Groundwater flow in rock and research activities at NTNU relevant for drainage of Åknes

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NVE workshop 30.-31.1.2017 - Drainage of large rockslides

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Agenda

- Groundwater flow in rock
  - Fractures in crystalline bedrock – location and different actions depending on purpose
  - Fracture conductivity
  - Ice thickness, isostatic uplift and hydraulic conductivity
  - Example: Temperature logging and hydraulic fracturing

- Research at NTNU IGP particularly relevant for planning drainage at Åknes
  - PhD- and master projects on Åknes and other landslide areas
  - Numerical modelling – challenges and limitations
  - Open pit mining, road cuts etc.
  - Tunnel and underground excavations

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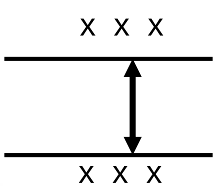
Groundwater flow in rock

Crystalline bedrock	Fractures
Sedimentary rocks	Pores
Limestone rocks	Cavities

Long fractures conducts more water than short fractures



b ~ fracture opening

Parallel plates theory

Water capactity, $Q \sim b^3$

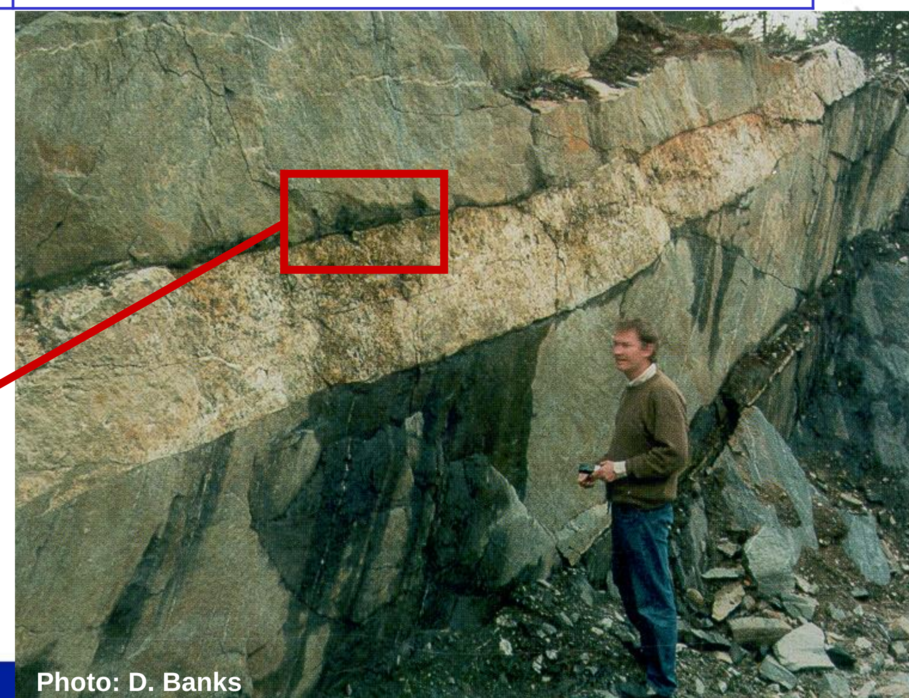
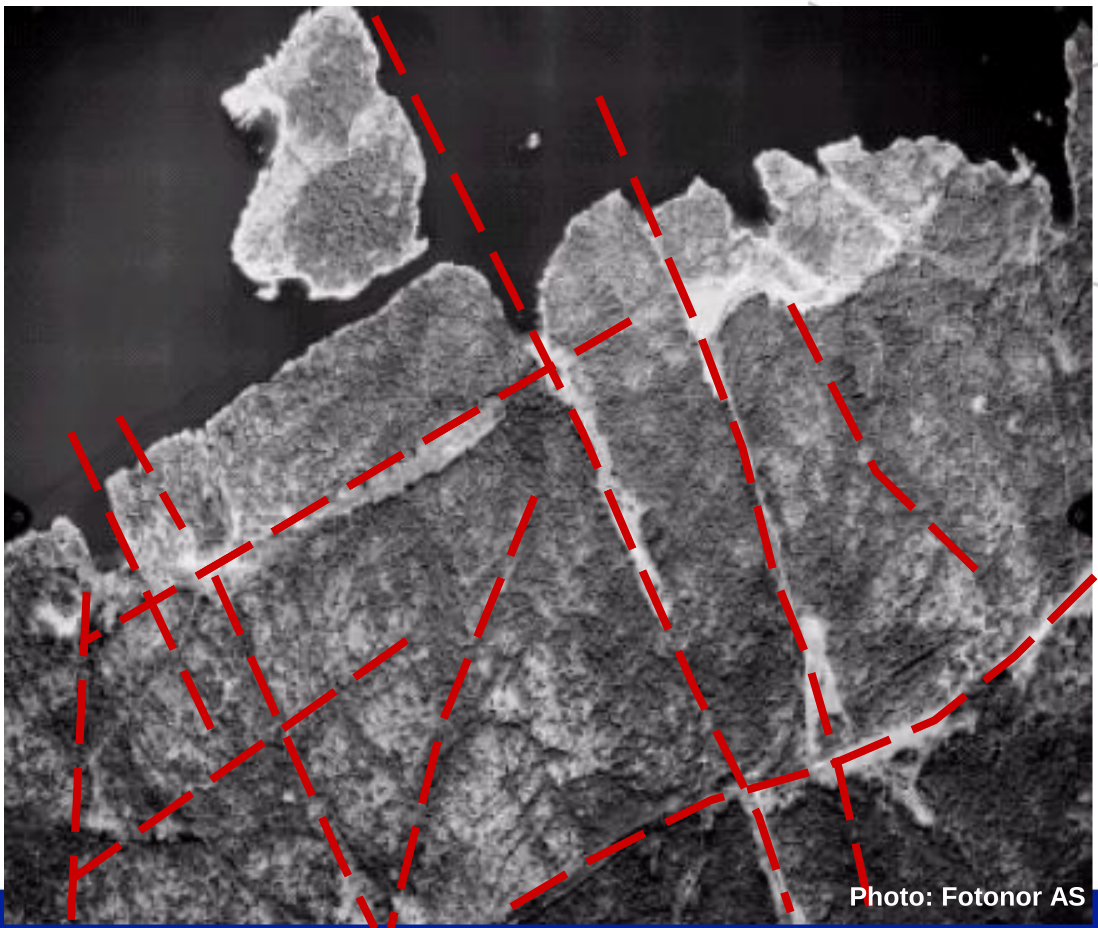


Photo: D. Banks

How to get / get rid of large amounts of water?

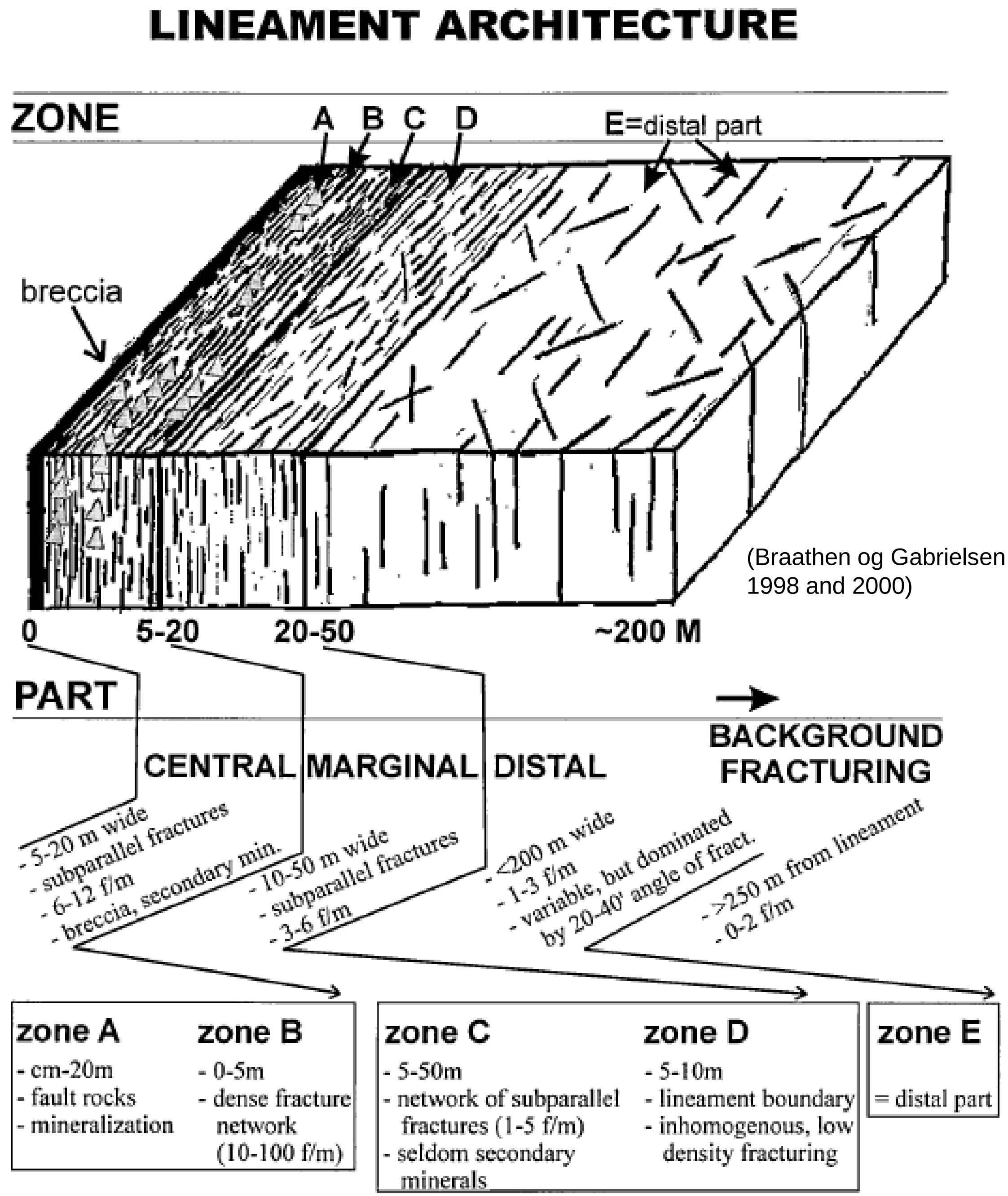
- Location of lineaments
  - Fracture zones
  - Faults

- Capacity increasing or –reducing actions
  - Hydraulic fracturing or blasting
  - Injection for sealing
  - Drainage



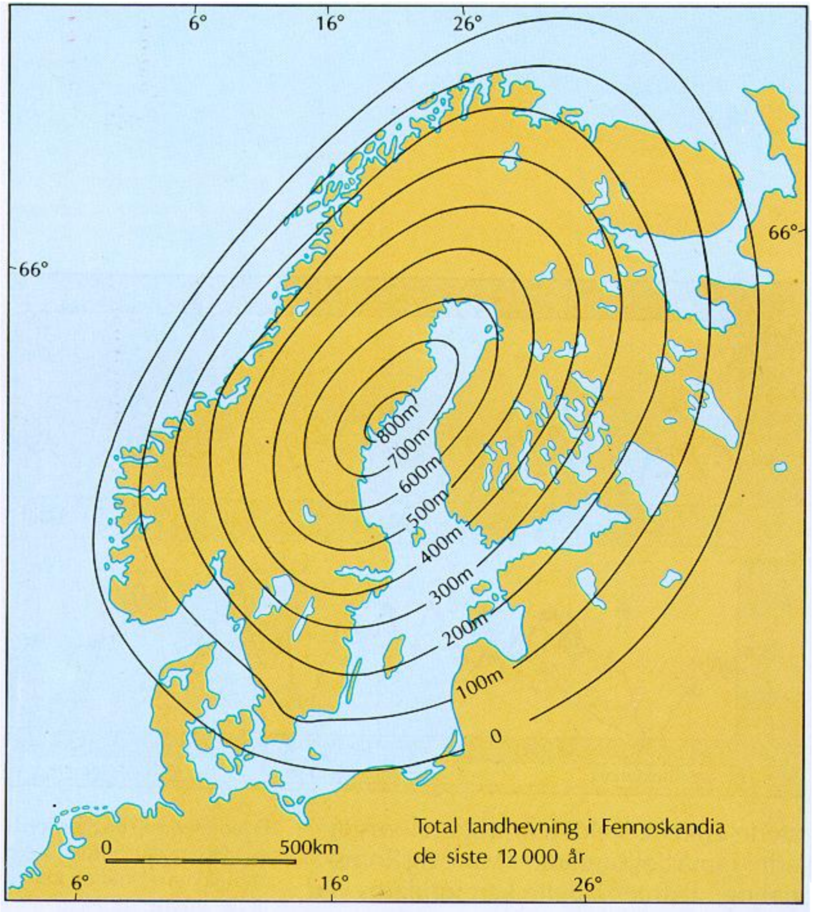
(Modified from Banks og Robbins, 2002)

Groundwater potential

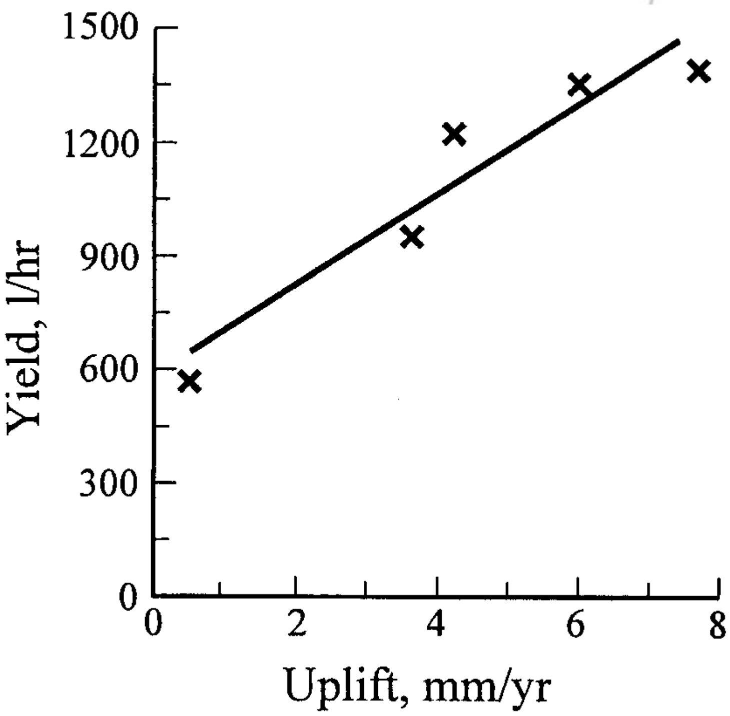


Groundwater potential: ***B: Medium*** ***C: Highest*** ***DE: Lower***

Ice thickness, isostatic uplift and hydraulic conductivity

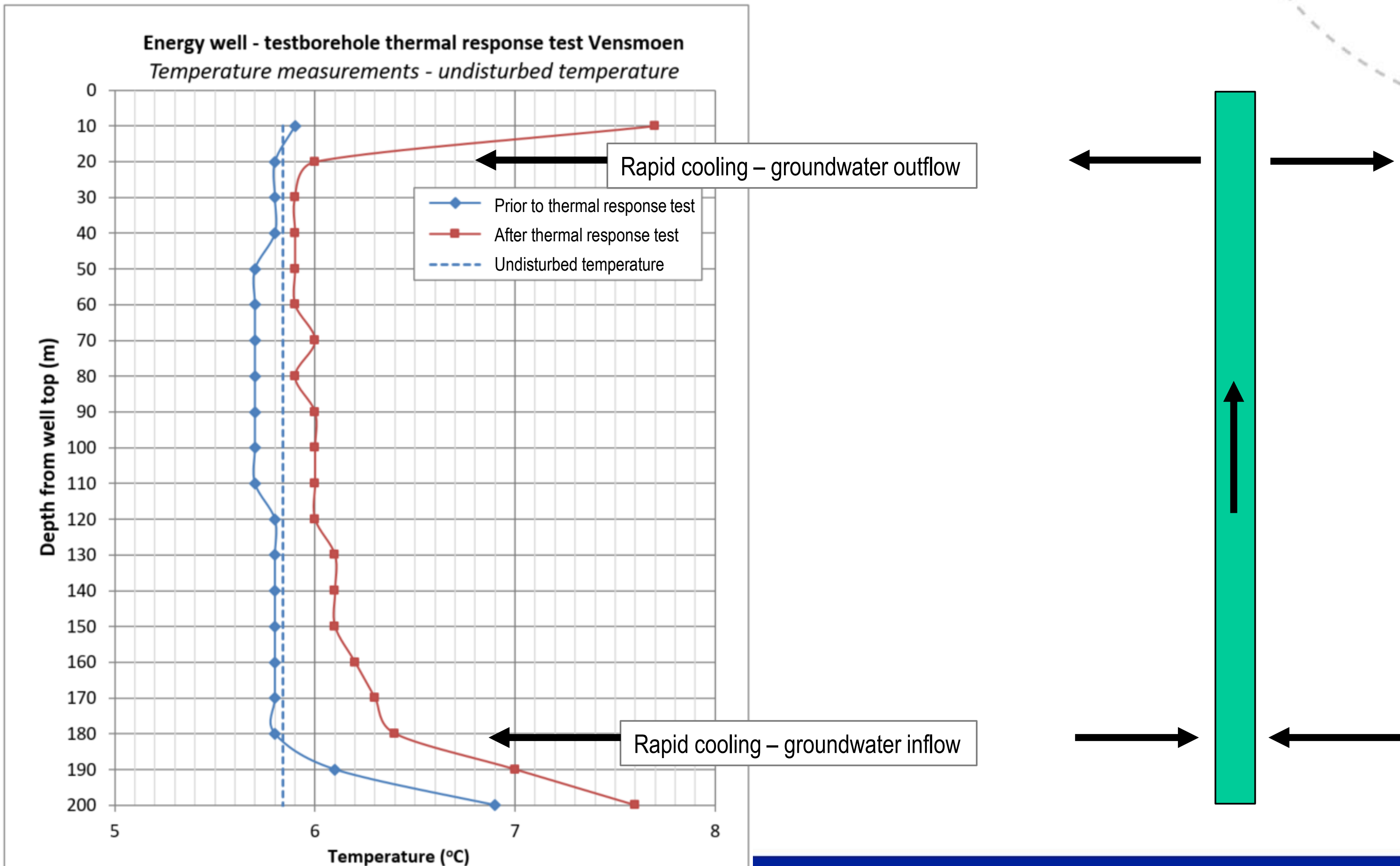


(From Mörner i Thoresen, 1991)



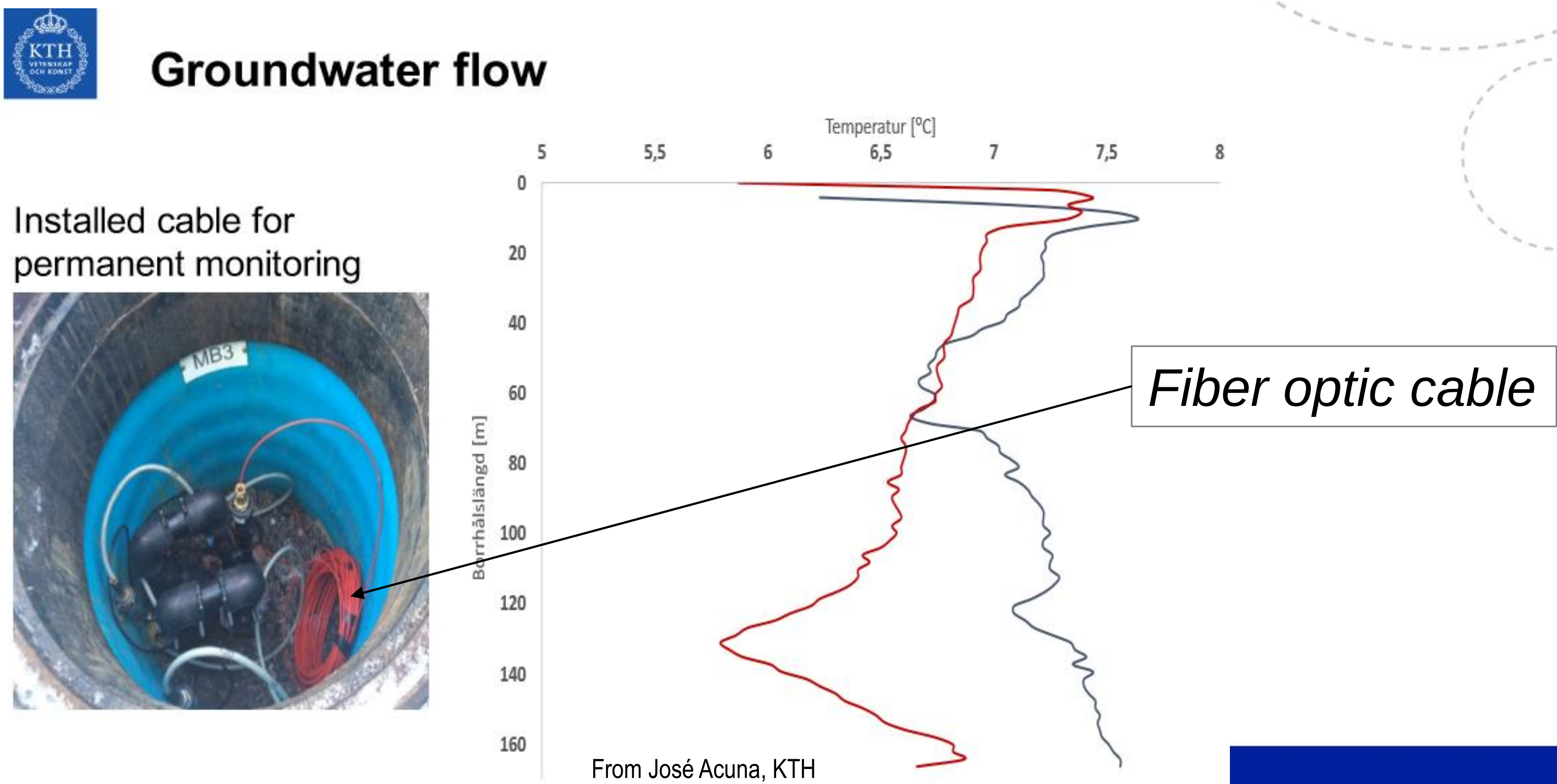
(Rohr-Torp, 1994)

Temperature logging for detection of fratures in boreholes



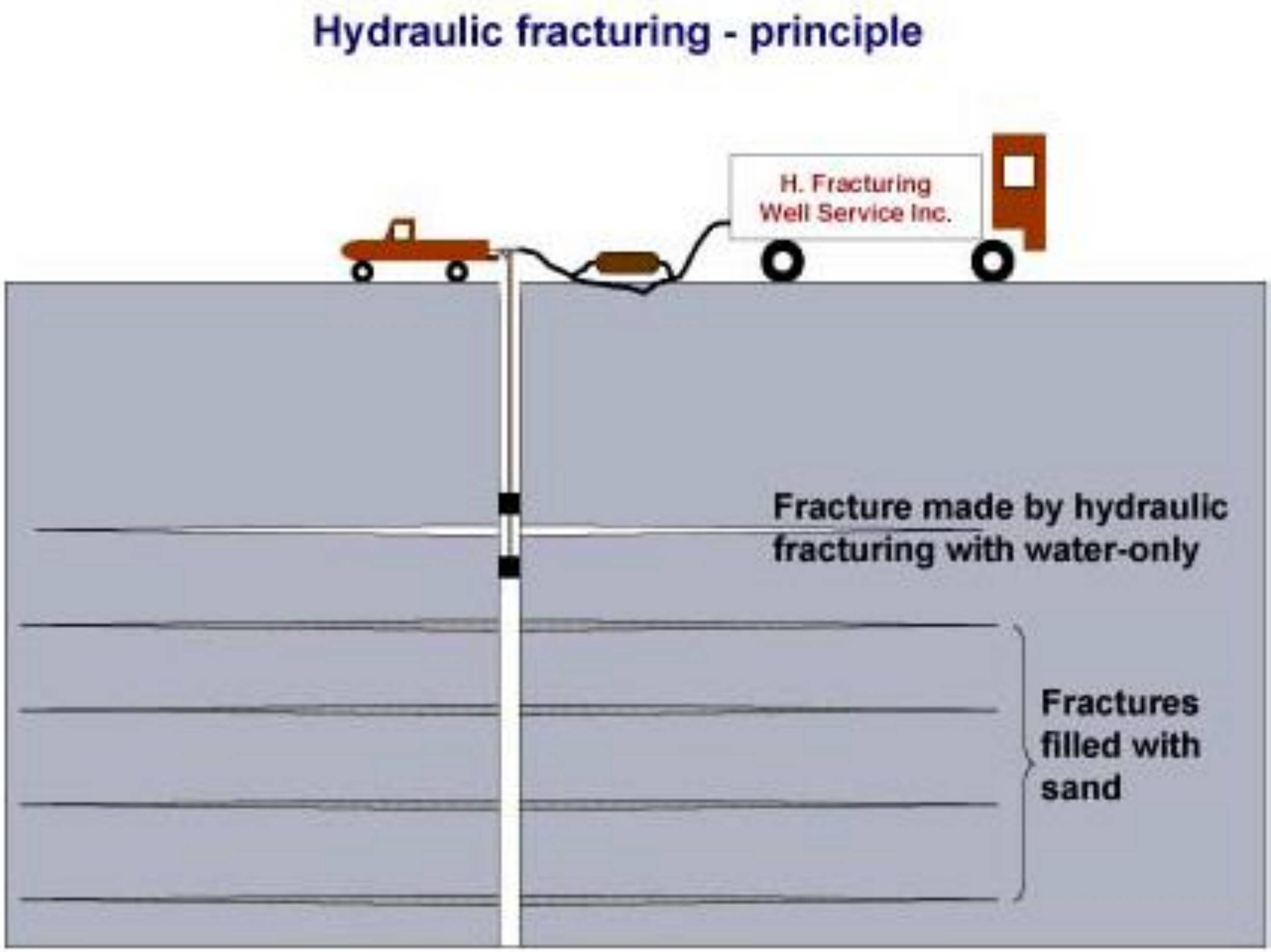
Asplan Viak AS, Båsum boring Trøndelag AS and Vensmoen eiendom (2013)

Temperature logging for detection of fratures in boreholes



From José Acuna, KTH

Hydraulic fracturing



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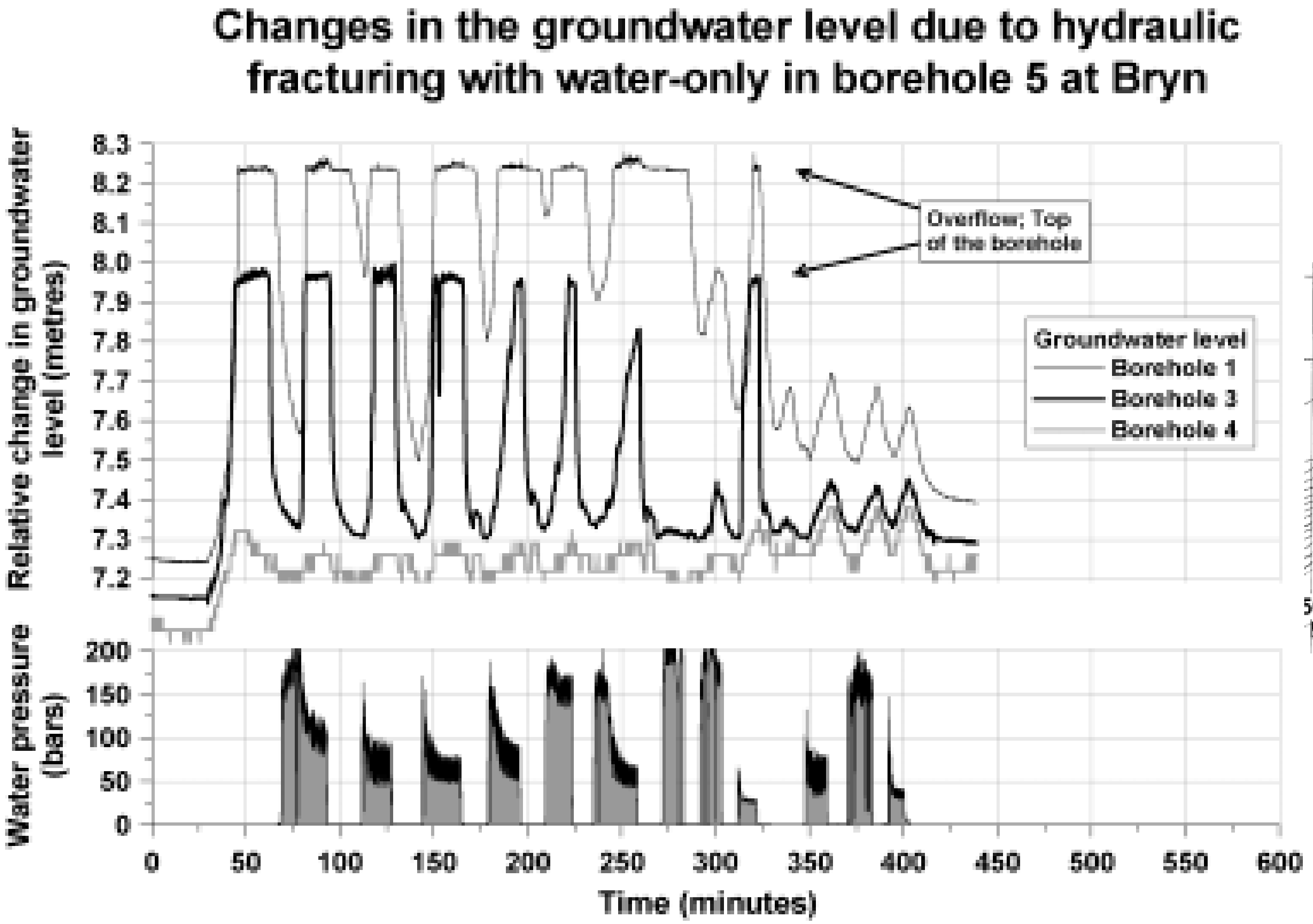
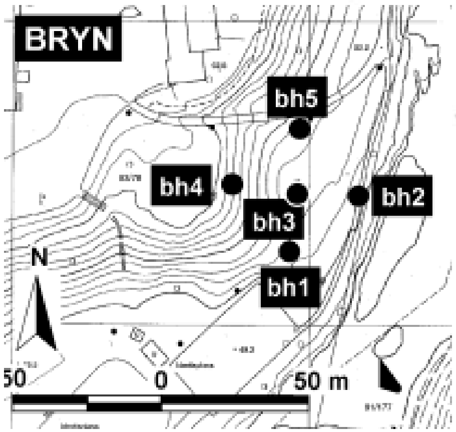
Hydraulic response of hydraulic fracturing





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Åknes – PhD and MSc at NTNU

- **PhD:** Vidar Kveldsvik (2008): «Static and dynamic stability analyses of the 800 m high Åknes rock slope, western Norway»
- **PhD:** Guro Grøneng (2010): «Stabilty analyses of the Åknes rock slope, western Norway»
- **MSc:** Nicole Ragvin (2006): «Åknes - Numerical modelling based on PLAXIS» (in Norw.)
- **MSc:** Ingrid B. Aardal (2007): «Åknes - Analysis of correlation between borehole geophysical data and fracture frequency from core logging»
- **MSc:** Elisabeth Holsbrekken (2007): «Correlation between displacement and climate/precipitation»
- **MSc:** Bjørnar Moen (2008): «Åknes landslide area – Analysis of possible effects of drainage» (in Norw.)
- **MSc:** Henrik Langeland (2014): «Development of revised geological model and stability analyses for upper parts of unstable rock slope at Åknes» (in Norw.)

https://brage.bibsys.no/xmlui/handle/11250/227459/discover

Main supervisor of all projects: Prof. Bjørn Nilsen

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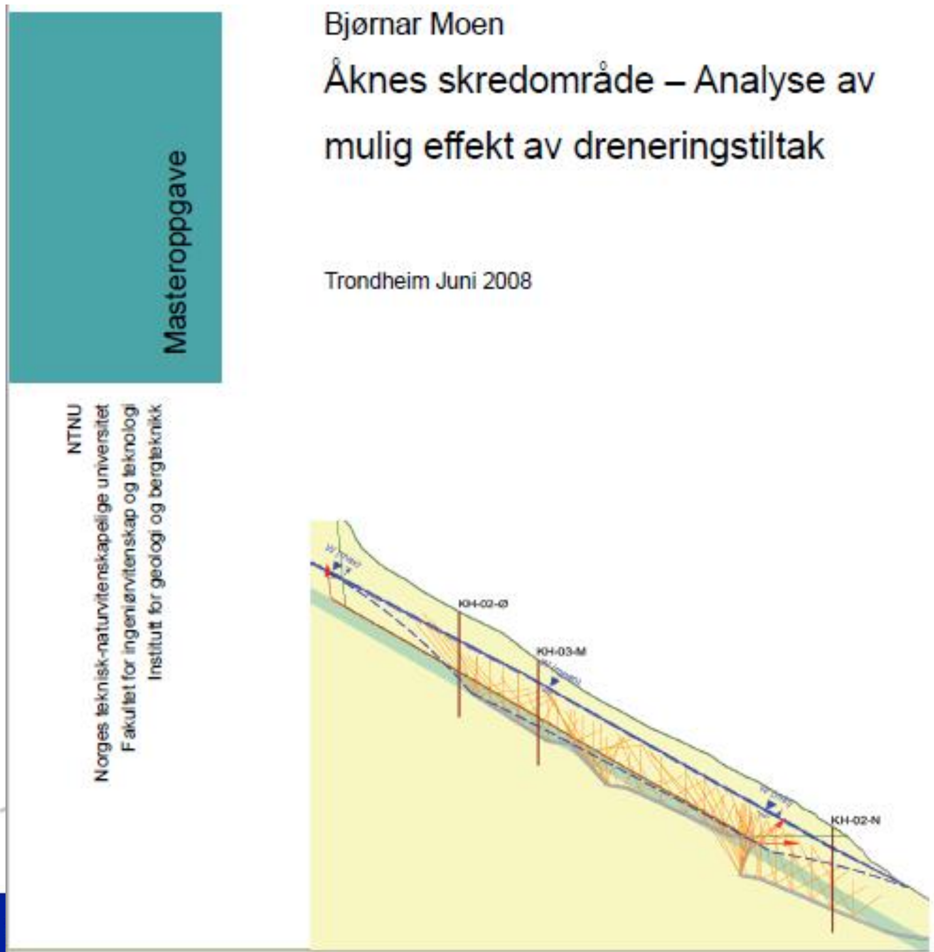
Åknes landslide area – Analysis of possible effects of drainage


Masteroppgave

Bjørnar Moen

Åknes skredområde – Analyse av mulig effekt av dreneringstiltak

Trondheim Juni 2008

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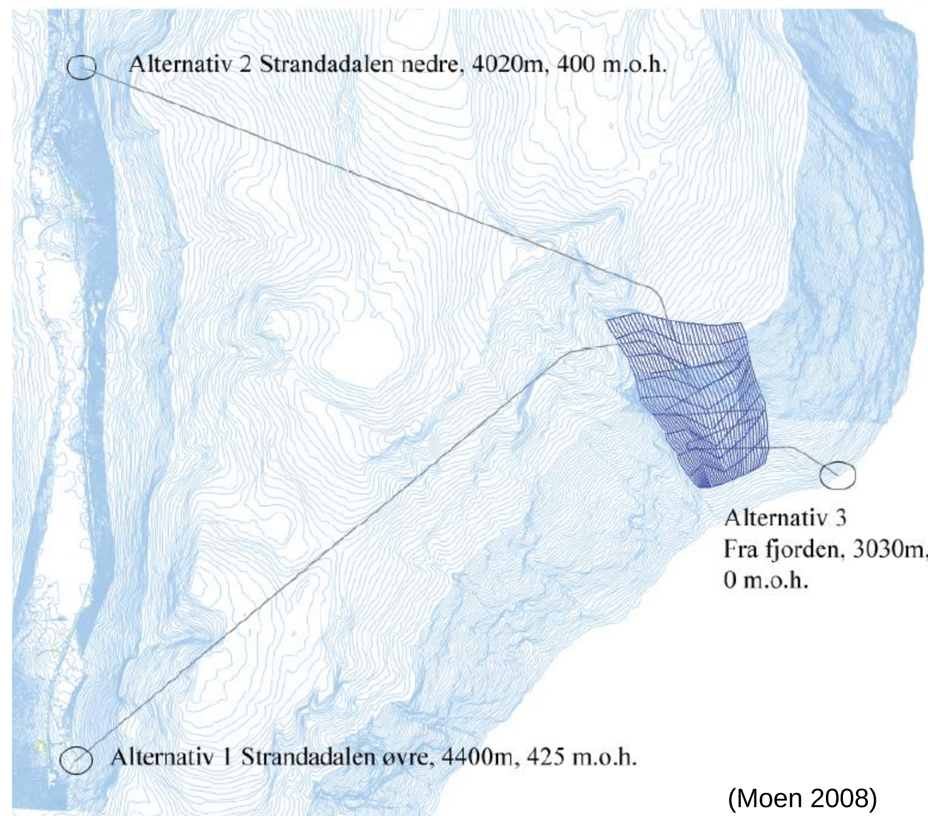
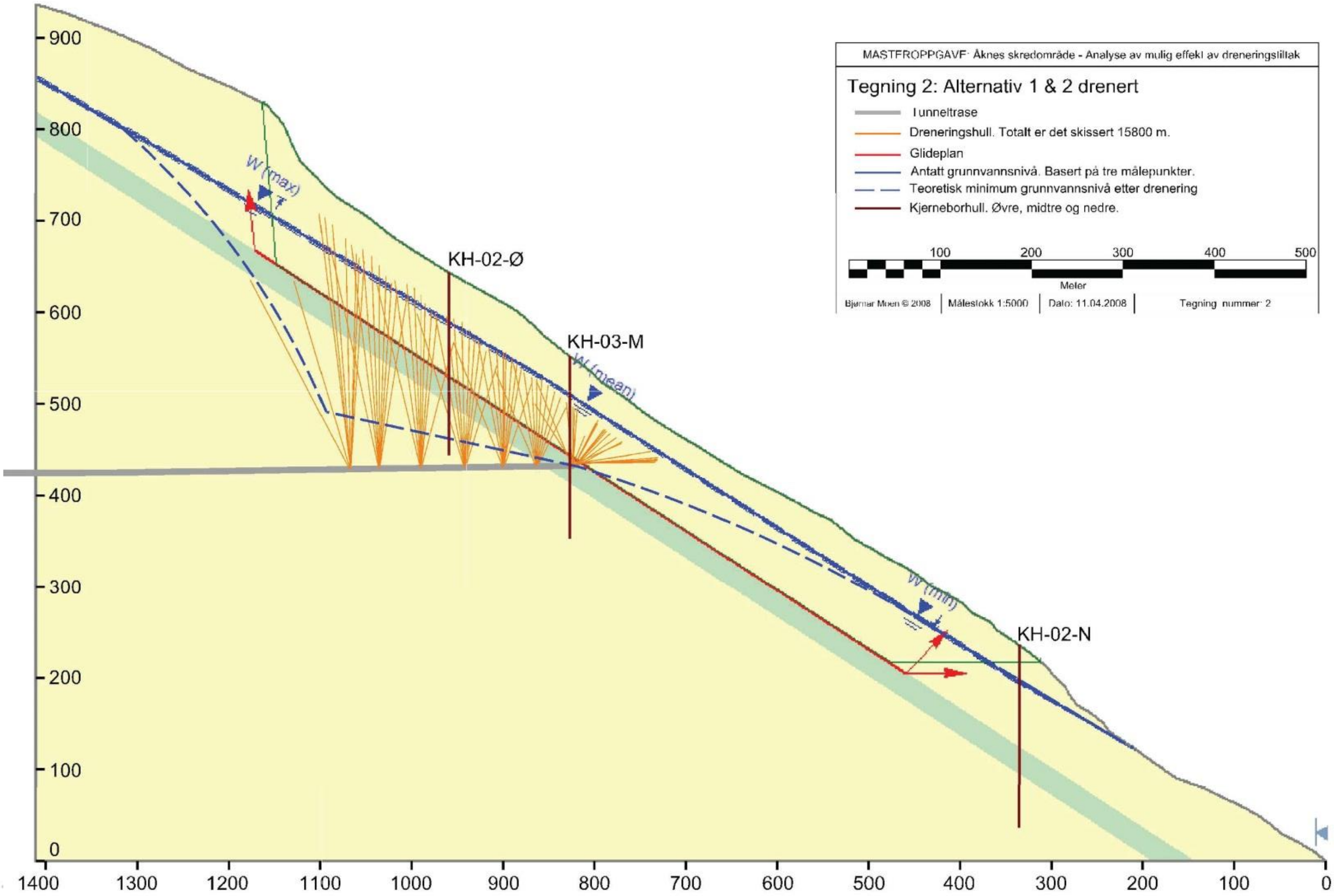
Institutt for geologi og bergteknikk

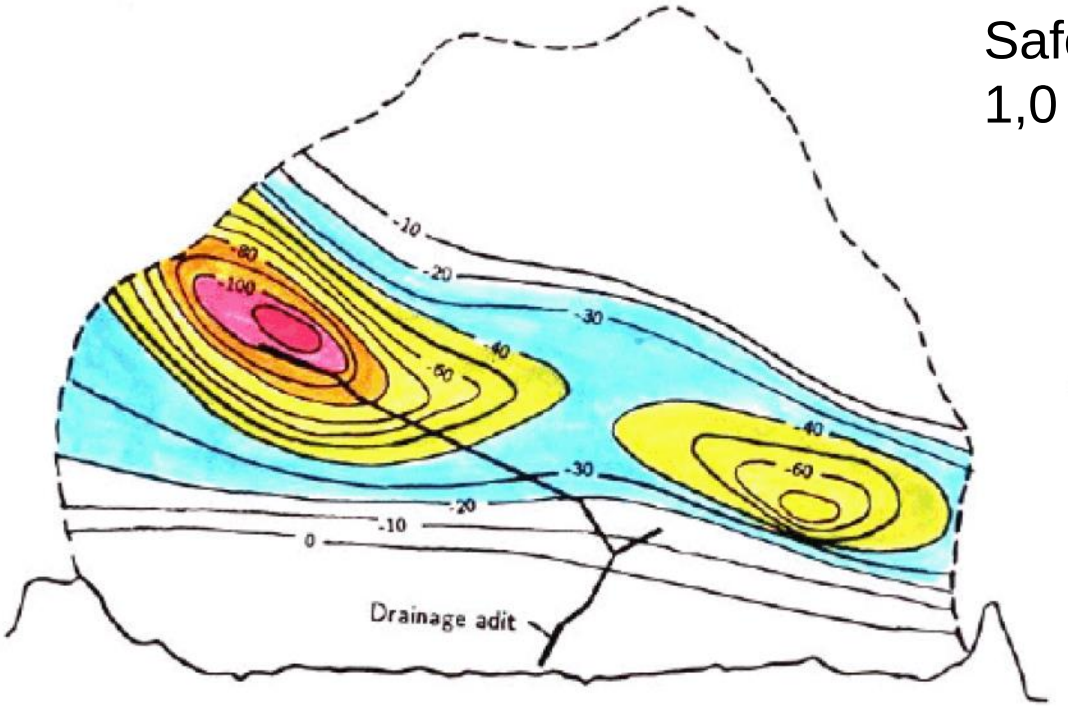


(Moen 2008)


MASTEROPPGAVE: Åknes skredområde - Analyse av mulig effekt av dreneringstiltak
Tegning 2: Alternativ 1 & 2 drenert
Tunneltrase
Dreneringshull. Totalt er det skissert 15800 m.
Glideplan
Antatt grunnvannsnivå. Basert på tre målepunkter.
Teoretisk minimum grunnvannsnivå etter drenering
Kjerneborhull. Øvre, midtre og nedre.
100
200
300
400
500
Meter
Bjørnar Moen © 2008
Målestokk 1:5000
Dato: 11.04.2008
Tegning nummer: 2
KH-02-Ø
KH-03-M
KH-02-N
W (max)
W (mean)
W (min)
900
800
700
600
500
400
300
200
100
0
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0

(Moen 2008)

Example: Draining of Dutchmans ridge



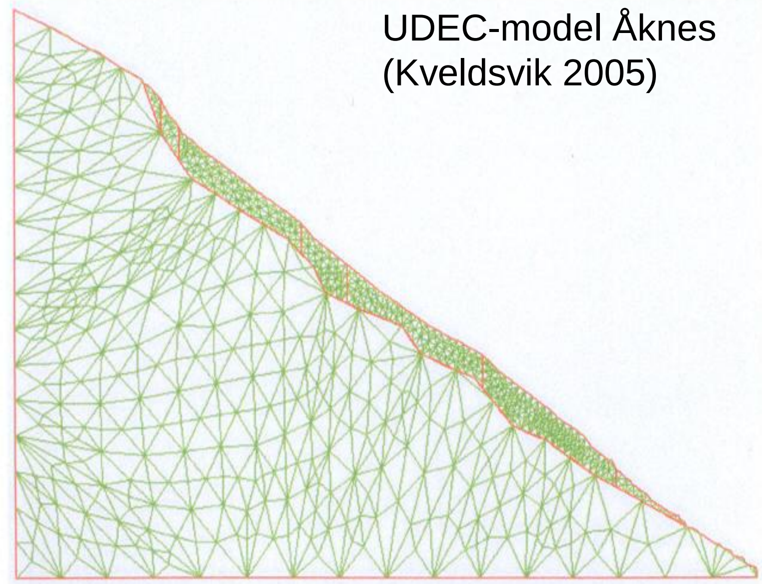
(from Hoek 1991, in Moen 2007)

Safety factor increased from 1,0 to 1,06 (acceptable).

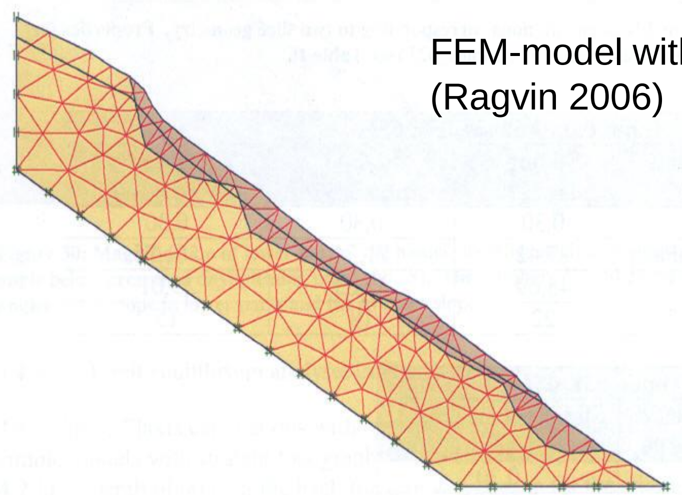
Numerical modelling

Main challenges/limitations:

- Complexity of geology/geometry
  - Failure mode
  - Joint pattern
- Definition of realistic input parameters
  - Boundary stresses
  - Friction of potential sliding plane
  - *Water pressure ← i.e. numerical modelling of limited value*
- Realism of numerical model
  - Continous vs. Discontinuous
  - 2D vs. 3D
- Interpretation of calculation result
  - Reliability of failure criterion
  - Critical limit for displacement



UDEC-model Åknes (Kveldsvik 2005)



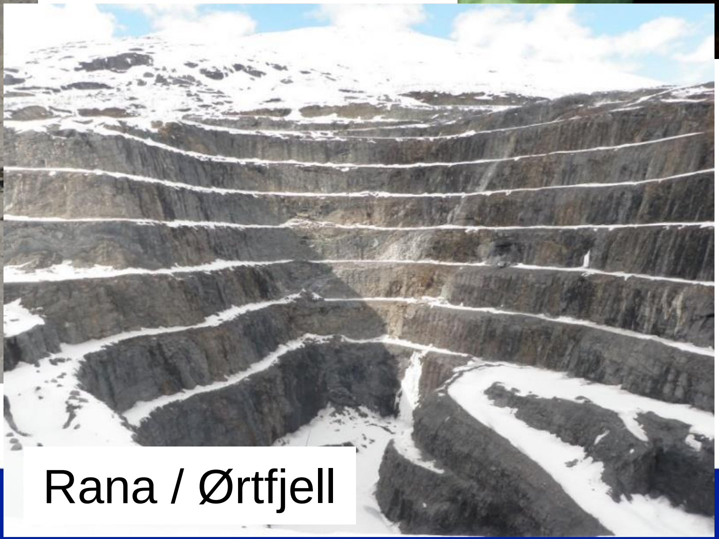
FEM-model with GW-table (Ragvin 2006)

Open pit mining, road cuts etc

- Drainage tunnel, with drillholes from tunnel
- Drain holes from surface

Tellnes

Chuquicamata



Rana / Ørtfjell

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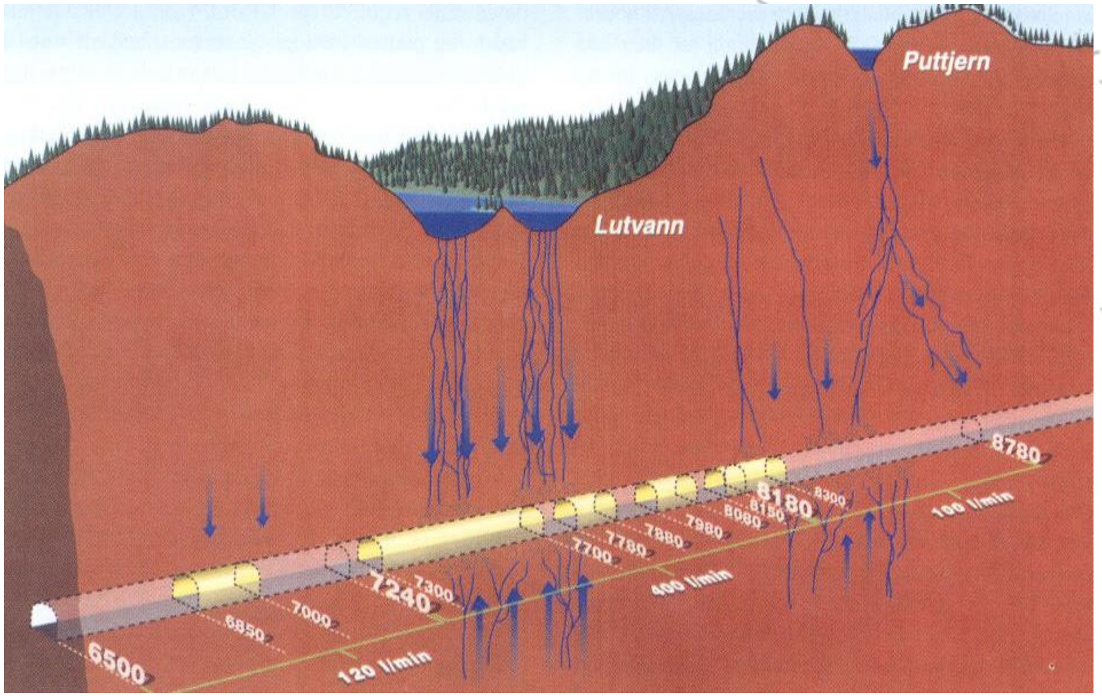
Tunnel and underground excavation
- example Romeriksporten railway tunnel

Tunnels in Norway: >3500km for hydropower tunnels and >1500 km for road and railway, plus much more

⇒ Considerable experience in Norway on drainage effect/water inflow in tunnels



THIS SHOULD BE TAKEN ADVANTAGE OF

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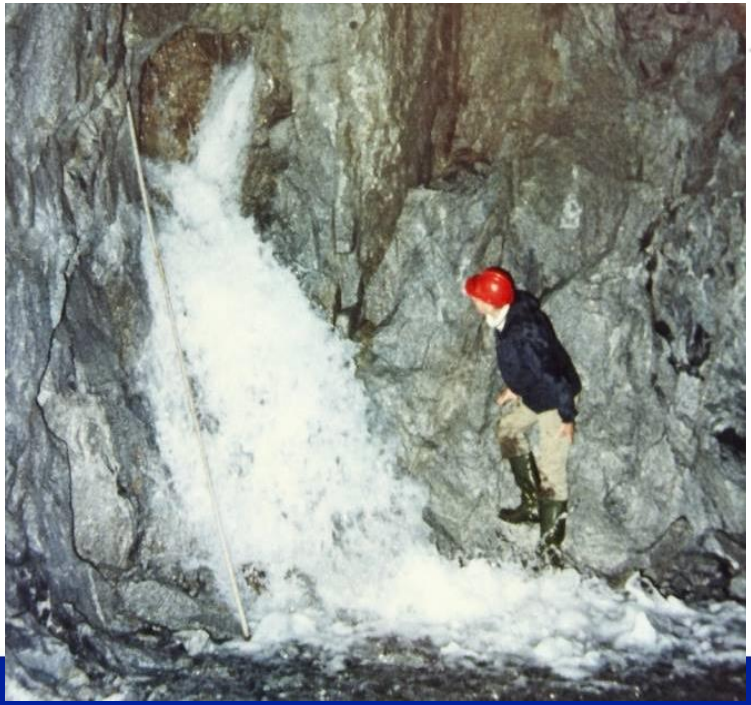
Ulla-Førre, in granitic gneiss

- Water inflow 12 000 l/min (= 200 l/s=720 m^3/h~17000 m^3/day=6,3 Mm^3/yr – i.e. 15% of produced drinking water in Oslo in 2009 (94,6 Mm^3/yr))
- Pressure of 40-50 bar
- «pipe flow»



Thank you!

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