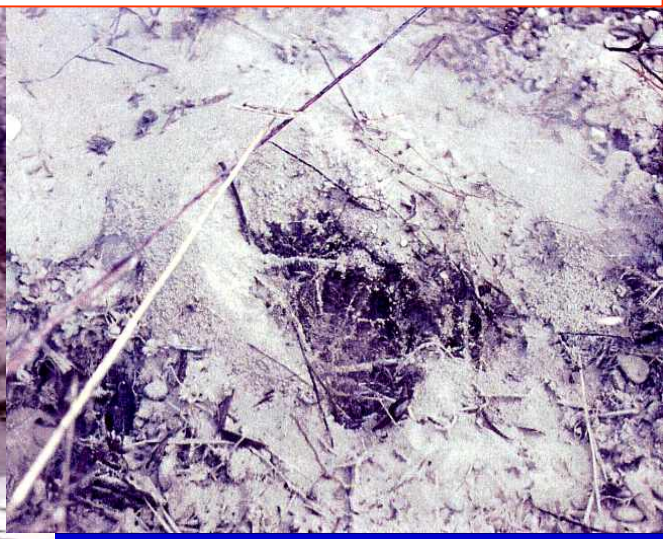


4 - Suffusion

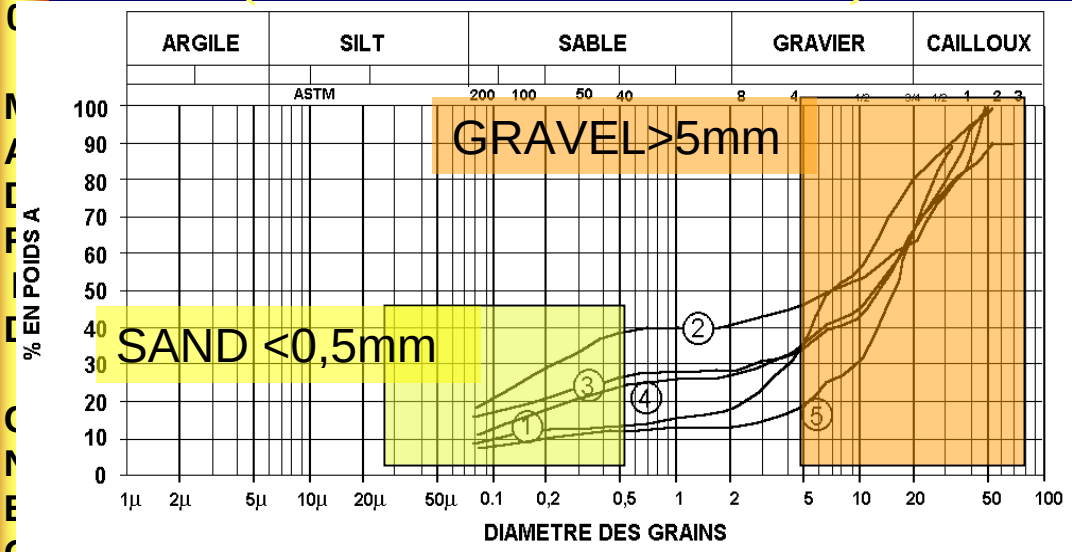
Embankment or foundation with unstable soil

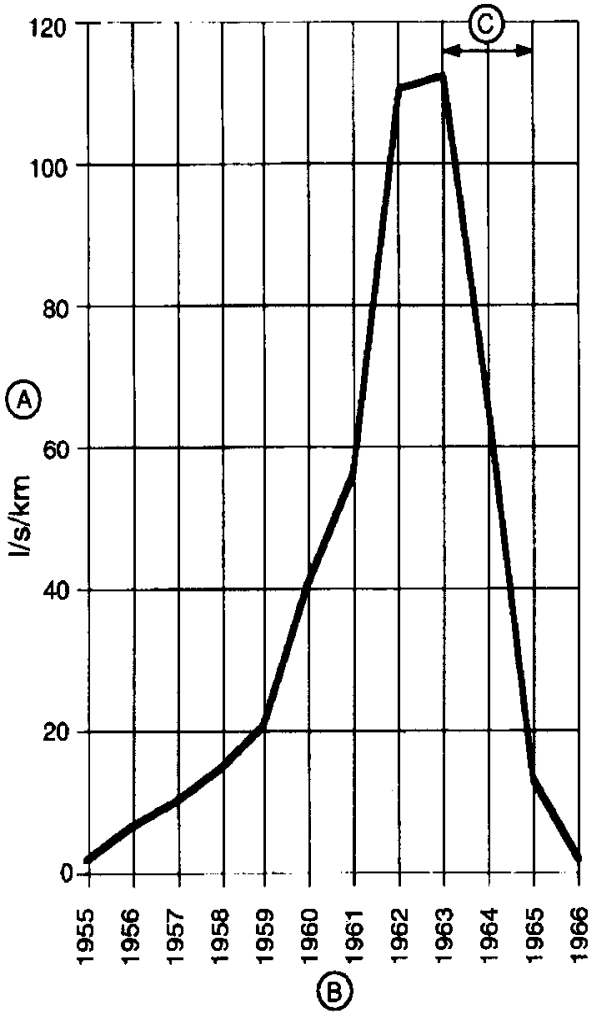
4 - Suffusion

No erosion with

V < # 0,5 cm/s ?

(M. GOLTZ 2009)





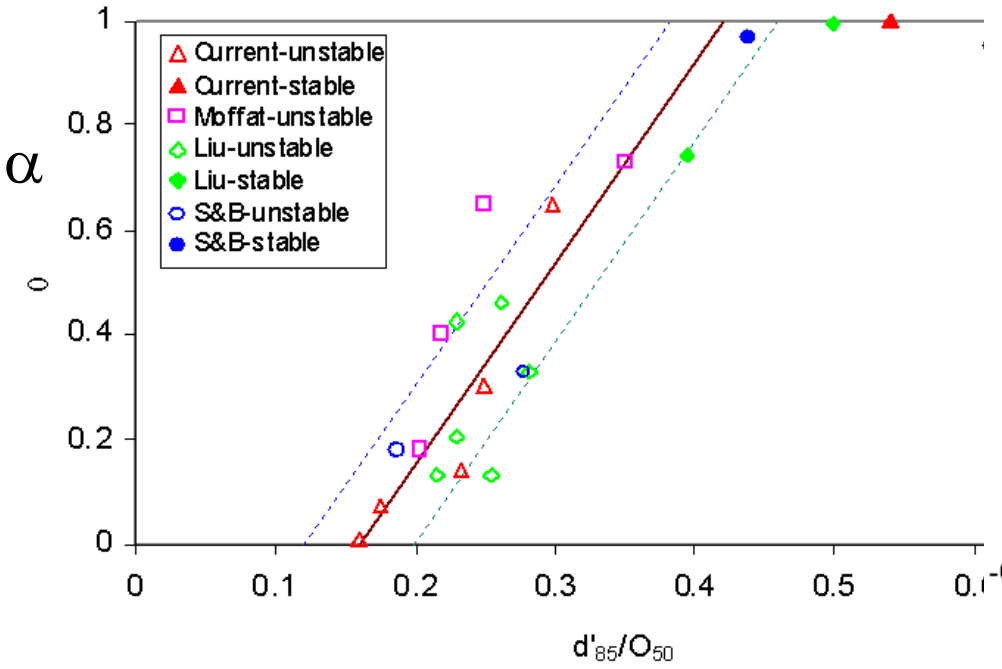
Digue de Cusset - Évolution des fuites au Pk 14.6

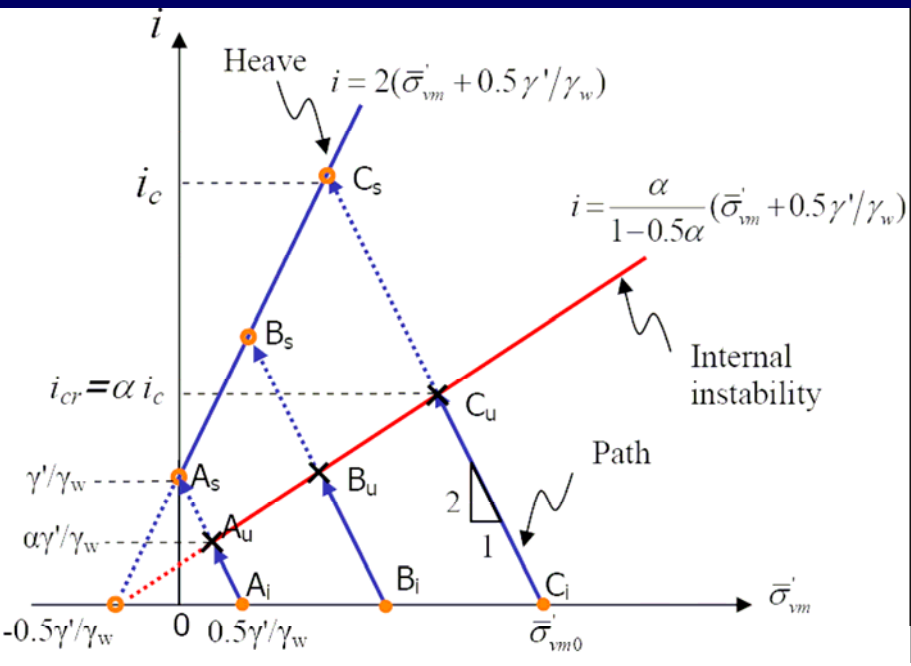
Cusset bank - Point 14.6 leakage variation

m Ⓐ *Specific leakage (l/s/km*
Ⓑ *Date*
Ⓒ *Grouting*

16

Initiation de la suffusion





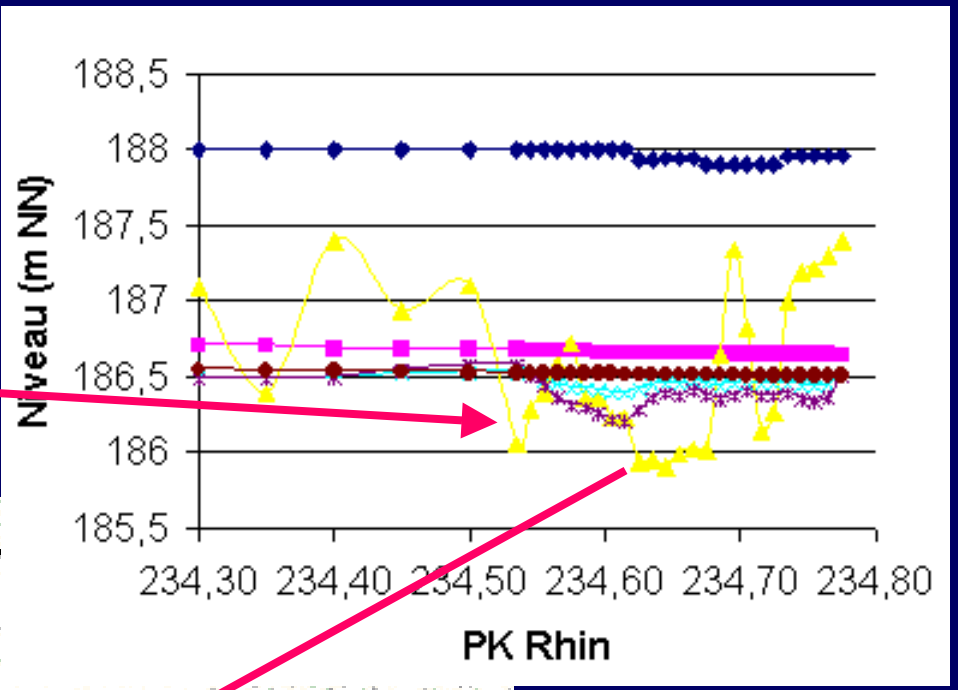
EGP

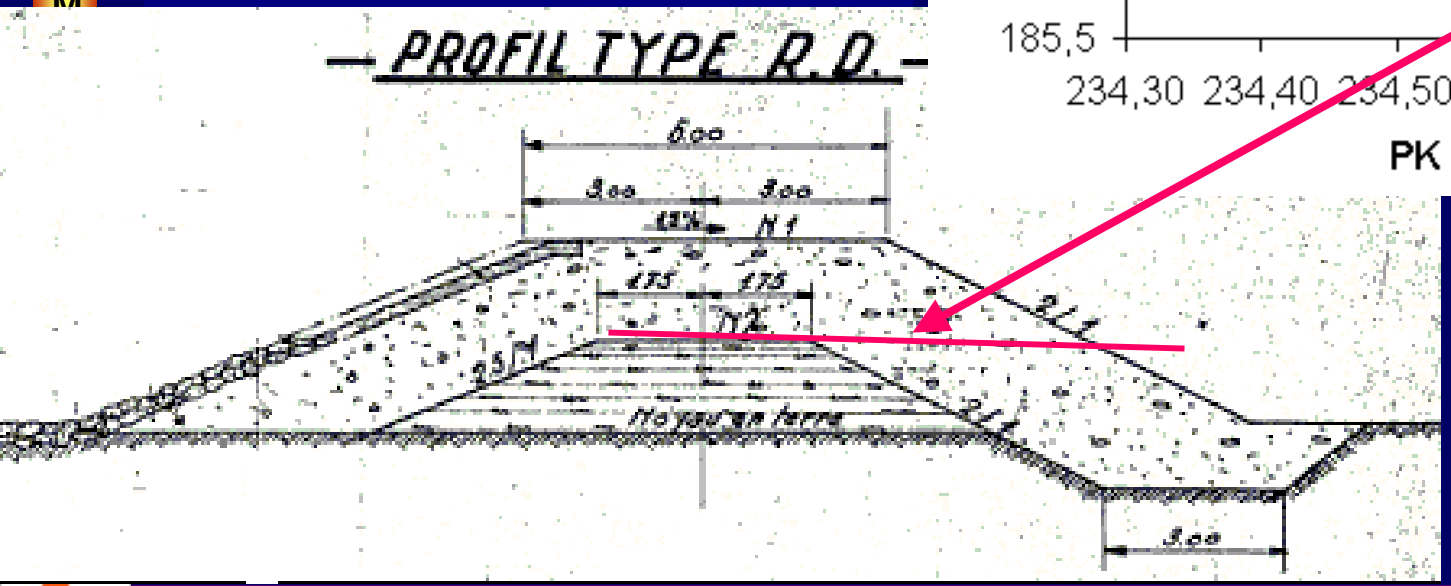
Geometric et hydromecanic criteria from Fannin (2008)

Contact erosion on Rhine river dike

Crest elevation after maintenance

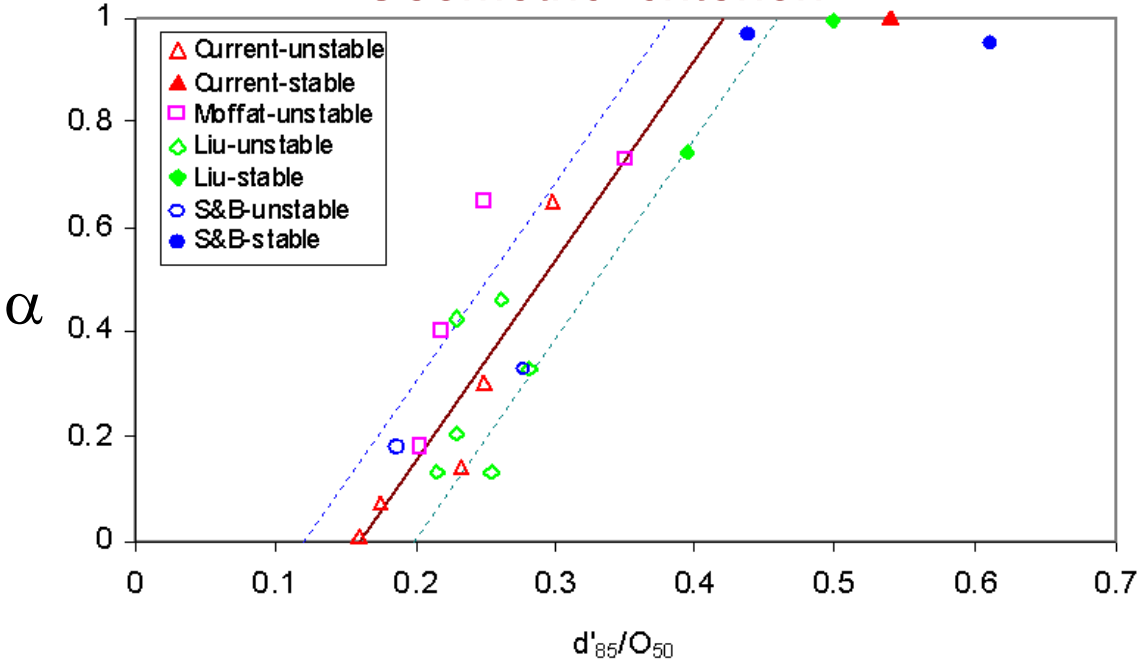
Core elevation



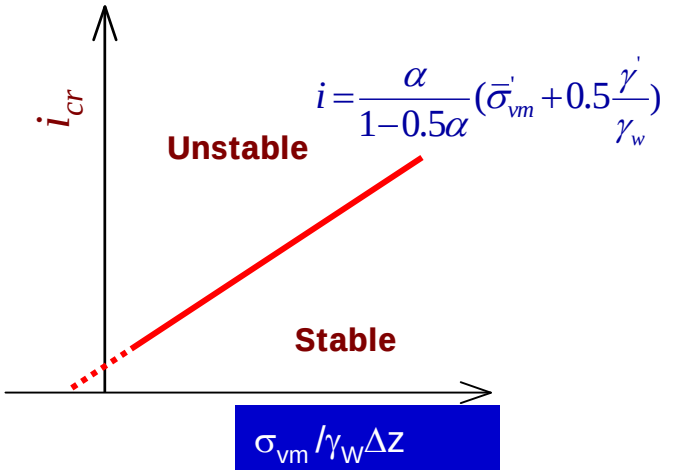


Initiation of suffusion

Geometric criterion



Hydromechanical criterion



Double criteria proposed by Fannin (2008)

CNEGP

Why a bulletin on detection methods?

- Too much on internal erosion in one bulletin only
- A lot of possible methods
- New effective methods

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Detection : the most effective methods

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The 3 Safety assessment conclusions :

1 Repair 2 No problem 3 Some Doubts

Remedial maintenance :

- SP
- Temperature
- Drill hole recording

Preventive maintenance :

- Fiber optic

Detection by SP in soft foundation

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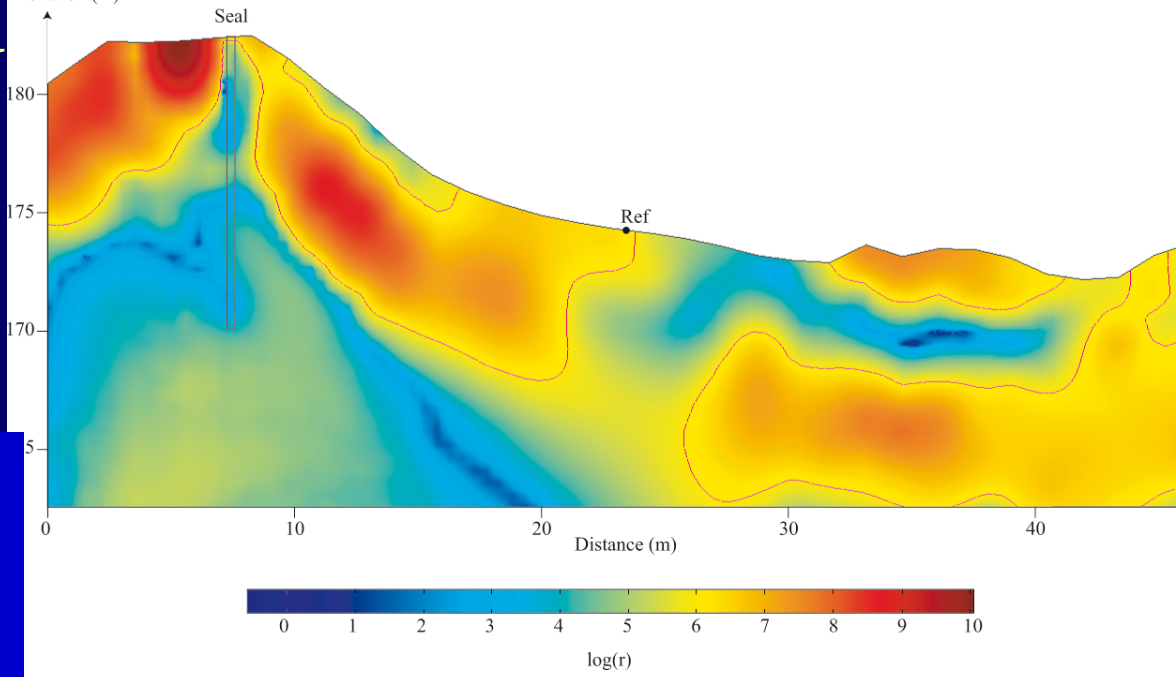
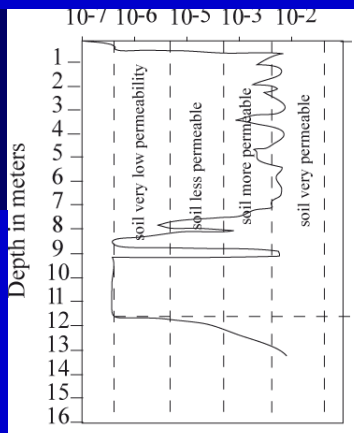
Resistivity Tomography (Revil & Bolève 2008)

Water leaks from External current density

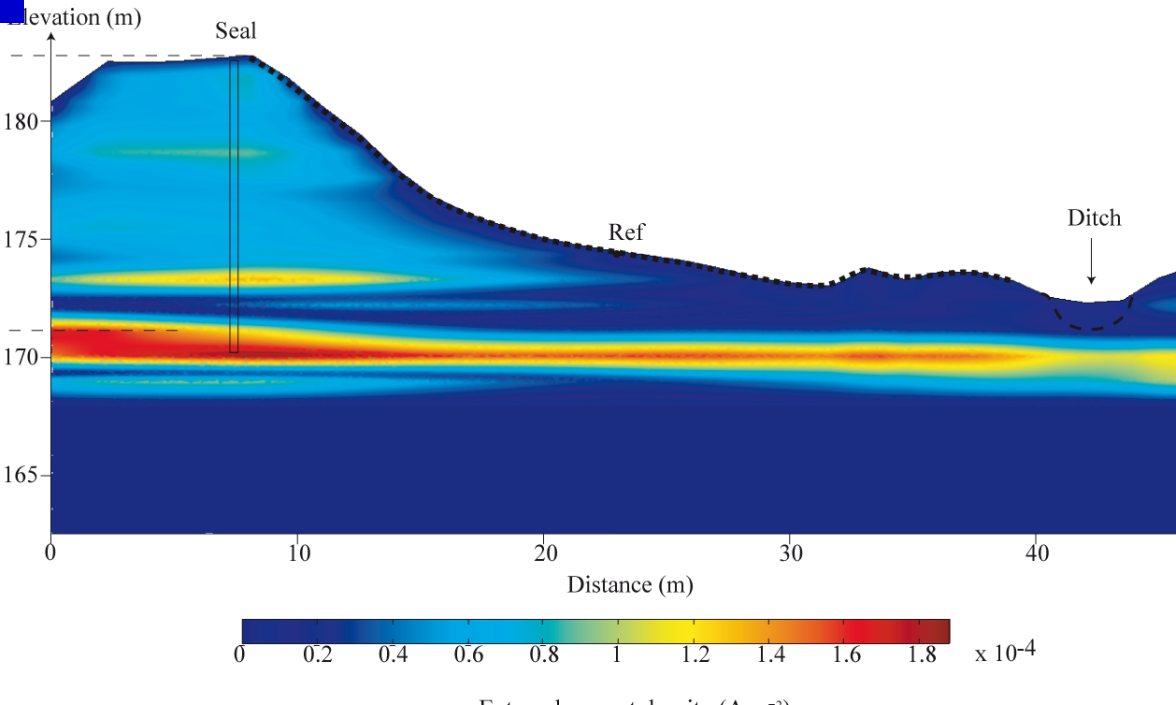


A

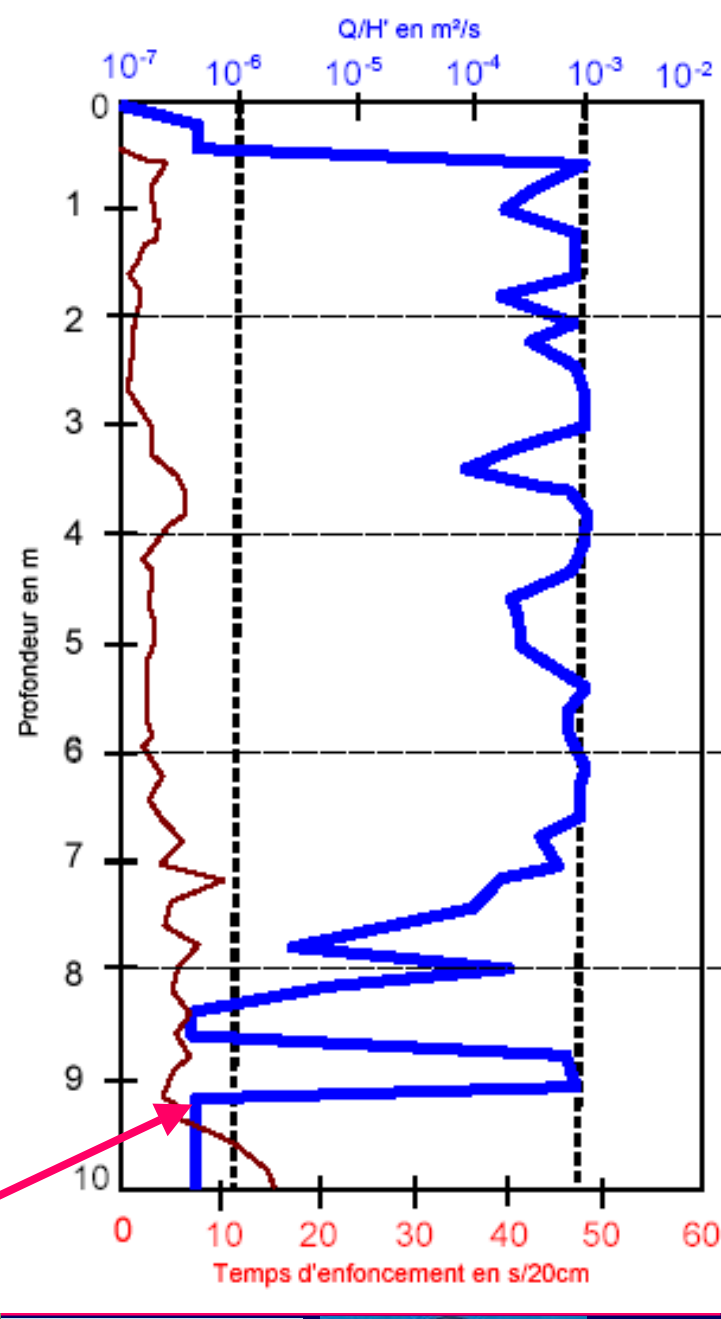
B



Permeafor

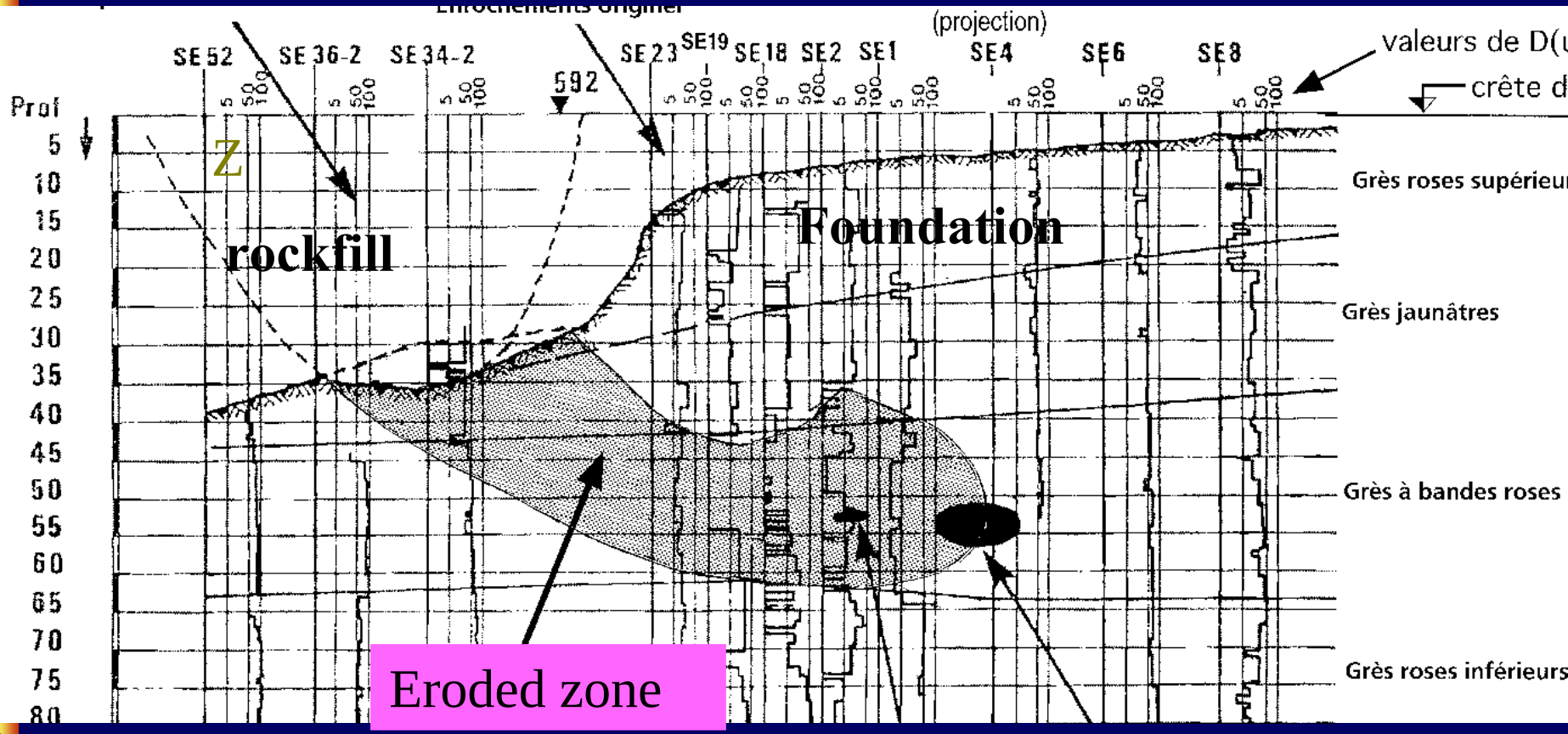


Detection of contact erosion with Permeafor



Contact erosion

Detection at ITIYURO dam



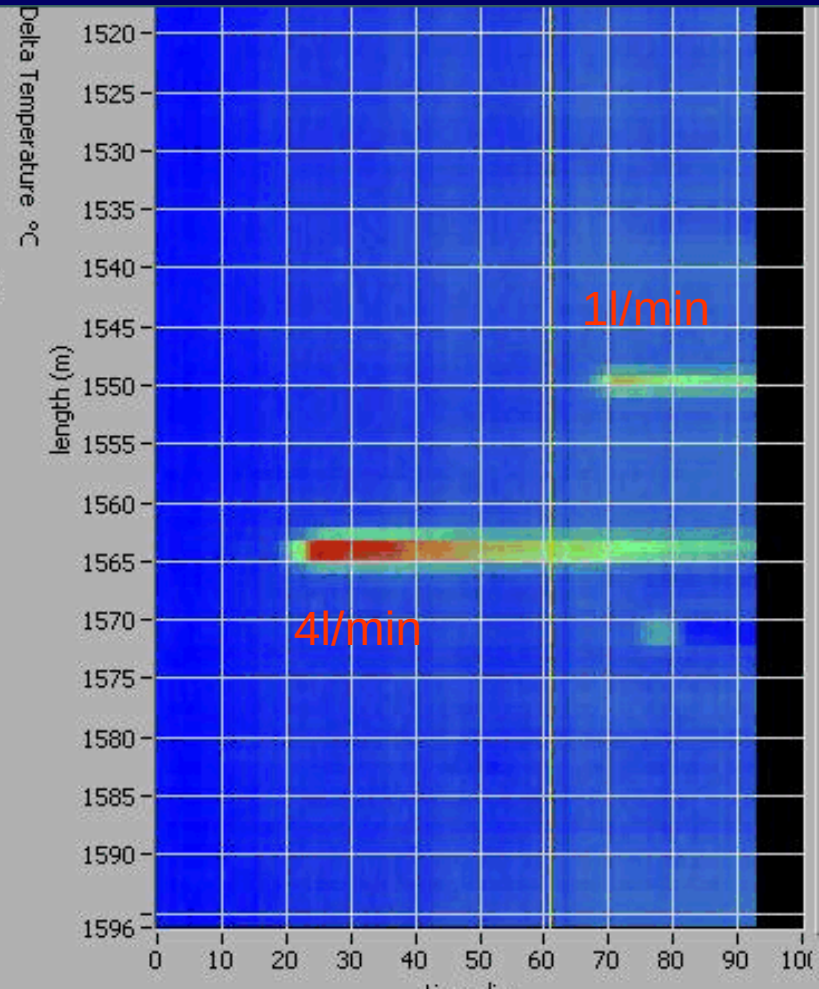
Drilling parameter recording on weak sandstones which suffered internal erosion show very low hardness values : DUR < 20.

Preventive maintenance

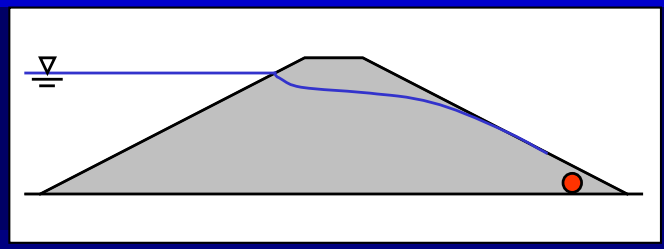
Optic Fiber : passive method

Oraison canal 2005

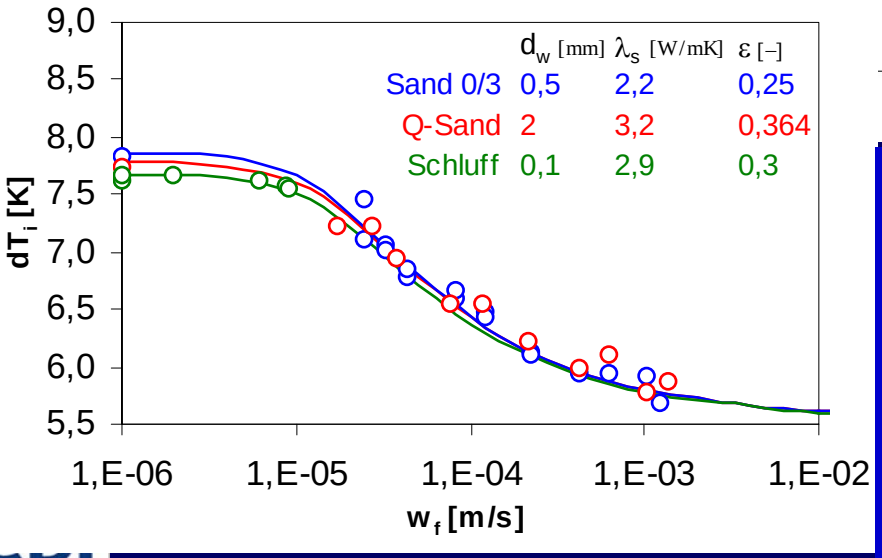
Leakage detection : 4 & 1 l/min?

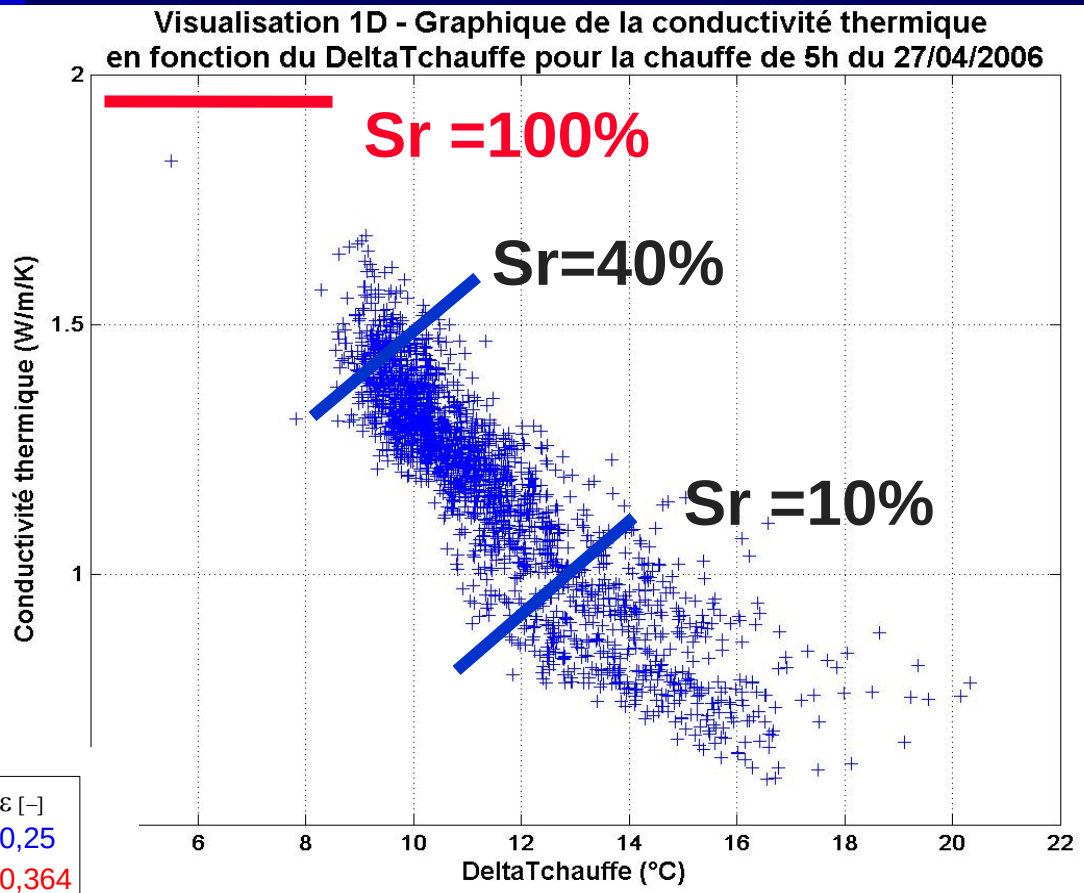


Preventive maintenance



Flow velocity (TUM 2006)





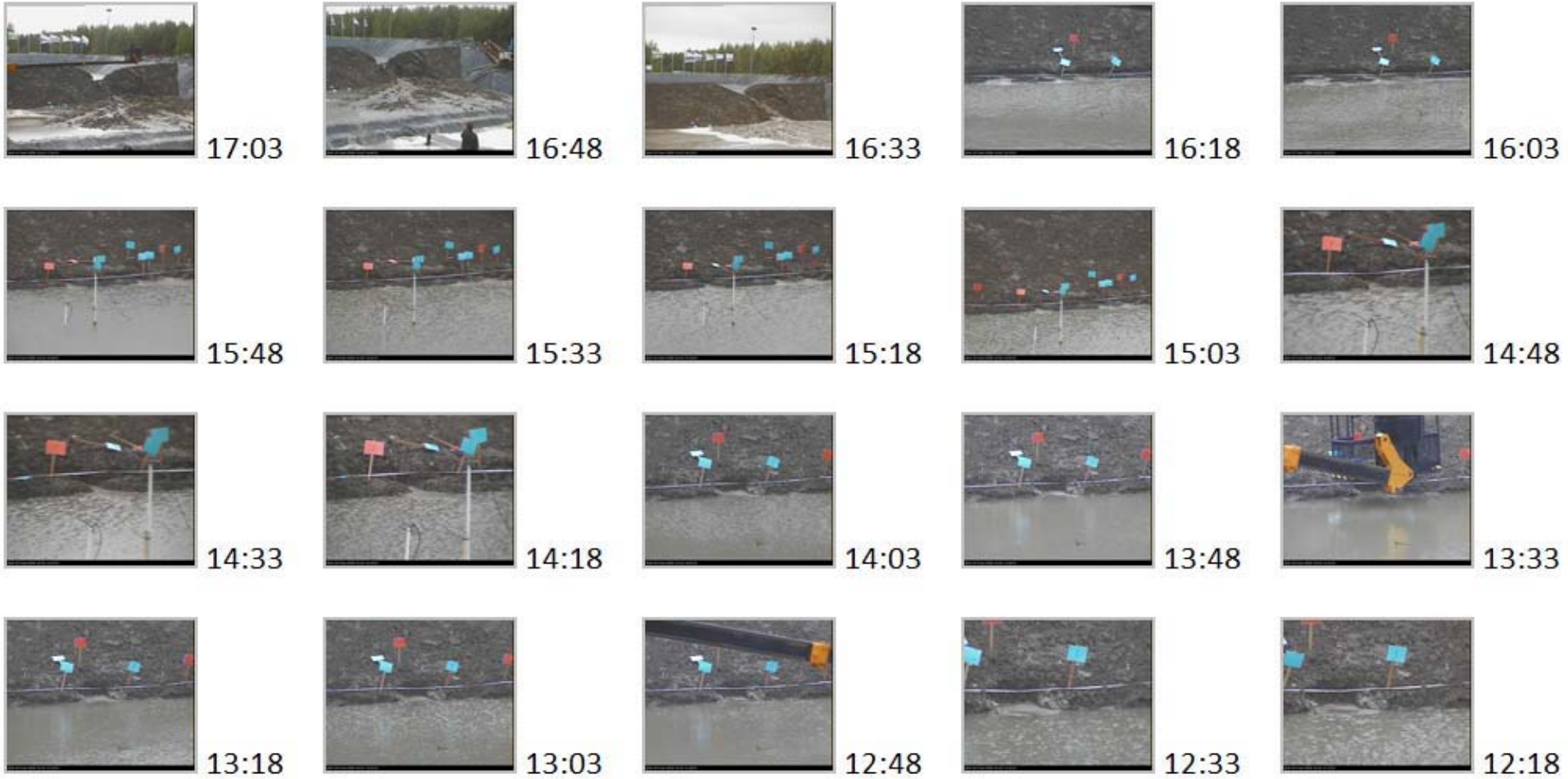
active method:

No leak at Oraison : (EDF 2006)

Preventive maintenance IJKDIJK Project (NL)

16 04

Piping detected by fiber optic in the 4 tests



IJKDIJK Test 2

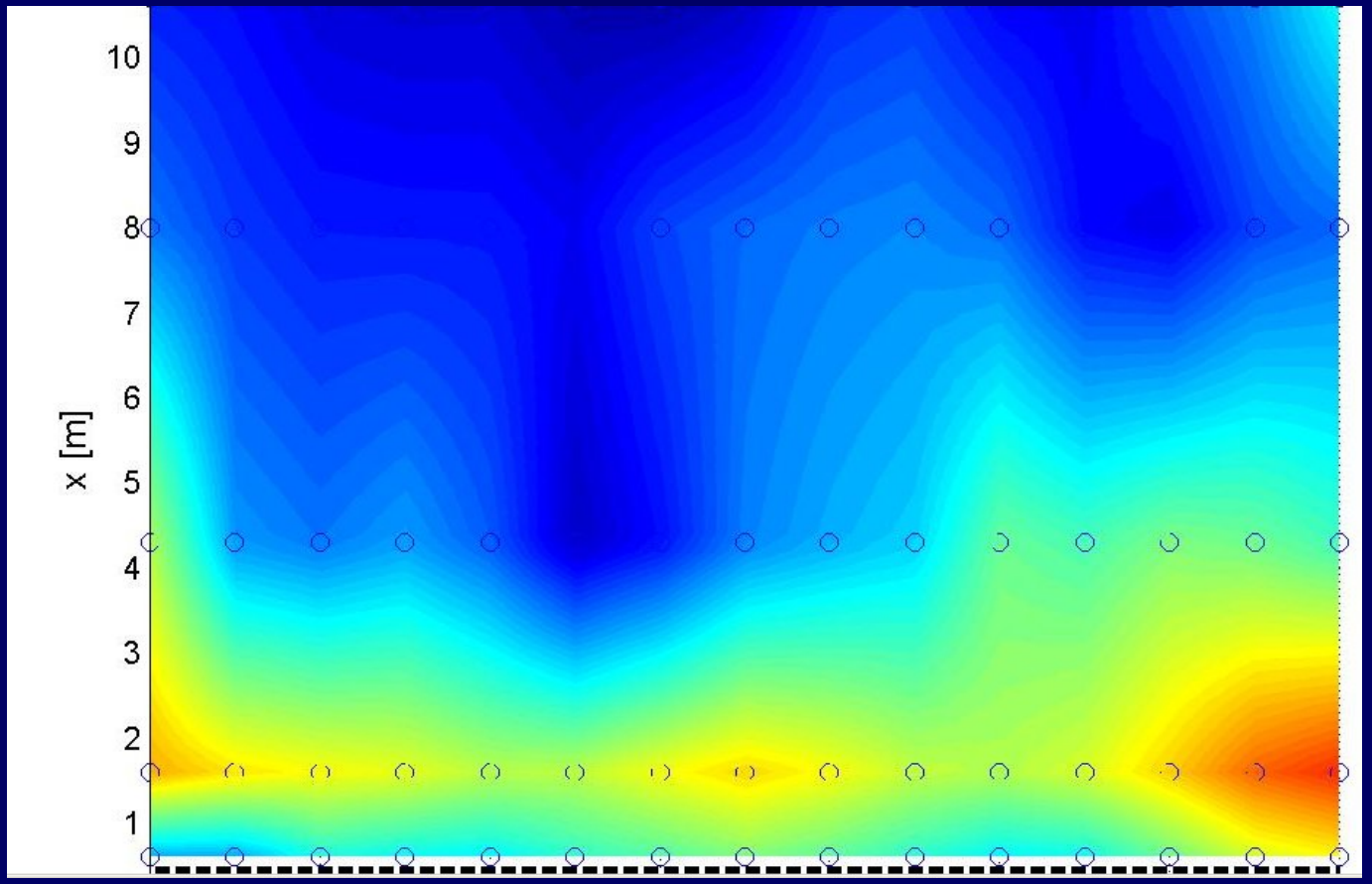
16 04 2010 MADRID CNEGP

Detection by température

19 october 2009

14h58

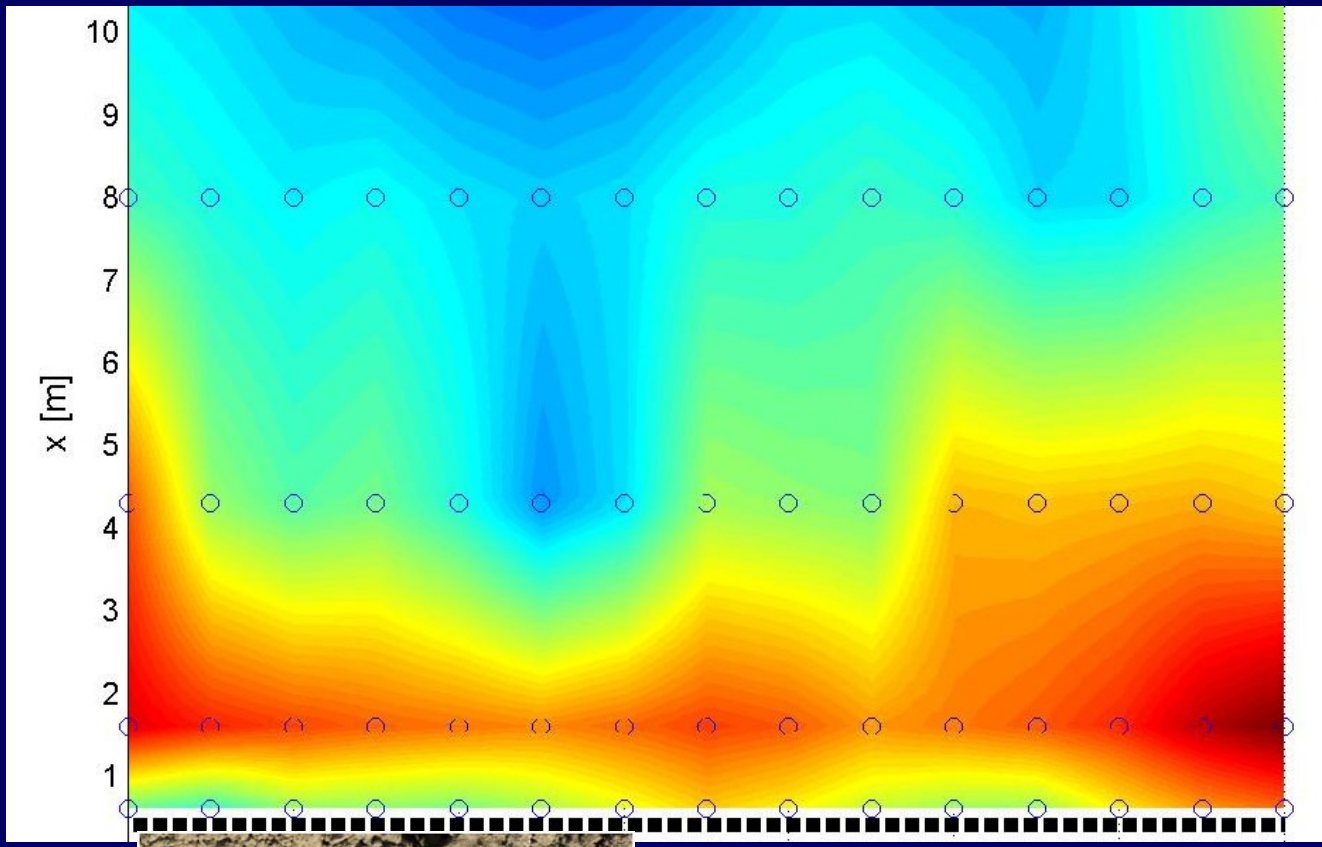
24H after the start



IJKDIJK Test 2

16 04 2010 MADRID CNEGP

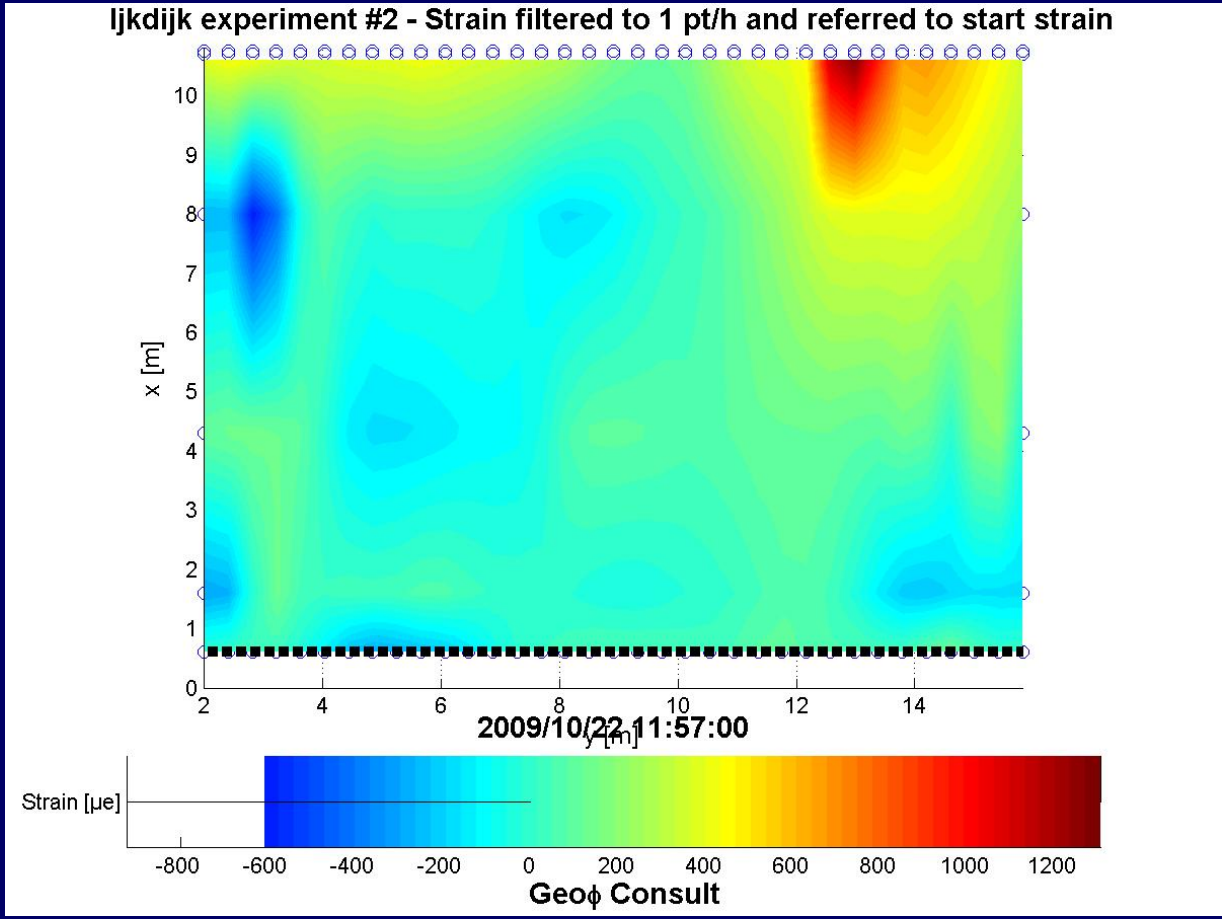
Detection by température 20 october 2009 11h58



IJKDIJK Test 2

16 04 2010 MADRID CNEGP

Erosion Détection with strain measurements 22 October 2009 11h57



References and acknowledgments

16 04 2010 MADRID CNEGP

Assessment of the Risk of Internal Erosion of
Water Retaining Structures: Dams, Dykes and Levees

Intermediate Report of the European Working Group of ICOLD

Contributions to the Symposium on 17–19 September 2007 in Freising, Germany

DTK

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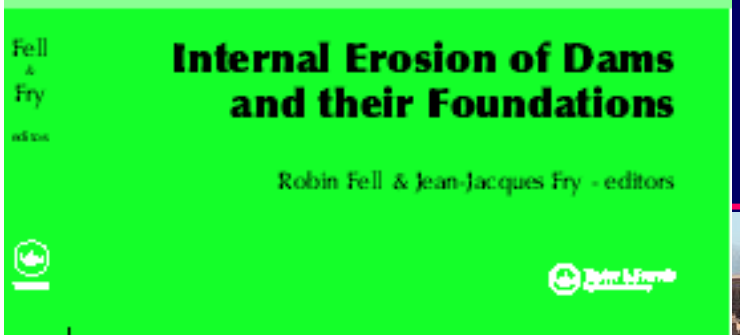

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