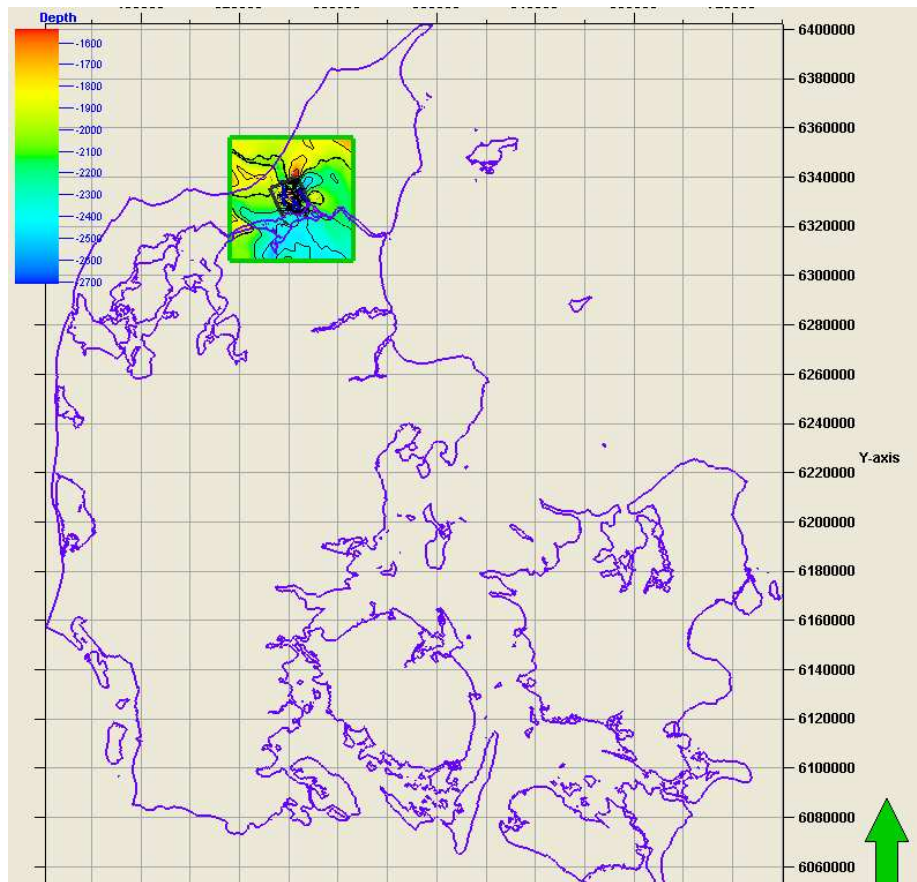# Storage licence application
- onshore aquifer, Denmark

Carsten M. Nielsen
Geological Survey of Denmark and Greenland (GEUS)

Vedsted storage site
- onshore Upper Triassic – Lower Jurassic aquifer

SiteChar objectives

➤ *Storage permit application*
- Draft dry-run application ultimo March 12
- Final dry-run application ultimo Dec. 12

o Full-chain characterization of onshore aquifer

- Reservoir characterization

- Risk assessment

- Monitoring plan

- Aquifer interaction with surroundings

- Economics

Vedsted site – candidate for CCS

Initial project - Vattenfall

- 2006/2007 plan to develop a full-scale demonstration project for CO_2 capture and storage in Denmark

- Vattenfall operates the Danish coal fired power plant "Nordjyllandsværket" (470 MW, CO_2 emission ~ 1.8 Mt/y, post. comp.)

- Vedsted structure situated approx. 30 km from power plant (transport by pipeline)

- GEUS contracted to map and model the structure for an initial assessment of storage capacity in order to warrant further investigations/investments

  - New seismic survey
  - Drilling
  - Decision to develop and issue application for storage permit
  - Operate

Vedsted site

Reservoir

• Onshore aquifer @ 1800 – 1900 m depth

• Anticlinal closure within a fault block

• Identified by hydrocarbon exploration campaign in the late 1950-ties

• Identified as candidate for CO_2 storage by GEUS in 2003 (GESTCO)

Challenges

• Sparse data coverage
  - One well with few wireline logs
  - Vintage 2D seismic surveys (1967 and 1983,regional scale)
  - Regional geological interpretation

• Caprock, secondary containment and faults

• Well integrity (Vedsted-1 well, P&A 1958)

Vedsted site – Reservoir characterization

Model version_0

o Geological model for both the Gassum reservoir and the shallower Haldager formation (secondary containment)
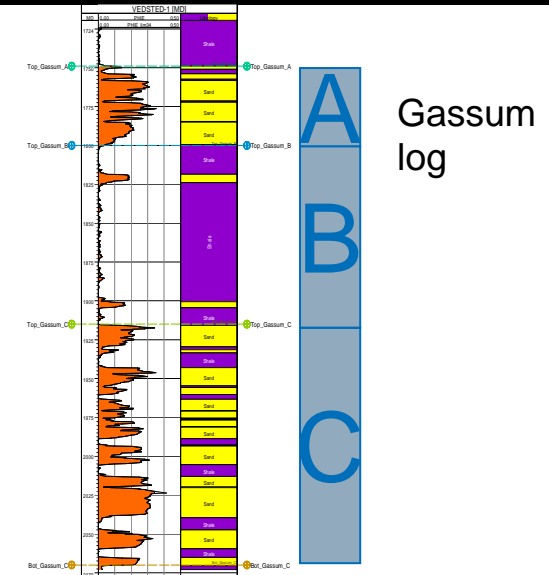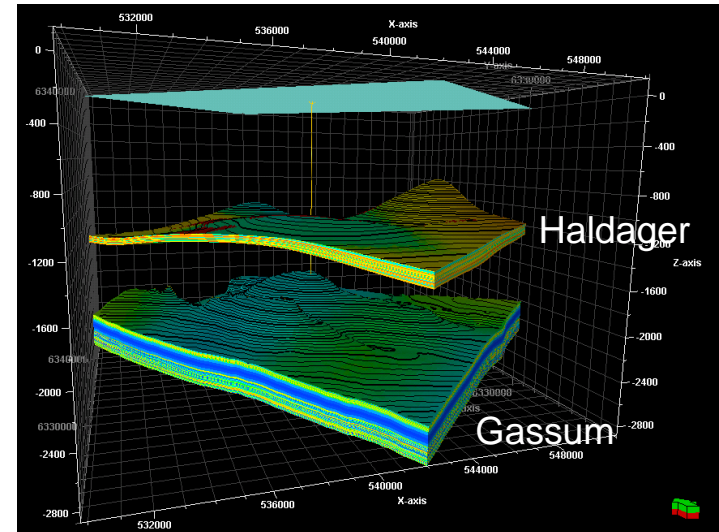
o Reservoir simulation (dynamic capacity estimation) primarily for the Gassum reservoir

o Model version_0 recommendations are to continue the project, but the various coarse assumptions must be addressed, *eg.*

- Geological complexity
- Storage security
- Etc. …

Plans

➤ New 2D seismic survey
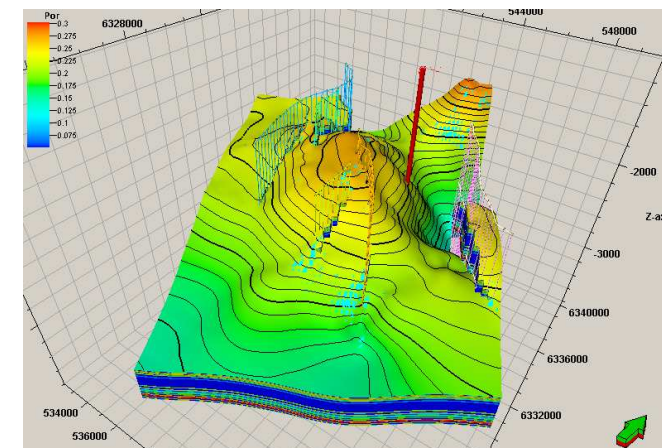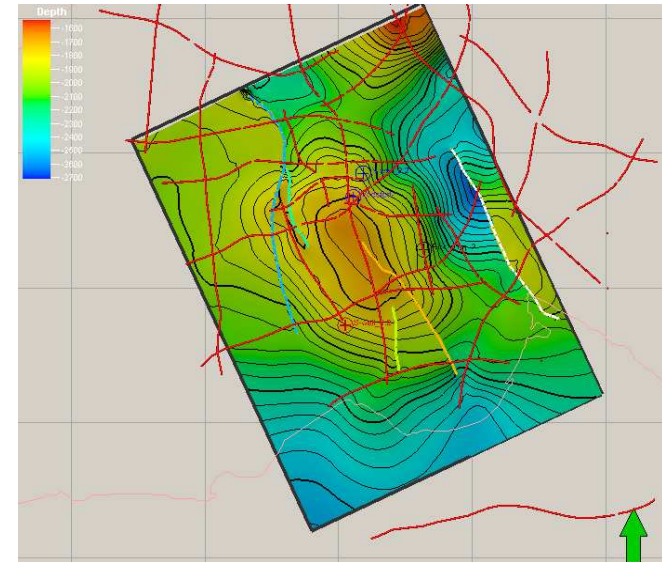➤ Risk assessment

Haldager

Gassum

Gassum log

A
B
C

Reservoir characterization – new 2D data

New 2D seismic mapping

o Data acquired in 2008

o Focus on Gassum reservoir

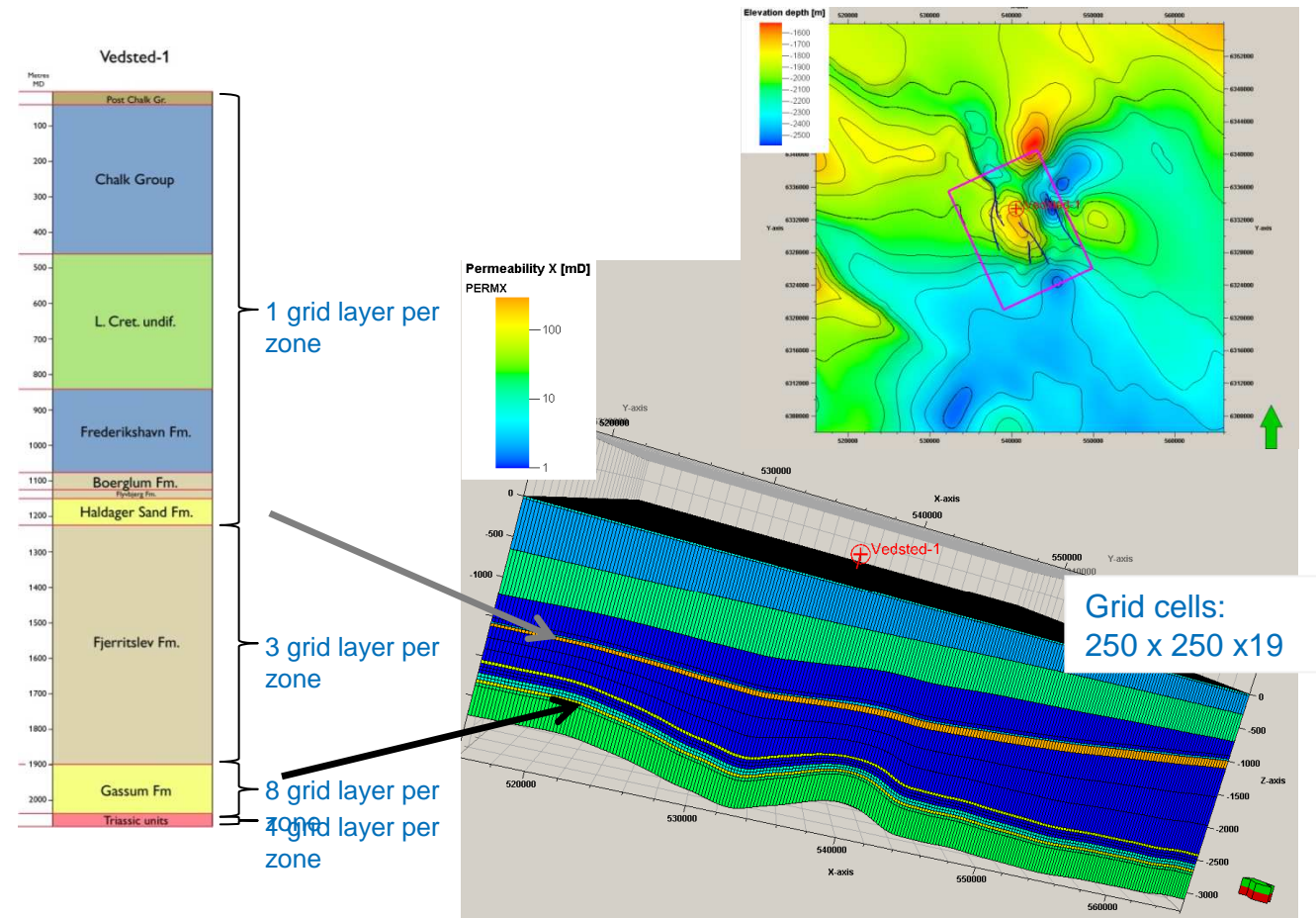o Only major faults interpreteated

Model version_1

o Structure "moved" to SW

o Some compartmentalization, if major faults are closed

o Appraisal well planning

o Injection strategies

o Model version_1.5 (lateral variability in properties)

Reservoir characterization

New static model

o Overburden included

o Larger areal coverage

o Geomechanics

o Leakage

Vedsted-1

1 grid layer per zone

3 grid layer per zone

8 grid layer per zone

4 grid layer per zone

Permeability X [mD]

PERMX

Grid cells:
250 x 250 x19

Risk assesment

Early risk assessment facilitated by DNV

- Expert workshop in June 2008

- Recommendation for planning future and relevant project activities

- Base for risk register

- Monitoring plan

- Remediation plan (safeguards)

Major risks

- Reservoir complexity; inter-bedded sands and shales, faults
  - ➢ Addressed by the new seismic survey and interpretations

- Secondary containment, *i.e.* the Haldager reservoir
  - ➢ To by mitigated by comprehensive characterization of the Haldager res.

- Abandoned Vedsted-1 well
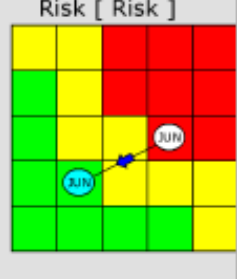 - ➢ Separate risk assessment (CO2WELLS JIP)

Risk assessment

Risk matrix – before and after implementation of safegurads

Risk assessment

Risk register – identify performance indicators

Risk [Risk]	

ID	R-0006
Excel ref	6
Hazard Name	Complex reservoir
Casue	Inadequate understanding of reservoir complexity. Interbedded sands and mudstones can form complex geometries with highly variable permeabilites.
Consequence	Reduces ability to make optimal use of available storage capacity. CO2 can disperse preferentially in high permeability streaks, thus failing to migrate into remaining reservoir volume in the vicinity of the injection point.
Safeguards	PREVENTIVE: data acquisition, reservoir testing PROTECTIVE: Shut off high permeable layers by injecting permeability reducing substances
Detection	Monitor injection pressure closely at start of injection. Seismic monitoring to image CO2 migration pattern.
Before actions Probability: Consequence: Risk [Risk]	Medium High
After actions Probability: Consequence: Risk [Risk]	Low Low
Notes	
Manageability	0

Consequence/
Impact categories

- Storage capacity
- Injectivity
- Storage integrity
- Ex. Environment
- Licence to operate
- Reputation

# Risk assessment of the Vedsted-1 well

- Two workshops facilitated by DNV for legacy well
    - Well integrity assessment (Sept. 2010)
    - "Future actions and way forward" (Nov. 2010)

- Facilitate decision to either re-abandon the well or accept to monitor and mitigate any irregularity

- No conclusion; suggest dialog with relevant authorities! (workover/re-drill, ….)

- In SiteChar; TNO review of the well
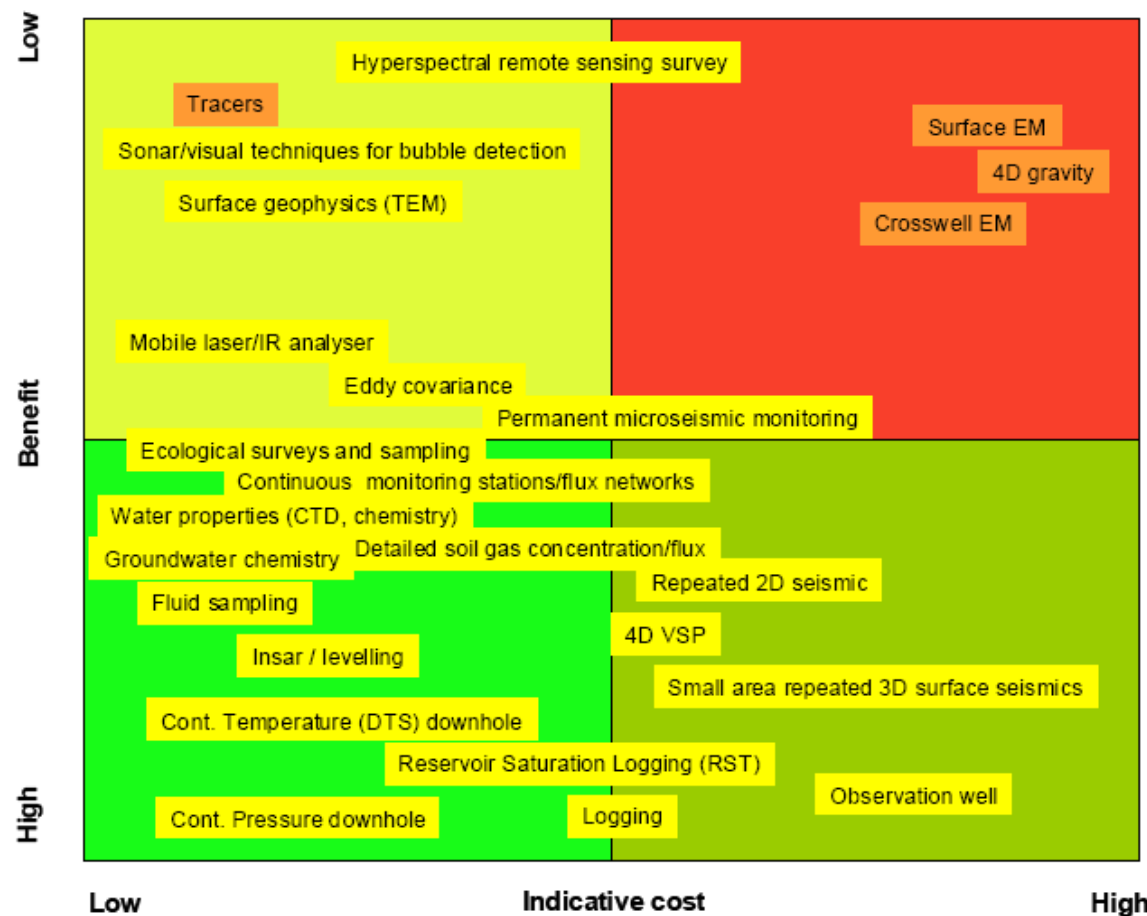
Risk assessment of the Vedsted-1 well

Vedsted-1
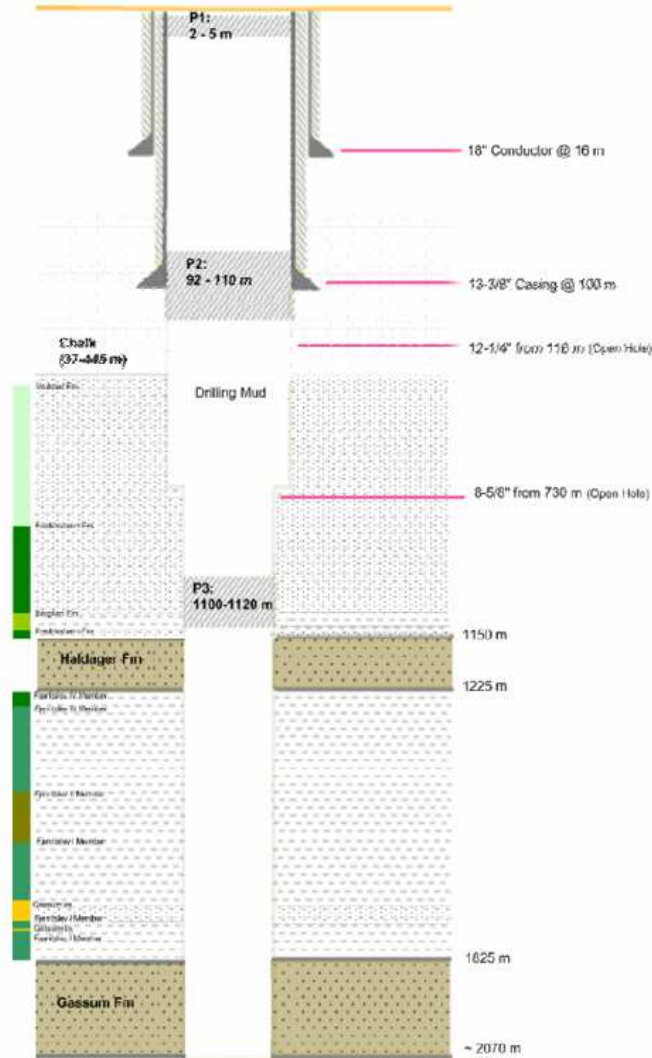
Danish Energy Authority P&A open-hole well
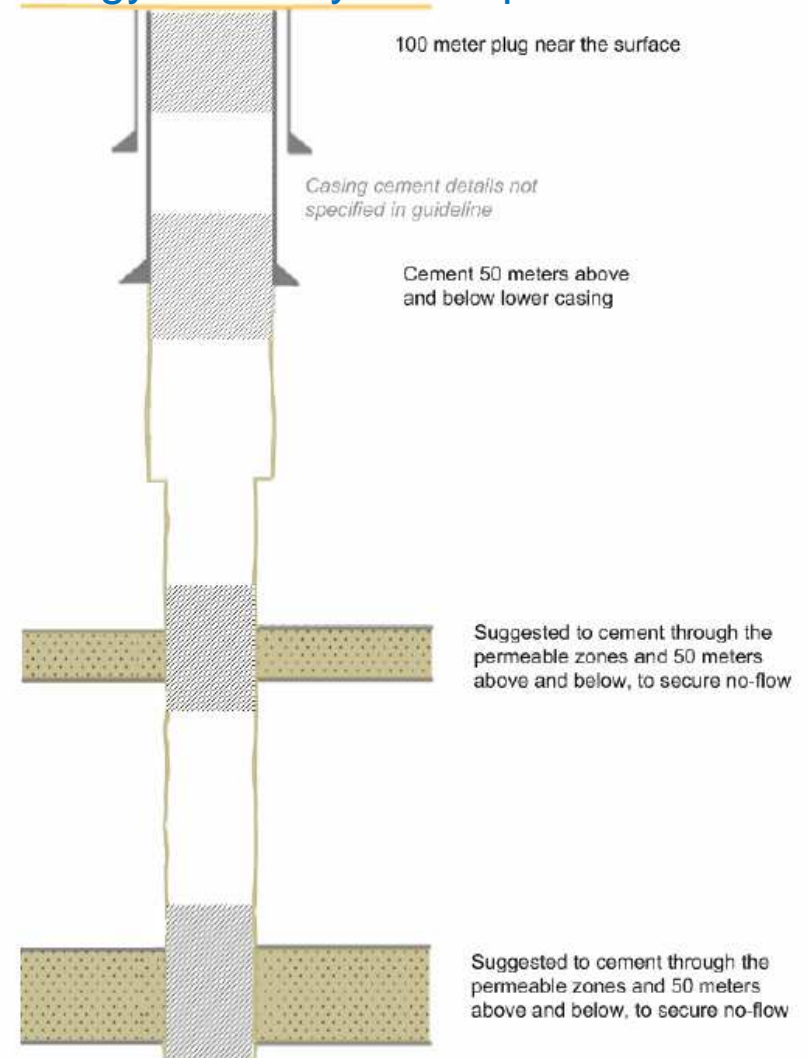
Monitoring plan

Comprehensive study assessing all relevant monitoring techniques for the Vedsted site (CO_2GeoNet)

Monitoring plan

Recommendations have been divided in to two groups:
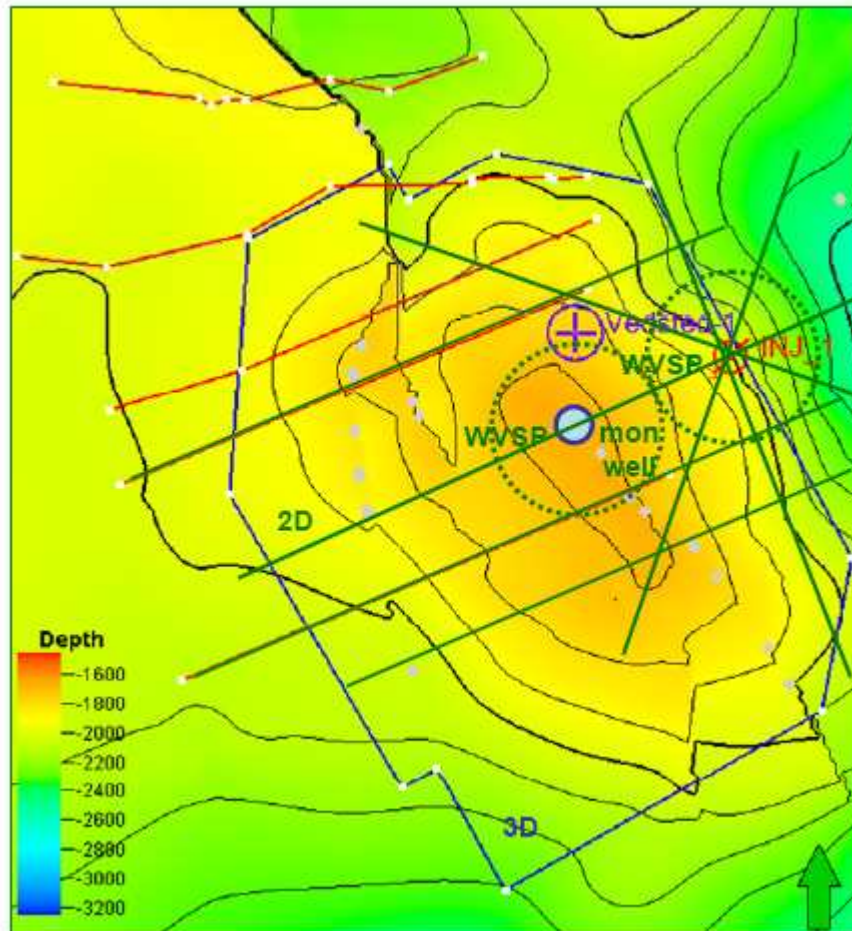
Deep monitoring (plume development)

- Seismic monitorig
- Vertical seismic profiling (VSP)
- Microseismic monitoring
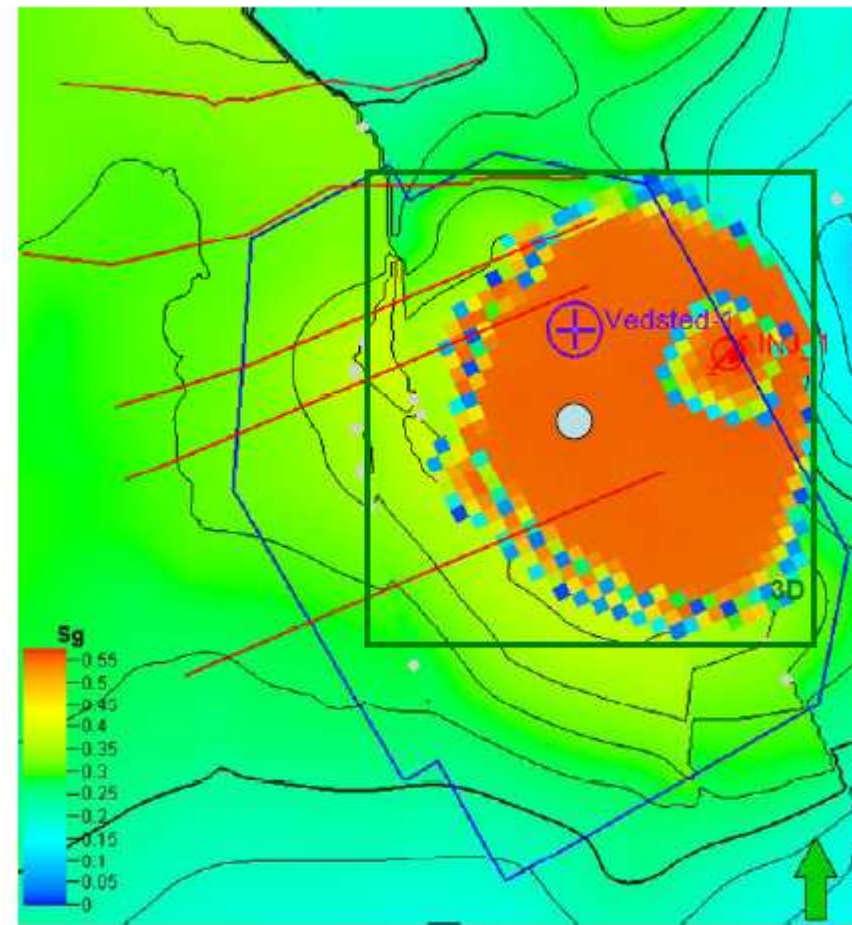- Downhole pressure and temperature measurements

Shallow (leakage)

- Near surface gas monitoring
- Shallow ground water monitoring
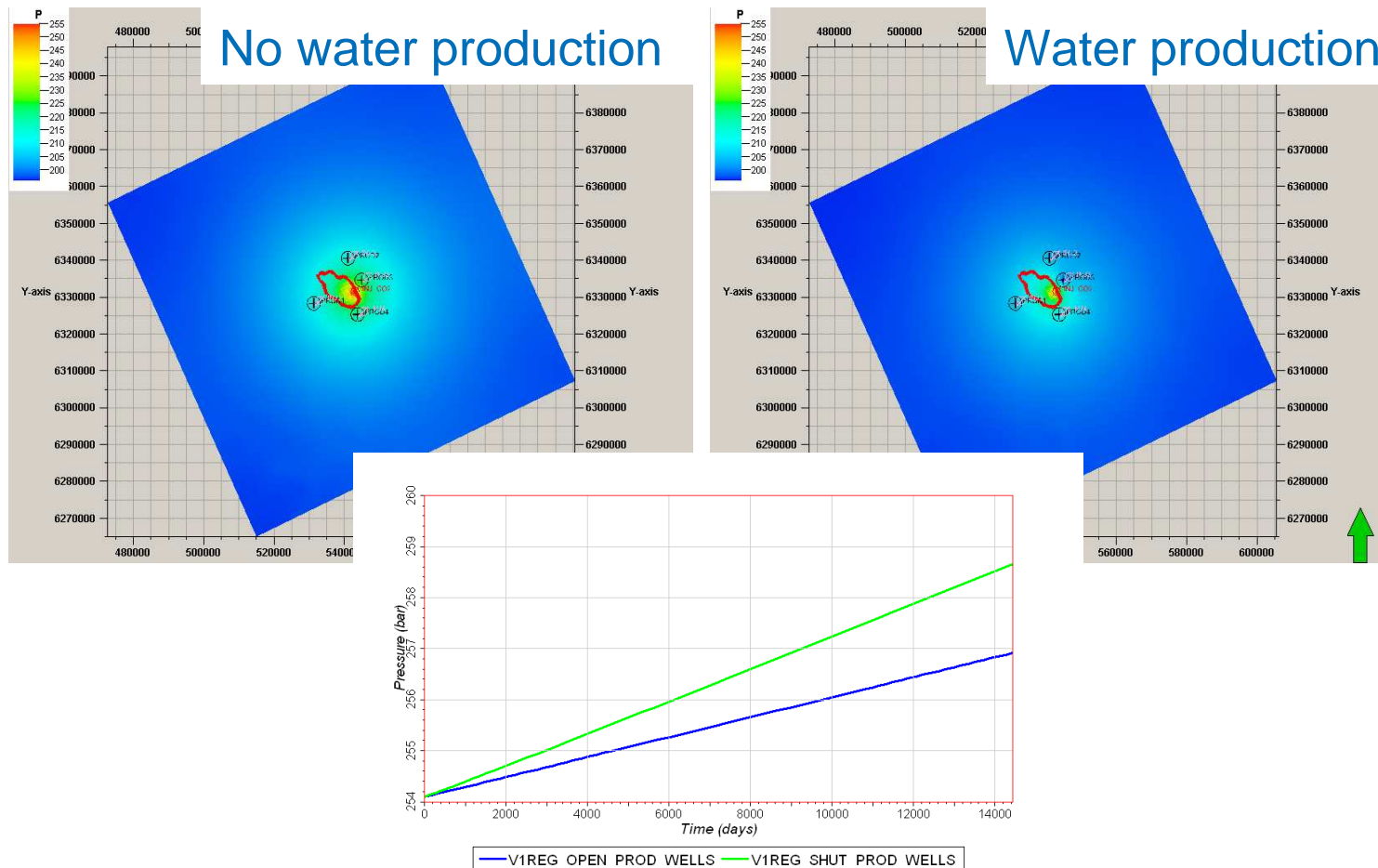
Deep monitoring - plume development

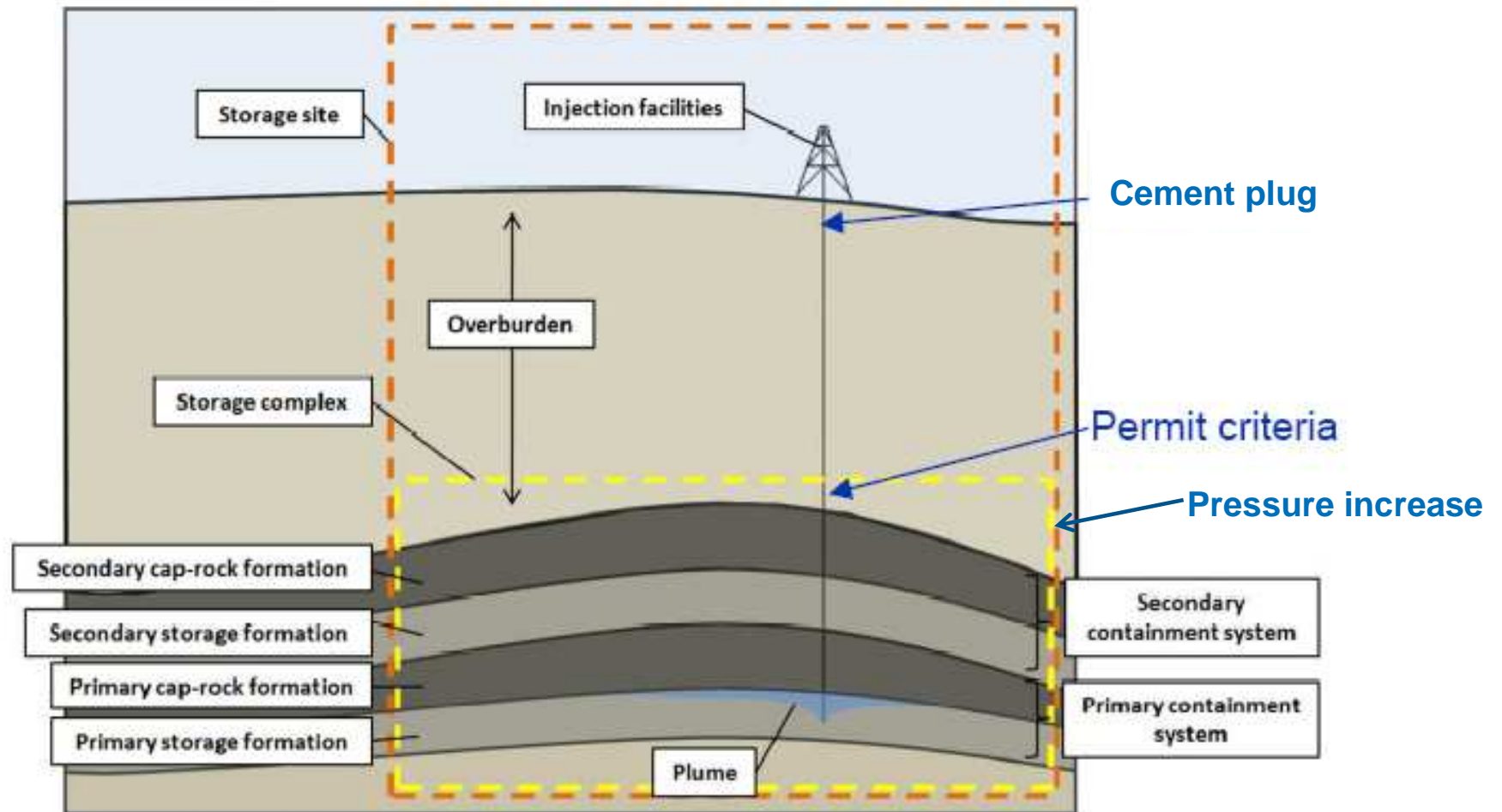

Deep-focussed monitoring: baseline

Injection: 40 years, 100 kg/s

Regional pressure propagation

No water production

Water production

Storage complex definition

Dry-run licence application

- Re-evaluate the recommendations and results of the individual studies with respect to the SiteChar template, the CCS directive and the CO2QUALSTORE guidelines

- Identify (key) performance indicators (*e.g.* regional pressure build-up, plume migration, …)

- Compile the various studies performed on the Vedsted site

- Write up the application as logical and transparent as possible