CO_2 storage; Legislation and risk management In the Netherlands

CCOP Meeting – Phuket 2010

Gijs Remmelts

Contents

Netherlands Organisation
for
Applied Scientific Research

- 4500 employees

Geosciences and energy

- Applied geosciences
- Geological Survey of the Netherlands
- Consultant for Ministry of Economic Affairs on mining activities

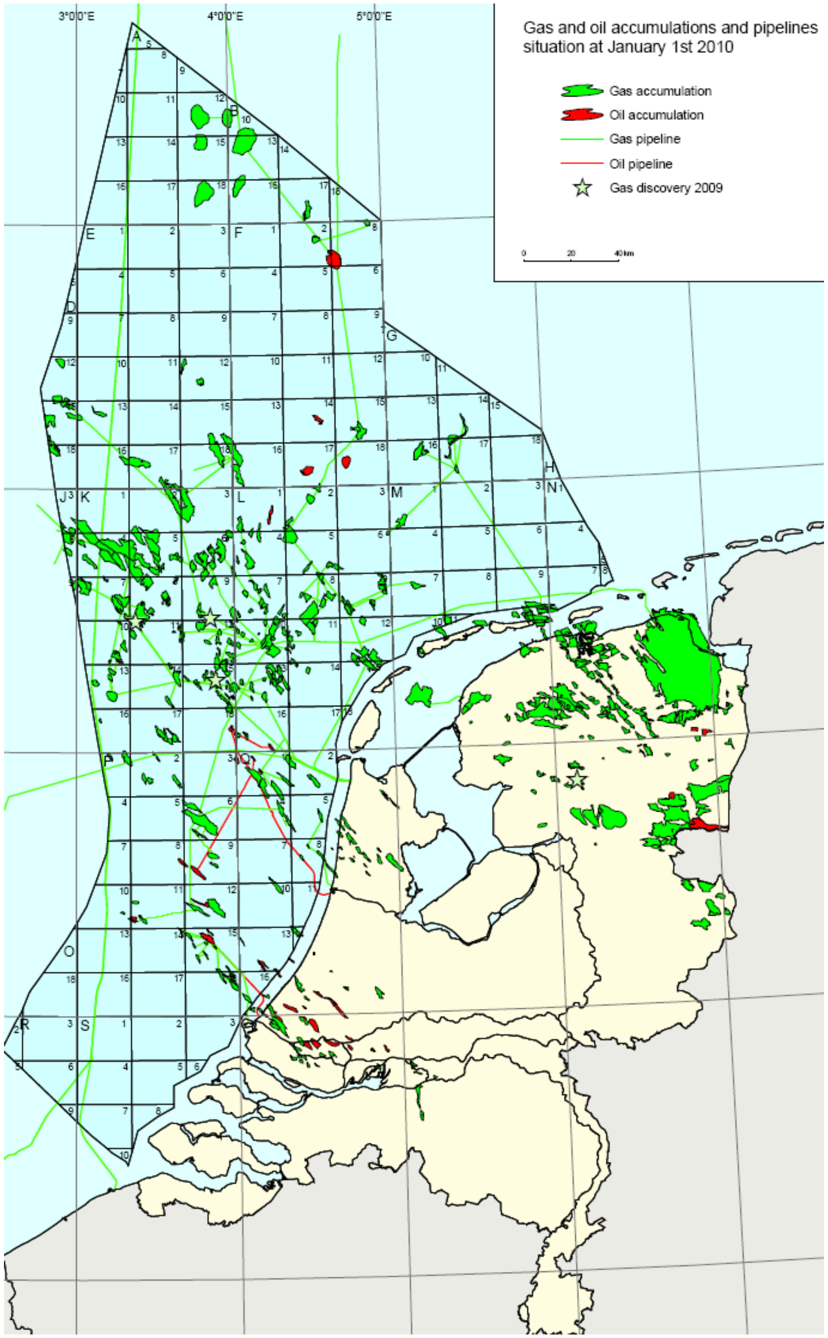
- 20 years of experience in CCS (National and European projects)

The Netherlands in a nutshell

- Gas producer
  (GIIP 4500 BCM, 70 BCM/y)
- 4 UGS facilities !
- End of gas production many gas fields in coming decades
- Practical storage capacity CO_2:
  >2000 Mton in depleted gas fields

Gas fields more suitable than aquifers

- GF: better defined
- GF: proven sealing capacity (CH_4)
- GF: dynamic behavior known
- GF: more efficient:
  (less rock volume, energy, pressure)
- GF: existing infrastructure



Current CCS projects in the Netherlands

- Pilot on K12B
  - Started in 2004, ongoing
  - CO_2 (13%) produced is reinjected
  - Total 70kT CO_2 injected till 1-1-10

  - Pilot storage project Barendrecht (+Ziedewij)
  - Start injection 2011/2012
  - 0.4 Mton CO_2 per year
  - max 10 Mton

- Two potential "flagship" projects in preparation (>2015)

NL Policy

- Netherlands Government has adopted CCS as *one* of the solutions for CO_2 emissions .
- Preference for depleted gas fields over other storage options
- Re use of existing infrastructure (see next slide)
- Need for Master plan to ensure efficient use of available capacity and infrastructure
- Research programs ongoing
- Public acceptance still is issue (proposed project Barendrecht)

Existing infrastructure

Abandonment principle: removal of equipment and boreholes
$\Rightarrow$ loss of opportunity for storage

Need for:

- Storage master plan (both for infra structure and storage capacity)
- Legal authority to prevent abandonment and/or ensure suspended abandonment
- Policy & financial matters: responsibility & financing mothballing

Legislation

Legislation:

- Scope of regulation
- International European context
- Dutch Mining Act

Typicality of CO_2 storage: long-term component

- No monitoring possible over a very long time period
  - Put emphasis on prevention
    (through proper site selection and characterisation)
  - Assess on sound scientific basis
- External factors
  - Be comprehensive in hazard/risk identification
- Large uncertainty in properties
  - Apply conservative approach or probabilistic approach
- Limited performance data
  - Use natural and industrial analogues
    - (Werkendam gas field, 78% CO_2)

What is subjected to regulation of CO_2 storage?

- **Effectiveness of emission reduction**
  - Guidelines for monitoring, reporting and verification
    - Kyoto instruments: Emission trading, Clean Development Mechanism, Joint Implementaion & accounting of emissions
    - European Emission trade system (ETS) & Linking Directives

- **Health, safety and environment**
  - International guidelines for marine environment: OSPAR Convention and London Convention/Protocol
  - Relevant European Directives, i.e. EU draft storage Directive
  - National regulations in mining and environmental laws

- **Ownership, IPR, responsibility & liability, and insurance**
  - European Environmental Liability Directive
  - National regulation

- **(Spatial planning/resource management)**

General issues in developing regulation (not exhaustive)

- Composition of the CO_2 stream *('overwhelmingly CO_2')*

- Transfer of responsibility
- Long-term liability
- Cross-boundary effects
- No performance database/lack of actuarial data (UGS analogue)

- Detection limits of monitoring techniques
- Performance standards

Art 4 Site selection

(2) A geological formation shall only be selected as a storage site, if under the proposed conditions of use there is no significant risk of leakage, and if no significant negative environmental or health impacts are likely to occur.

Art 7 Permit applications

Applications to the competent authority for storage permits shall include the following information: …

(3) The characterization of the storage site and complex and an assessment of the expected security of the storage pursuant to Article 4(2) and (3) …

(5) A proposed monitoring plan pursuant to Article 13(2) ..

EU Storage Directive

Art 13 Monitoring

(1) Member States shall ensure that the operator carries out monitoring (…) for (…):

- *comparison actual – modelled behaviour CO_2*
- *detecting migration of CO_2*
- *detecting leakage of CO_2*
- *detecting significant adverse effects for surrounding environment, human populations, or users biosphere*
- *assessing effectiveness corrective measures*
- *assessing whether stored CO_2 will be completely contained in future*

Dutch Mining Legislation

- Mining Act(2003) provides basic framework for storage licensing (CH_4, CO_2, N_2 etc.): storage permit, storage plan, monitoring, inspection, closure plan.

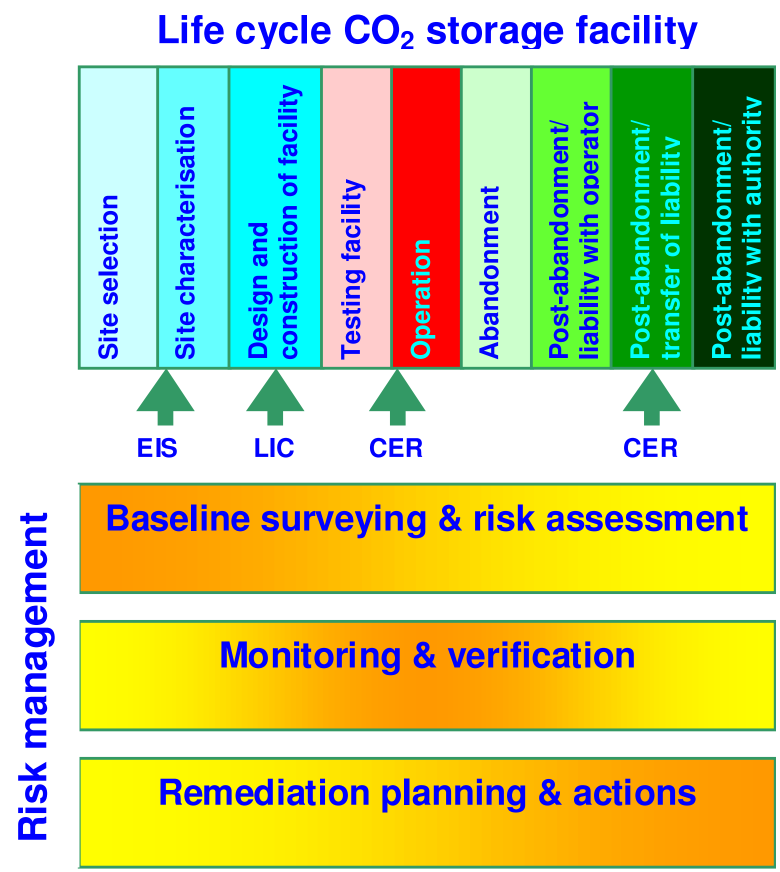
- No special rules on:
  - access to transport and storage of CO_2
  - long term stewardship of storage sites
  - financial arrangements long term monitoring

Regulation in the Netherlands – Important milestones in licensing

Preparation phase
- EIA Approval by EIA-Commision
- Environmental License
- Storage Plan: site characterisation, assessment, monitoring, well integrity
- Measurement/monitoring Plan
- Drilling Programme

Closure phase
- Closure plan
- Well abandonment plan

After care
- Transfer of responsibility/liability
- Optional Monitoring



EU CCS directive vs Dutch Mining Act

New elements for Dutch Mining Act

- Transfer of responsibility (20 years after closure)
- Financial security operators during storage and before transfer
- Financial contribution operators for post transfer monitoring (30 years) and containment CO2
- General rules on access to transport and storage
- Role EU Commission:
  - ✓ information on permit applications & transfer report by operator
  - ✓ non-binding opinion on draft storage permits and draft decision of approval of transfer of responsibility (both within 4 months)

Implementation EU directive + OSPAR guideline in progress

Risk analysis and Risk management

Content

- Types of risk
- What is risk management?
- Stages of a storage project
- Risk assessment (RA)
  - Qualitative RA
  - Quantitative RA
- Risk-based monitoring
- Remediation: Preventive and corrective actions

Types of risk: impact

Source: Cudd Well control

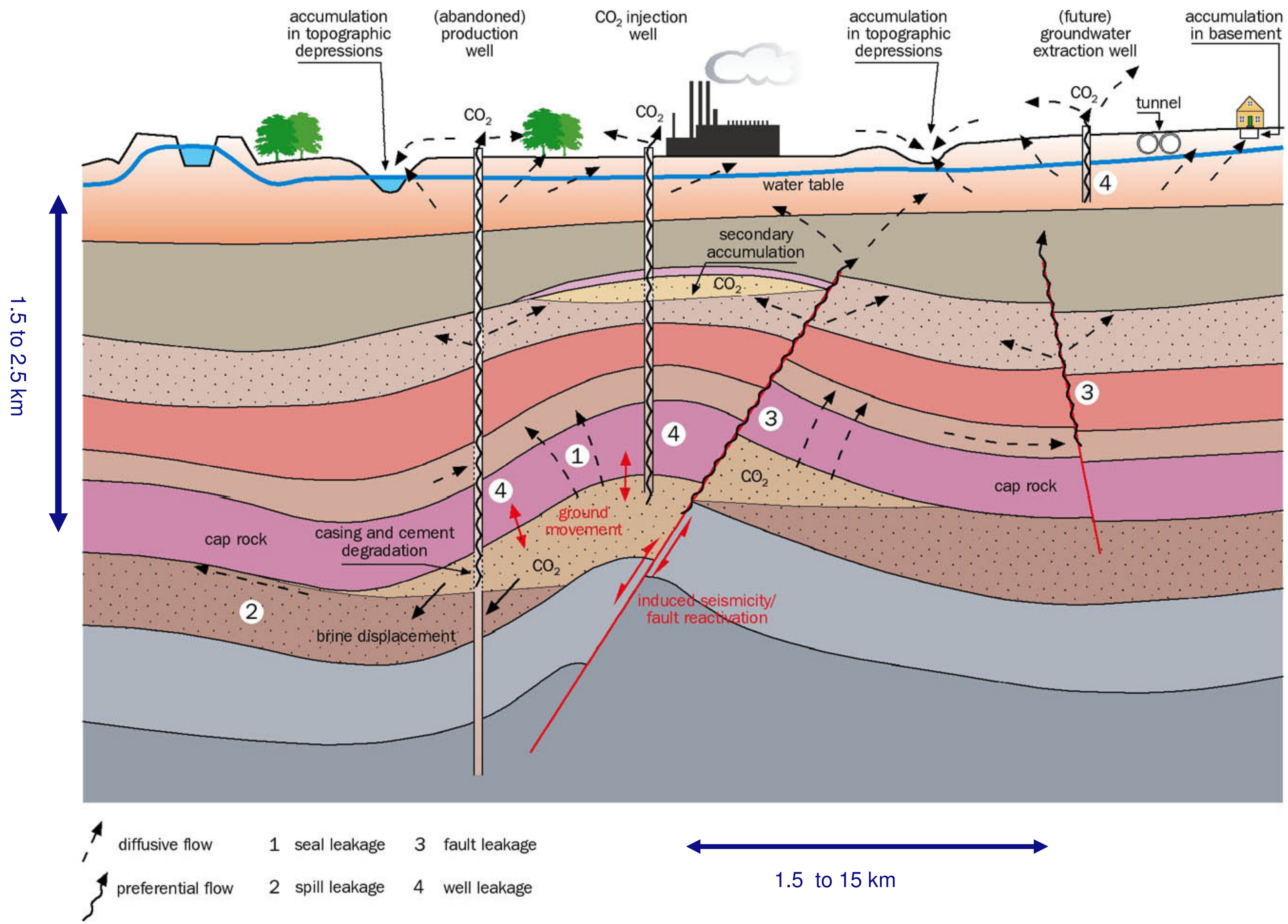
Global impact

- Leakage of CO_2 back to the atmosphere lowering the affectivity of global CO_2 emission reduction

Local impacts

- Leakage of CO_2 to the biosphere leading to unacceptable effects on men and environment
- Pressure/stress changes leading to gradual (aseismic) or episodic (seismic) ground movement
- Displacement of brine and fresh water

Potential migration pathways to be managed

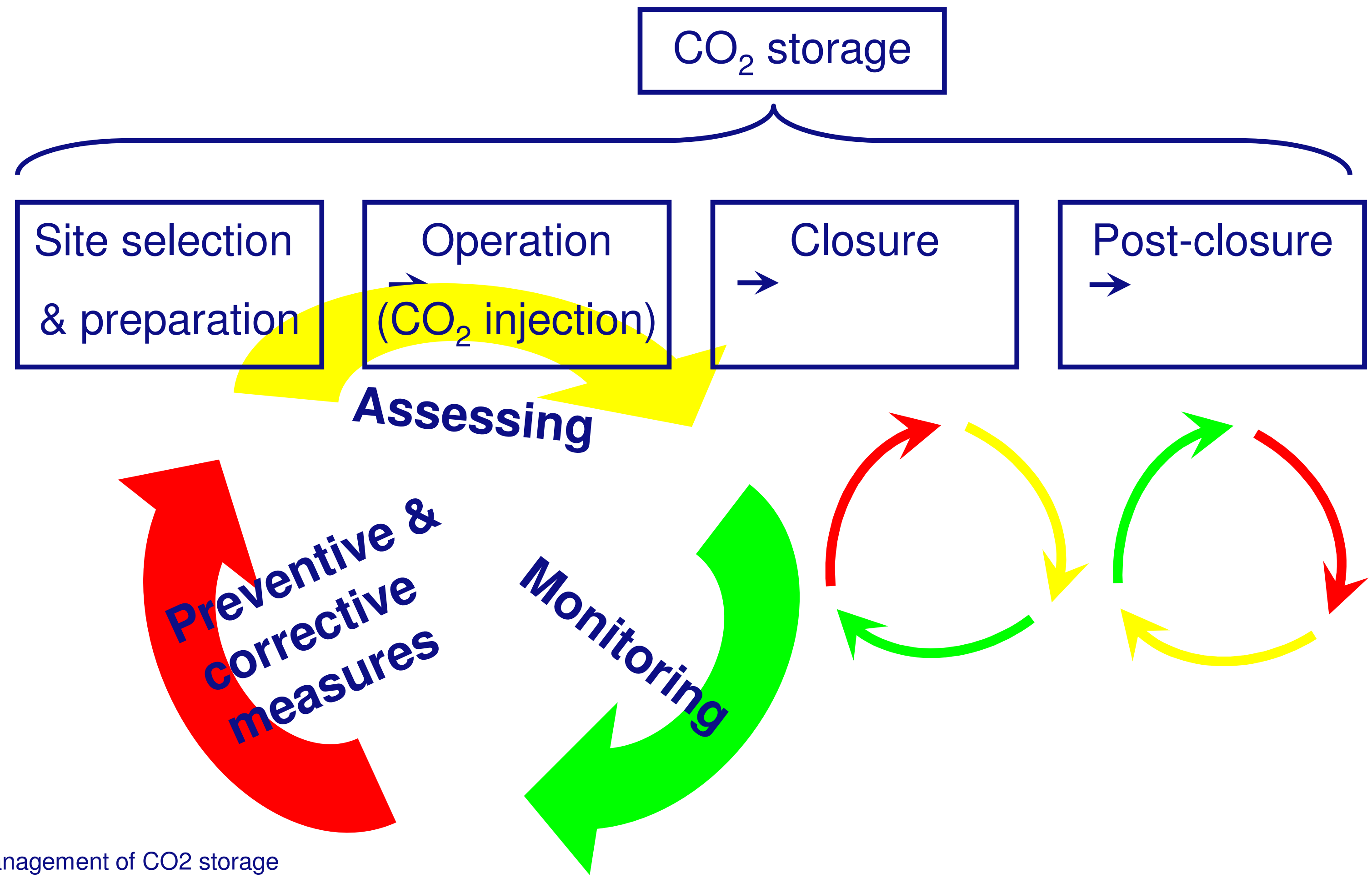


Risk management

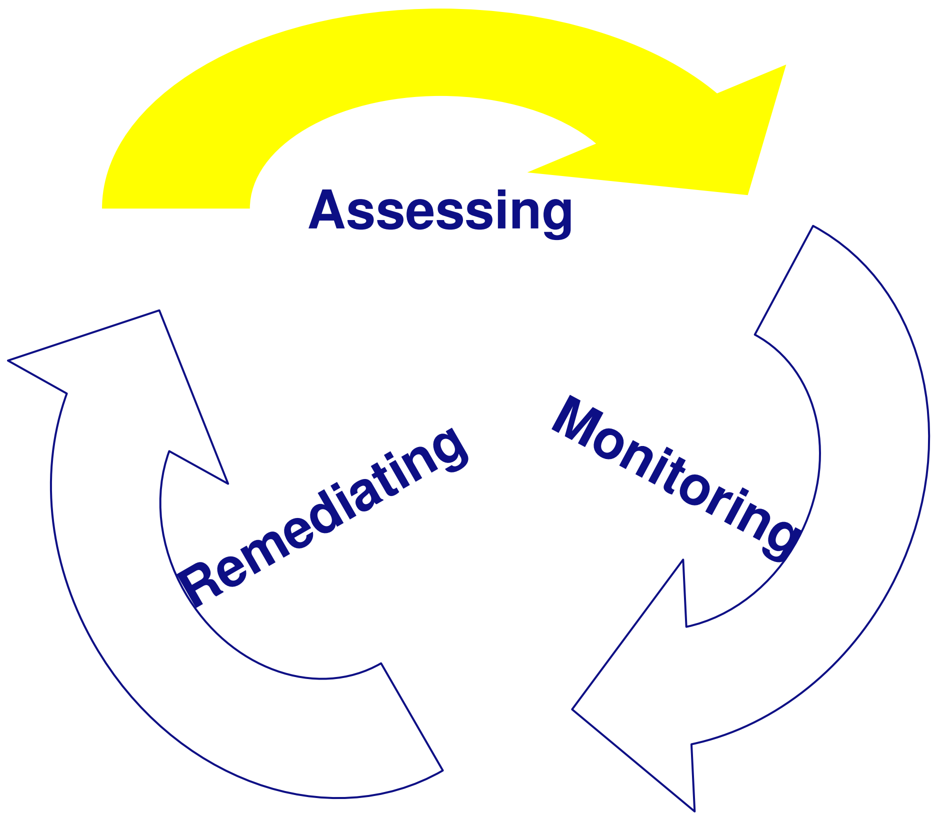
- The process of assessing, monitoring and mitigating risks during the lifetime of a CO_2 storage facility so that they can be kept below pre-defined performance/risk levels.

- The active process of risk management comes to an end when the facility has reached a fail-safe condition.

Risk management during CO_2 storage lifecycle



Risk management
I. Assessing risks



Risk assessment

Objective

- Identify and evaluate risks which may affect the containment of CO_2 and can lead to leakage of CO_2

1. Assessment basis

Defining the scope and purpose of assessment

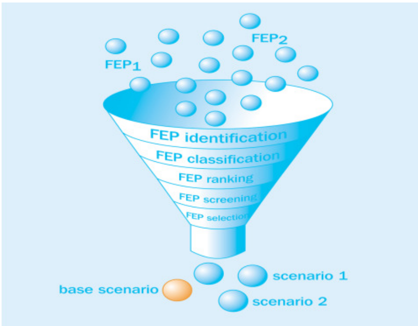
2. Qualitative assessment

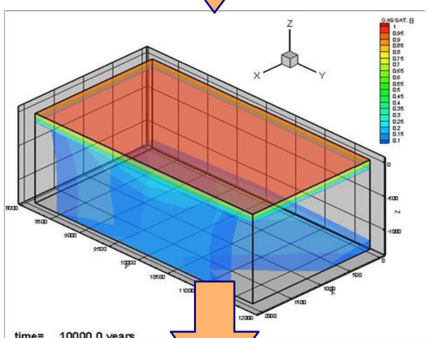
Review of existing programme of technical studies

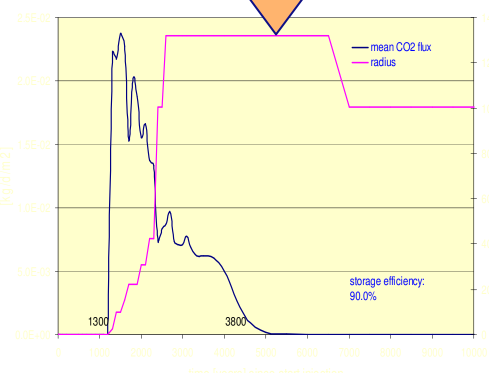
3. Quantitative assessment

Quantitative evaluation of CO_2 containment

Risk Assessment Work Flow







Risk management of CO2 storage

Definition of assessment basis

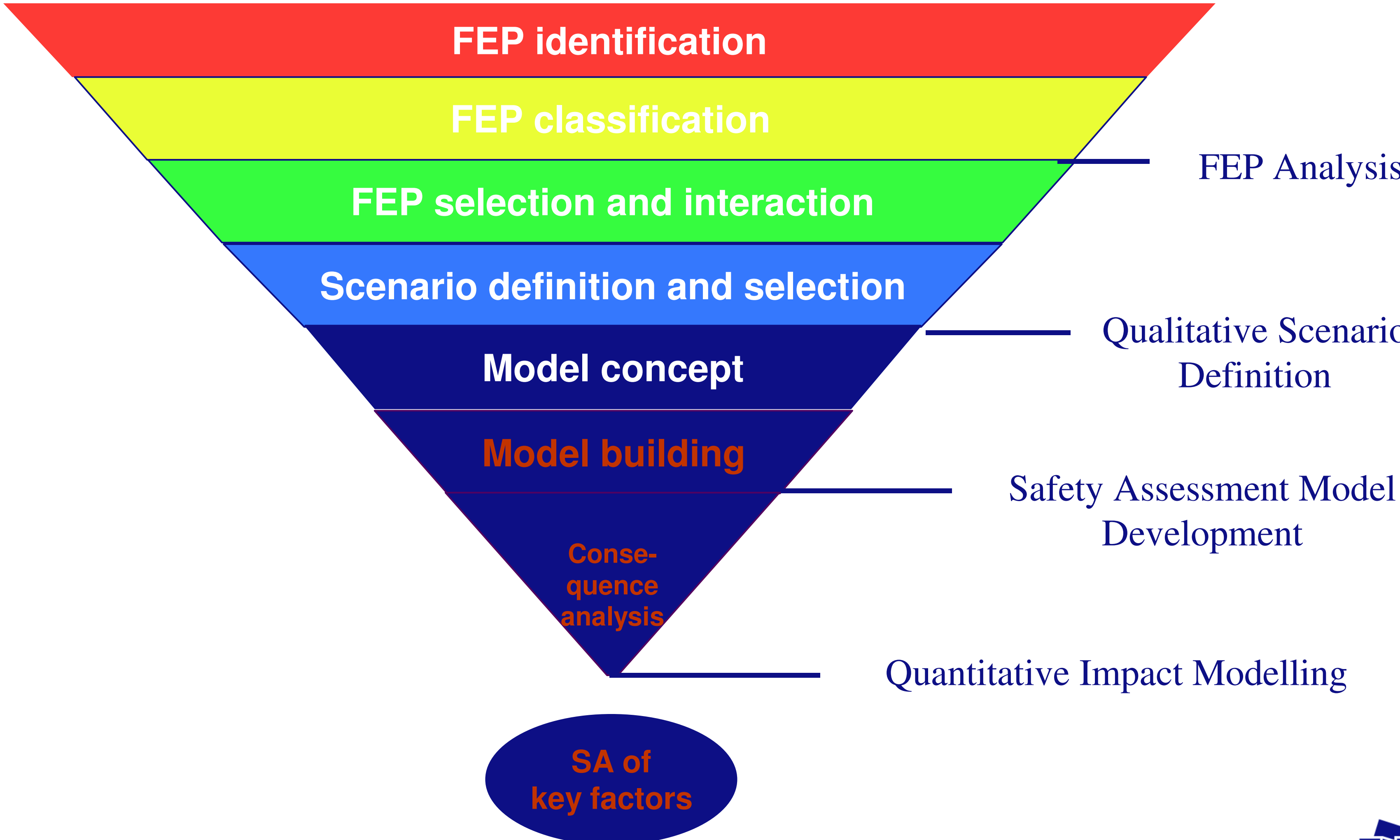
Qualitative

- **Scenario analysis**
  - FEP identification/ classification → FEP ranking/ screening → FEP interaction/ grouping
  - ↓ Scenario (element) formation
  - ↓ Conceptual model development

Quantitative

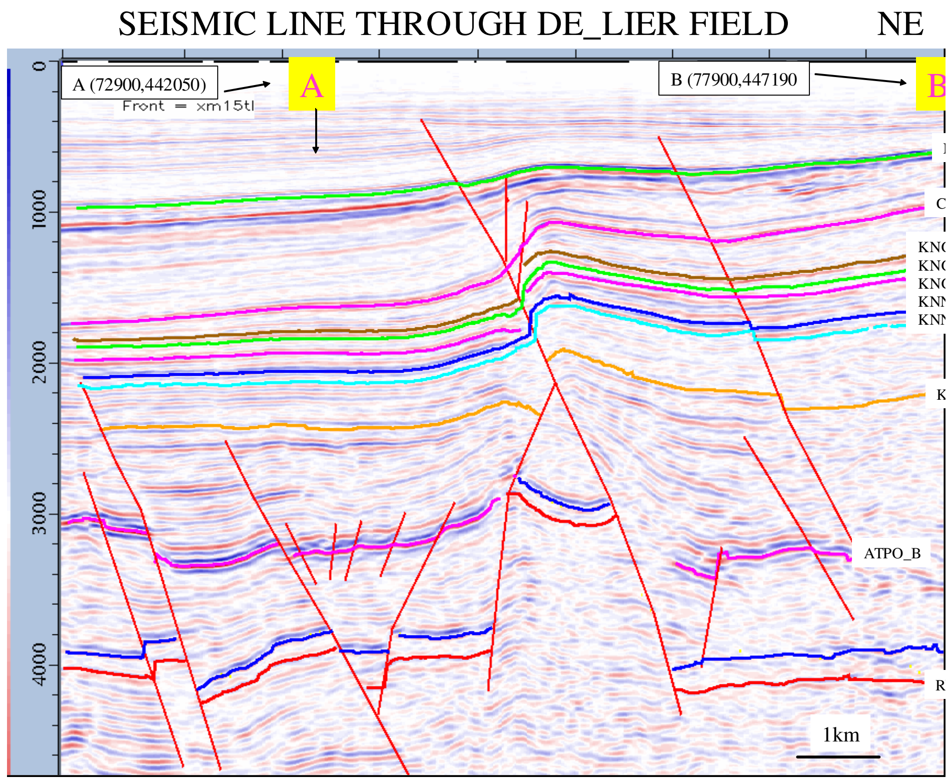
- **Model development**
  - Conceptual model development → 3D <> 2D numerical model → Testing with (natural) analogues
- **Consequence analysis**
  - ↓ Probabilistic 2D numerical simulation
  - ↓ Statistical processing/ assessment

Qualitative scenario analysis



1. Defining the assessment basis

- Geographical and geological setting
- Containment concept
- Assessment target



2. Qualitative assessment

Objective

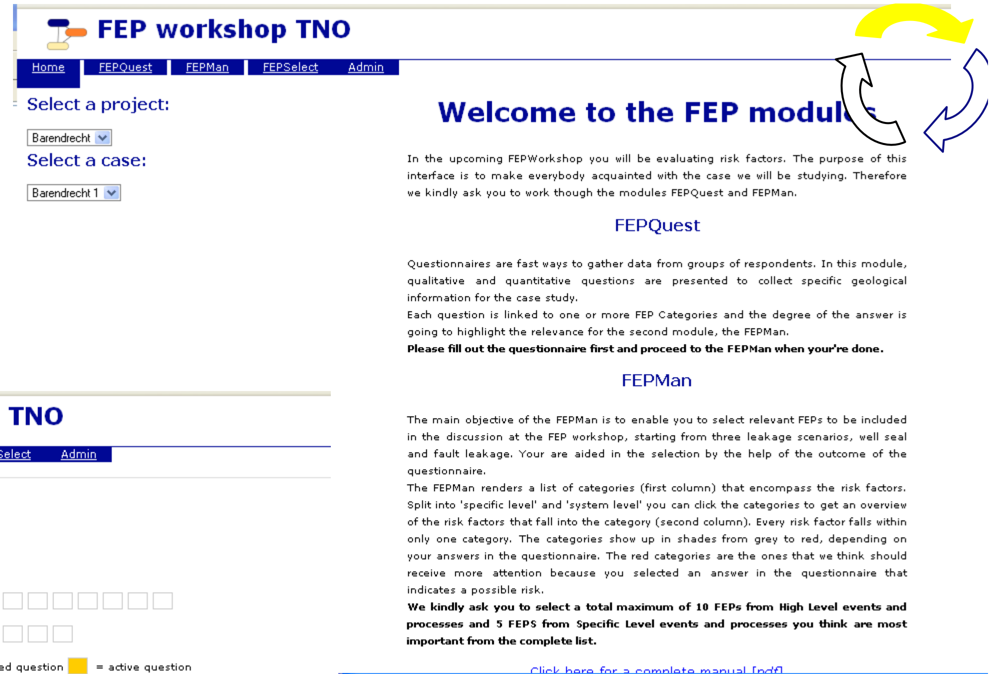
- Evaluate completeness of programme of technical studies

Qualitative assessment

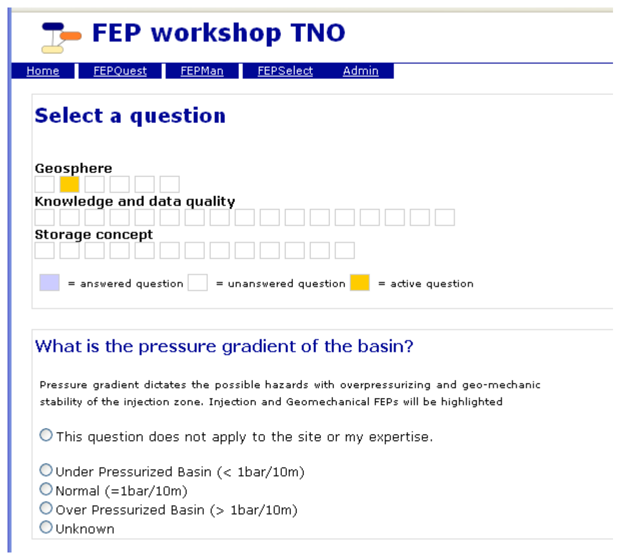
1. Preparation and screening of the FEP database
2. Ranking of FEPs by experts
3. Preparation of a workshop document for the experts
4. Input of the experts is processed by TNO
5. Workshop with experts: Identifying leakage paths and related FEPs
6. Brief report of the conclusions of the workshop: Review of existing programme of technical studies

Improvements

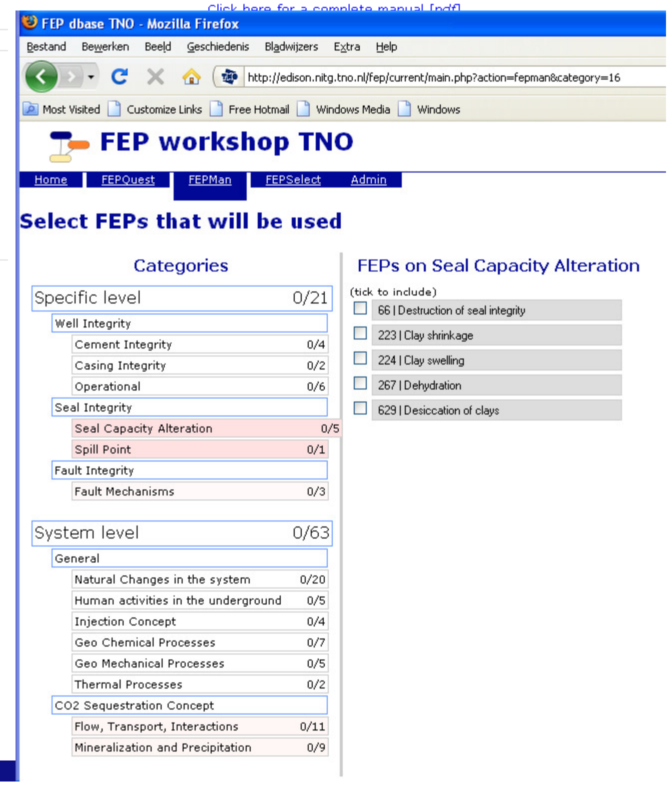
- SQL database – web based



- Questionnaire



- Online Database Manager (FEPMan)



Outcome and Expected Results of FEP Workshop

- Initial step for feasibility study
- Risk scenario formation
- Gain confidence on suitability and feasibility of the site
- Traceability and transparency for the decision making

3. Quantitative assessment

Objective

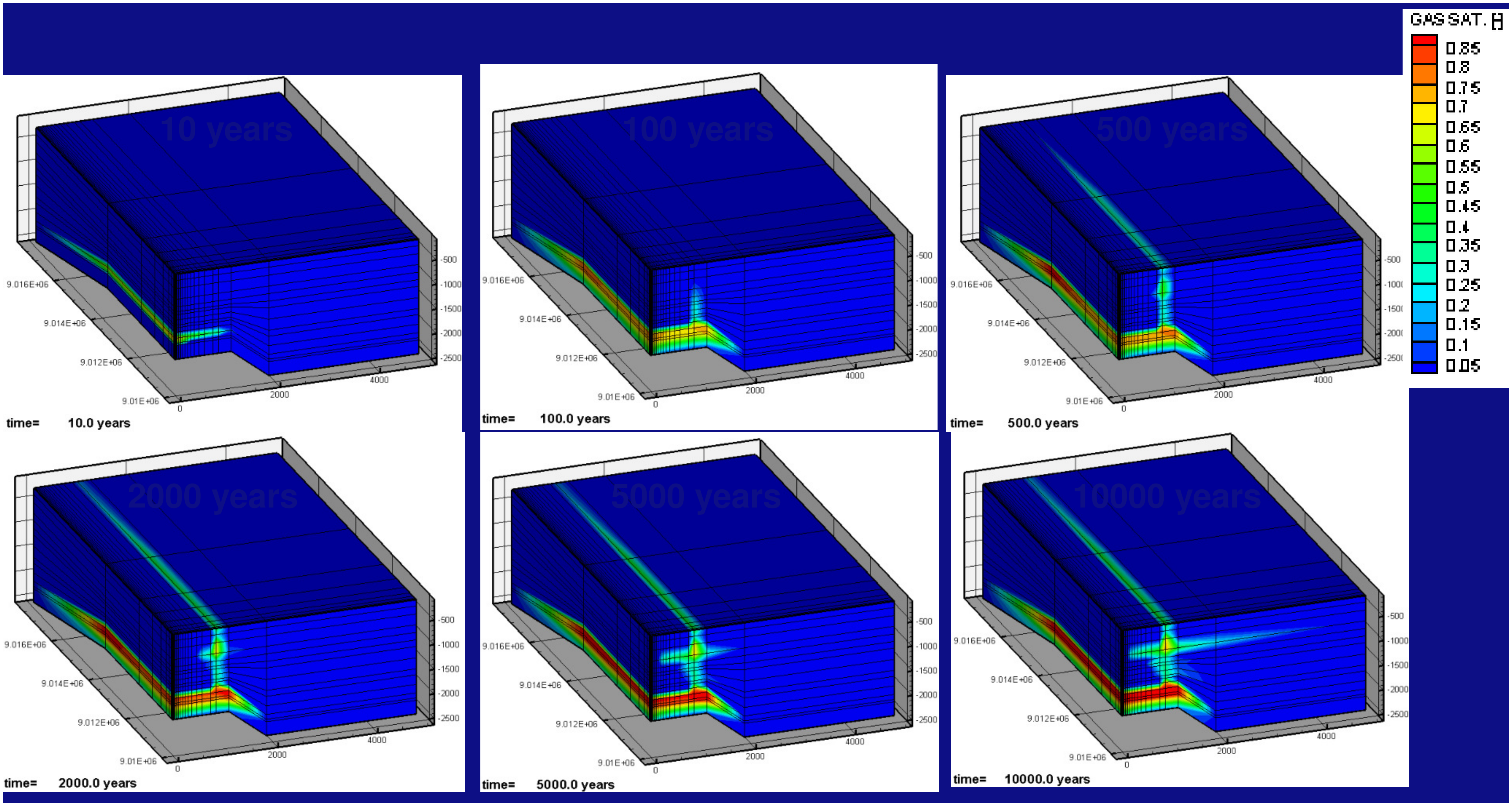
- Quantitative evaluation of risks which may affect the integrity of the storage site and can lead to leakage of CO_2
- Predict the performance, i.e. the leakage rates, of CO2

- Research items
- Analysis of seal integrity (C, M)
- Reservoir integrity (F, C)
- Well integrity (C, M)

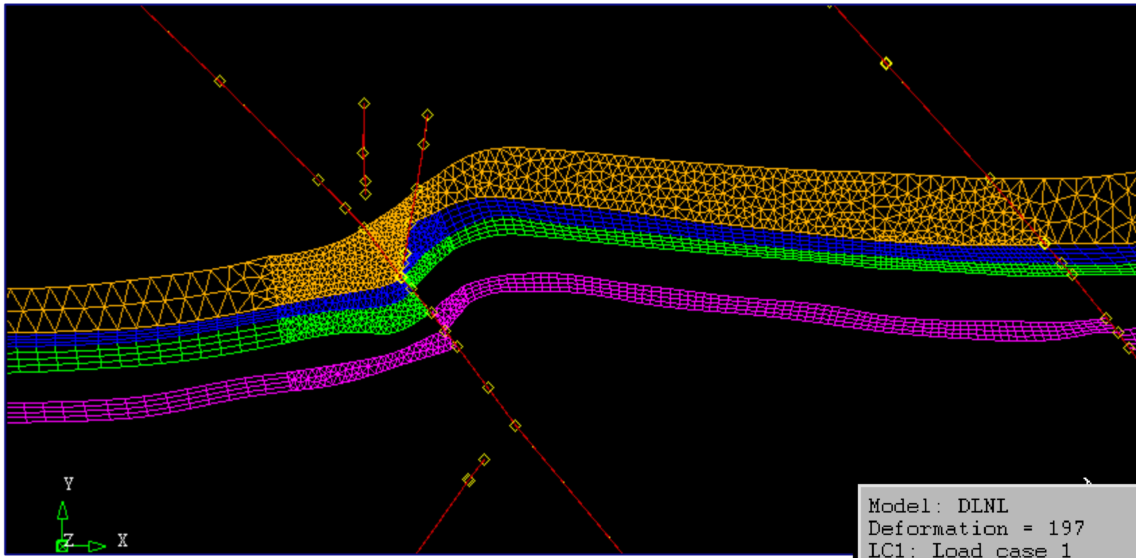
- Methods:
- Numerical Models and Reservoir Simulators
- Deterministic and Probabilistic Models

(F = Fluid flow processes)
(C = Chemical processes)
(M = Mechanical processes)

Performance Assessment (PA)
Fault leakage

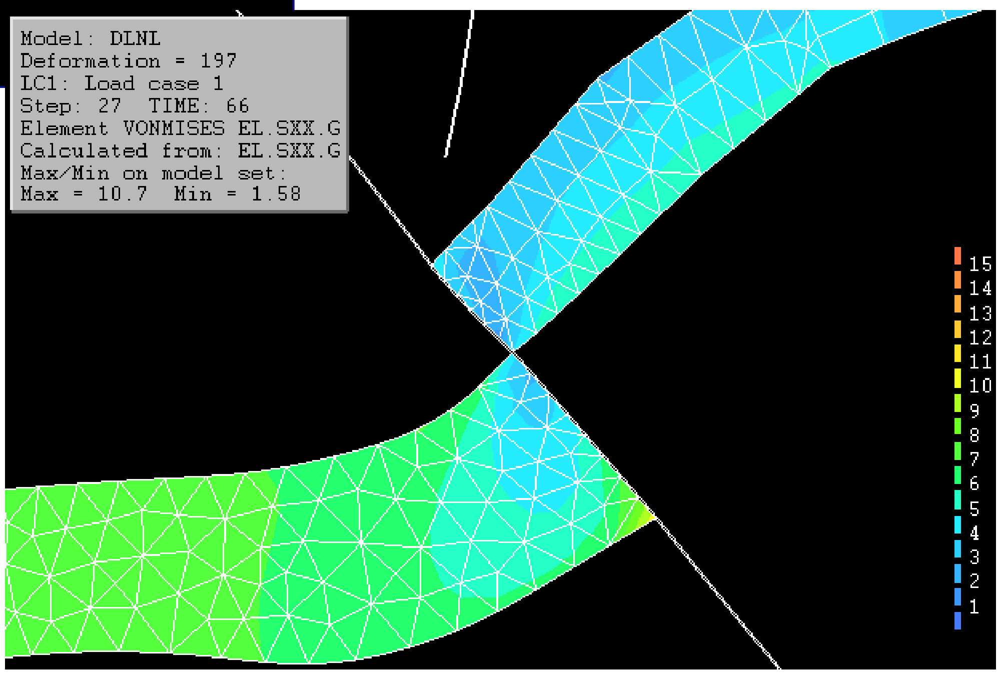


Mechanical seal and fault integrity



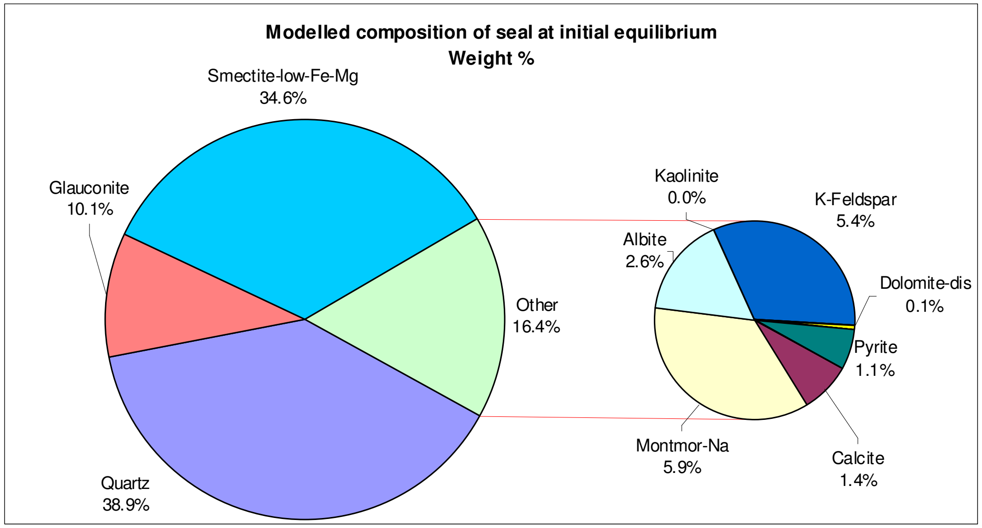
Fracture propagation:

PWRI-Frac simulator

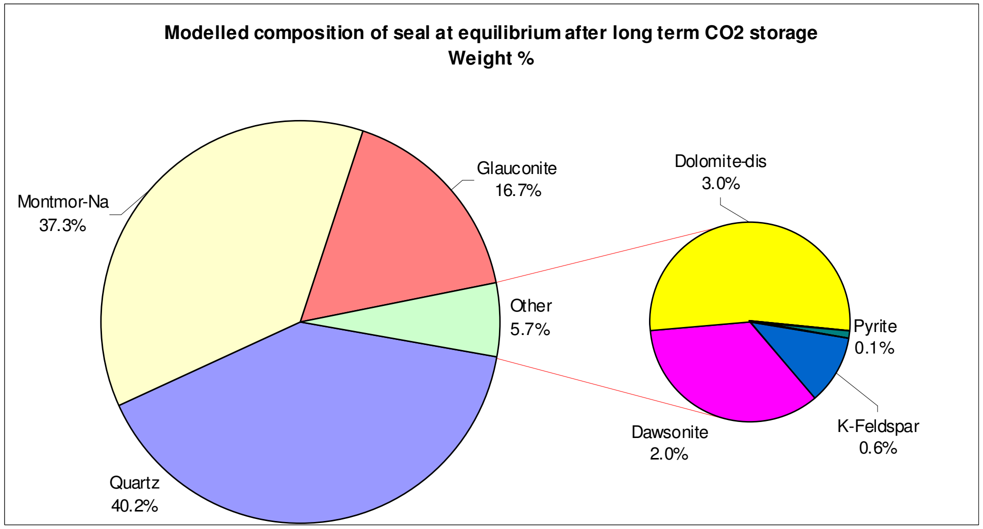


The largest stress change at reservoir edges

Chemical integrity of reservoir and seal

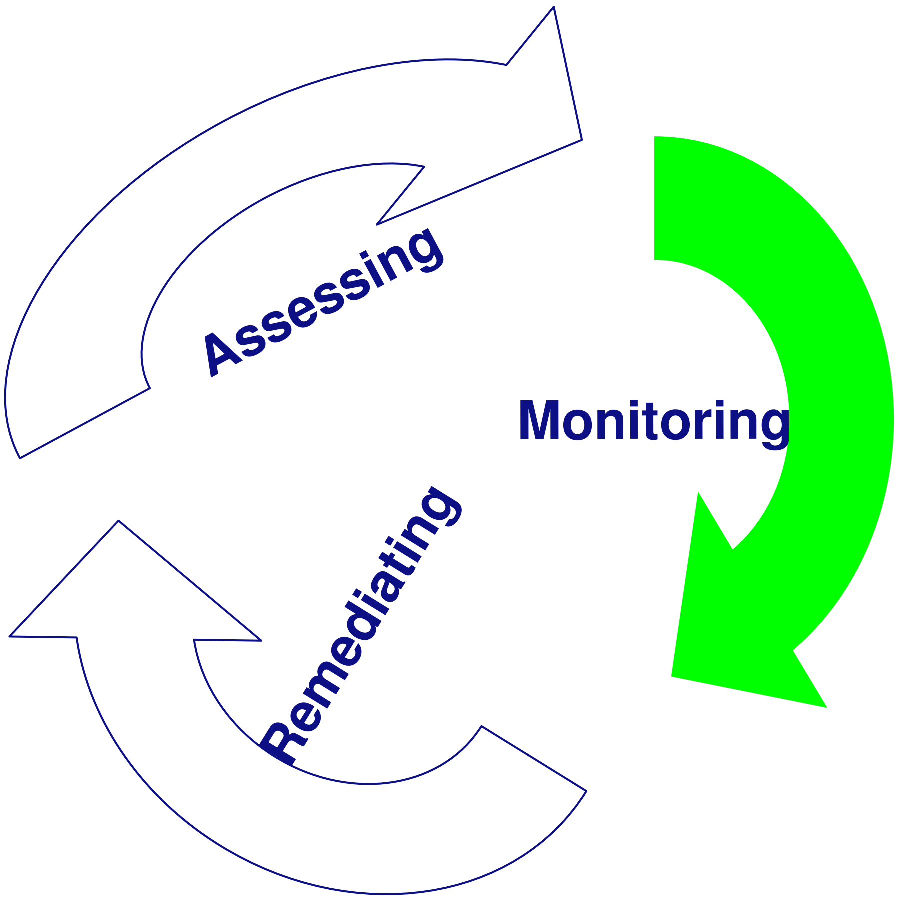


Significant re-arrangement Minerals



Decreased porosity

Risk management
II. Monitoring risks



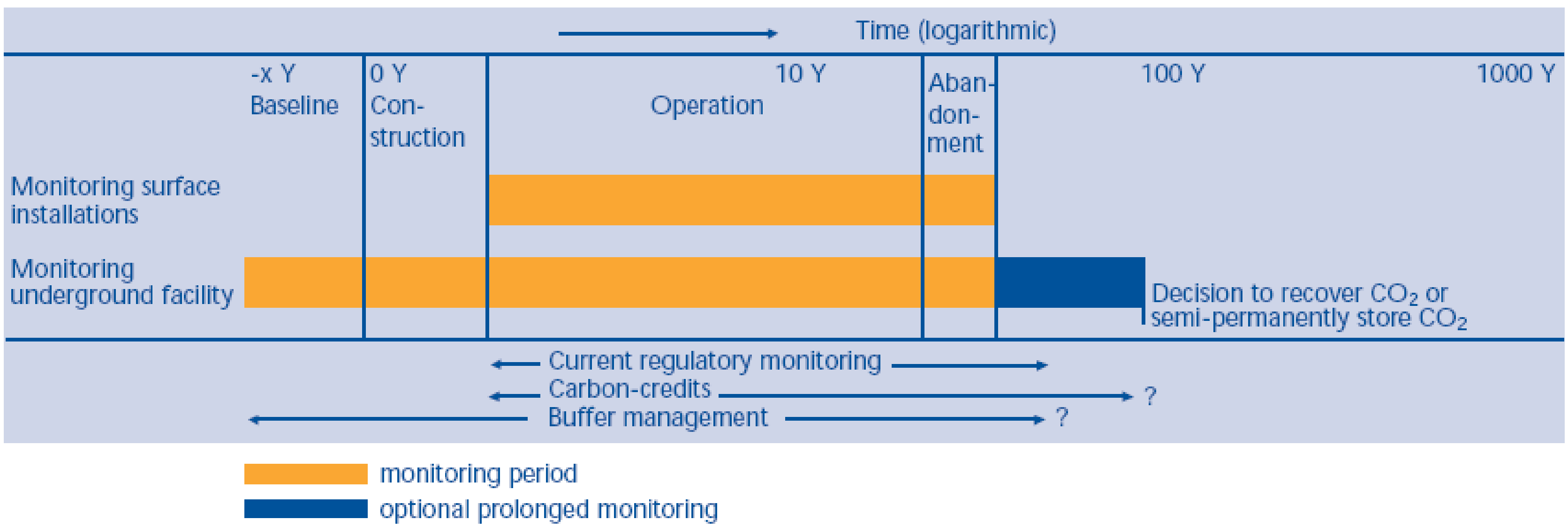
Risk Management: 2. Risk – based Monitoring

Monitoring requirement:

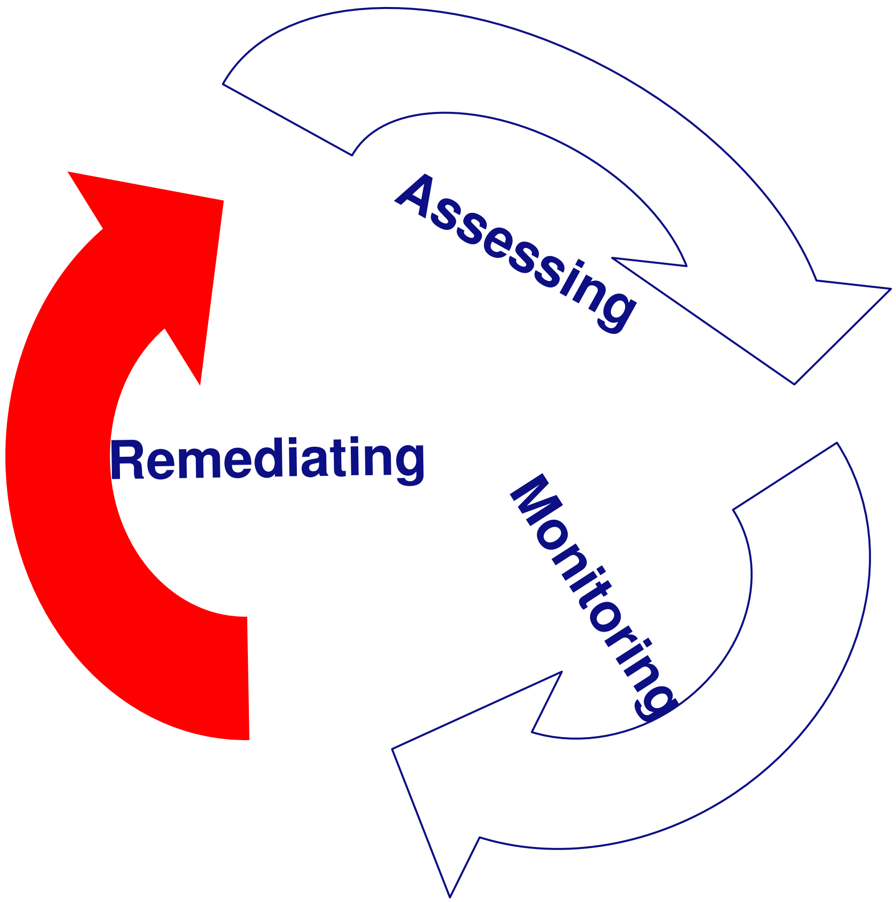
- Provide (short-term) measurements to test long-term assessment

Other monitoring purposes

- Operational monitoring
- Control HSE criteria
- Initiate mitigation measures
- Verify for emission trading
- Understand storage process
- Test novel monitoring technique
- Visualise storage for public



Risk management
III. Remediating risks



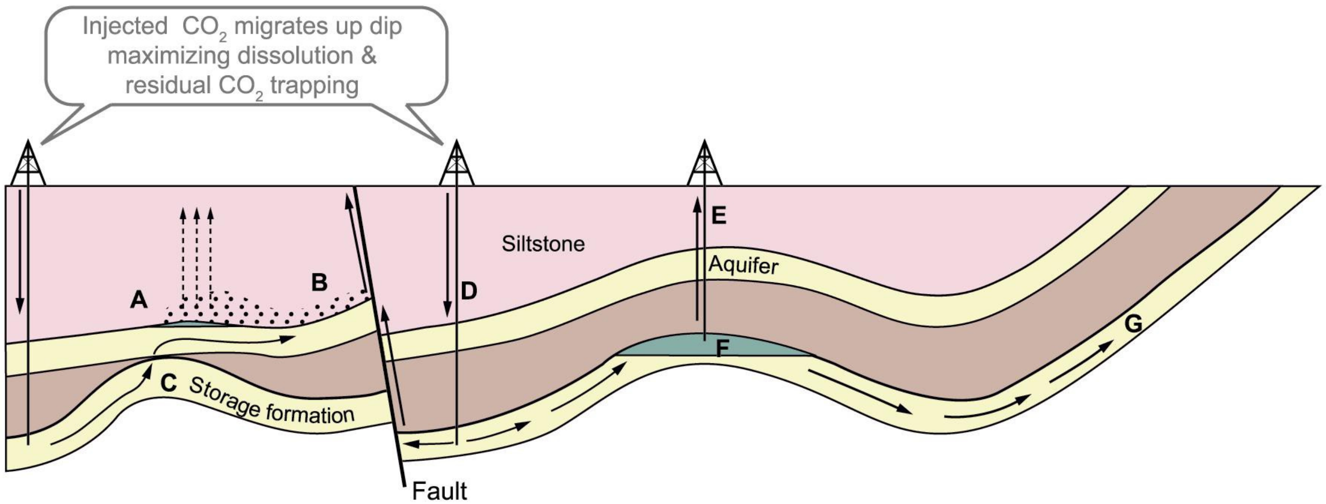
Risk management: 3. Mitigation

- *Control measures of*

  preventive nature
  - Site characterization
  - Engineering design

  corrective nature
  - Adapt operation plan
  - Adapt engineering design
  - Stop injection
  - Release injected CO_2

Risk management:
3. Mitigation measures



Potential Escape Mechanisms

- **A.** CO_2 gas pressure exceeds capillary pressure & passes through siltstone
- **B.** Free CO_2 leaks from A into upper aquifer up fault
- **C.** CO_2 escapes through 'gap' in cap rock into higher aquifer
- **D.** Injected CO_2 migrates up dip, increases reservoir pressure & permeability of fault
- **E.** CO_2 escapes via poorly plugged old abandoned well
- **F.** Natural flow dissolves CO_2 at CO_2 / water interface & transports it out of closure
- **G.** Dissolved CO_2 escapes to atmosphere or ocean

Remedial Measures

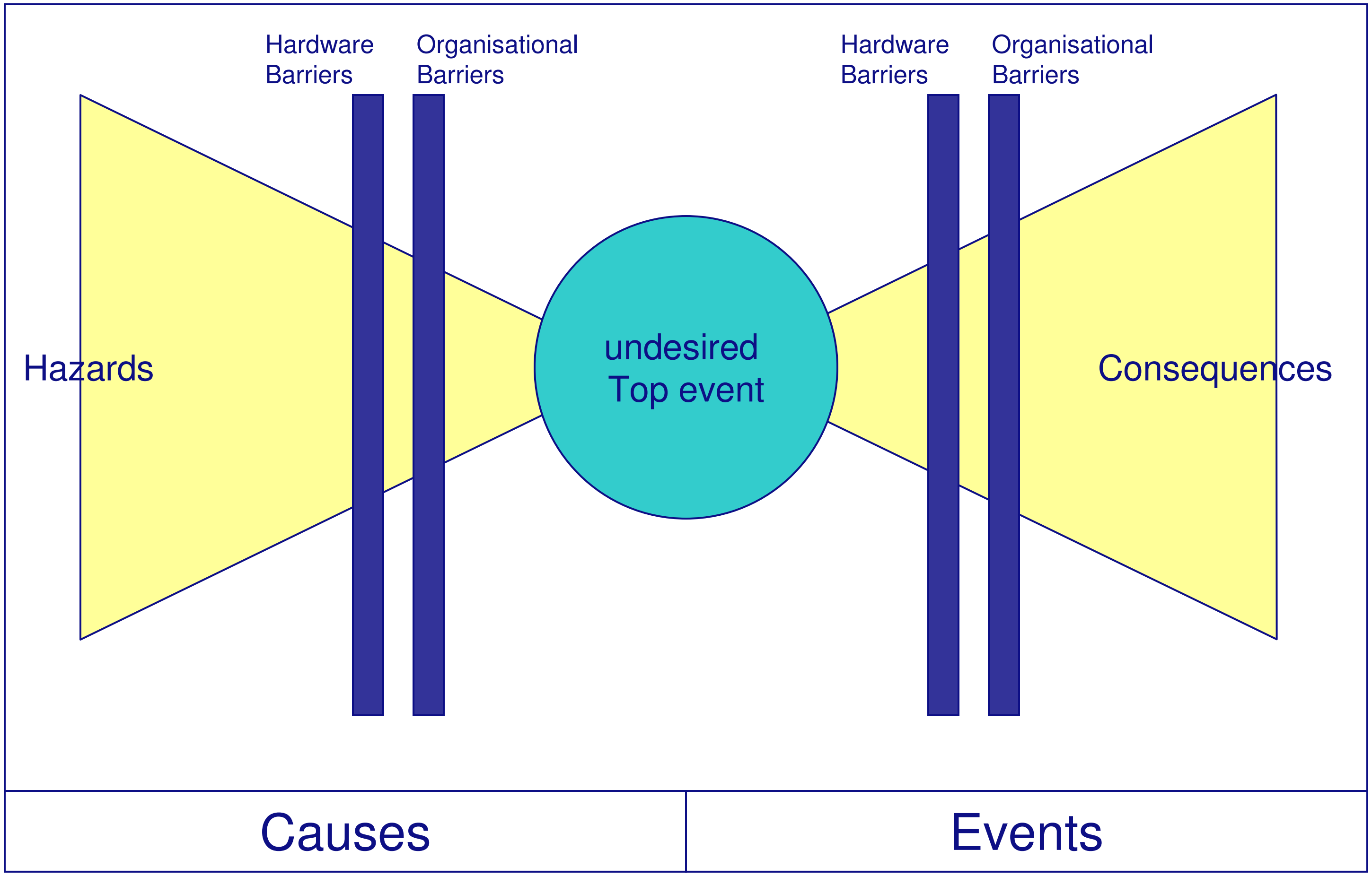
- ***A.** Extract & purify ground-water*
- ***B.** Extract & purify ground-water*
- ***C.** Remove CO_2 & reinject elsewhere*
- ***D.** Lower injection rates or pressures*
- ***E.** Re-plug well with cement*
- ***F.** Intercept & reinject CO_2*
- ***G.** Intercept & reinject CO_2*

Closing remarks

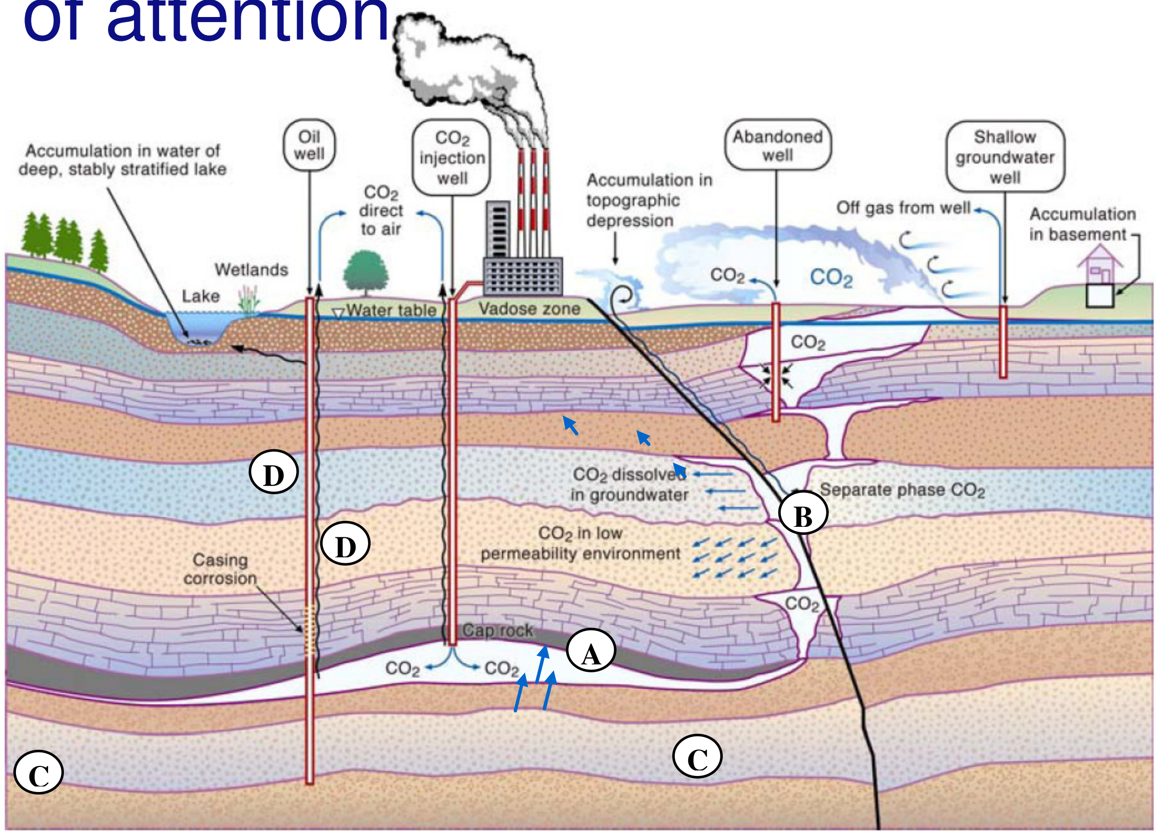
- Typicality of CO_2 storage:
  - long-term component
- No monitoring possible over a very long time period
  - Put emphasis on prevention (through proper site selection and characterisation)
  - Assess on sound scientific basis
- External factors
  - Be comprehensive in hazard/risk identification
- Large uncertainty in properties
  - Apply conservative approach or probabilistic approach
- Limited evidence to date
  - Natural and industrial analogues

TNO

Bow tie Risk model



Main points of attention



Hazards	**Barrier**
• Well integrity • Cap rock • Faults • Spill point	} Monitoring

Well Integrity Failure:
Main Hazards(1)

- Hazard
  - Failure of casing
  - Failure of cement plugs or sheath

- Barriers
  - CO_2 resistant well completion material (surface and downhole)
  - CO_2 resistant cements
  - CO_2 Blow out control and equipment
  - Well abandonment designs

  - (Time lapse) logging methods to identify hydraulic isolation, porosity- & permeabilty cement, casing corrosion, detection of flow behind casing etc.

Reservoir and caprock:
Main hazards (2)

- Hazard
  - Reactivity, dissolution, settlement and mineralization.
  - Post production caprock integrity.
  - Fracture sensitivity and injectivity behavior .
  - Dehydration of shale by CO_2 .
  - Lower CO_2 breakthrough pressures through shale (as compared to hydrocarbons).
  - Self enhanced leakage behavior .
  - Geomechanical modeling.
- Barriers
  - Thickness of seal and reservoir
  - Composition of seal and reservoir

Monitoring (barriers)

- Micro seismicity
- Down hole pressure and temperature
- Well logging
- Continuous H_2O monitoring
- Geochemical tracers
- Soil gas survey
- Others..

Messages on CO_2 storage

- CO_2 storage: *individual* site studies.
- CO_2 storage is not the usual E&P activity.
- E&P has the technical and scientific basis and best practice to make a significant contribution.
- Empty gas reservoirs have, compared to aquifers ,a proven seal for **CH_4**.
- “Indefinite future” is a long time.

Barendrecht Demonstration project

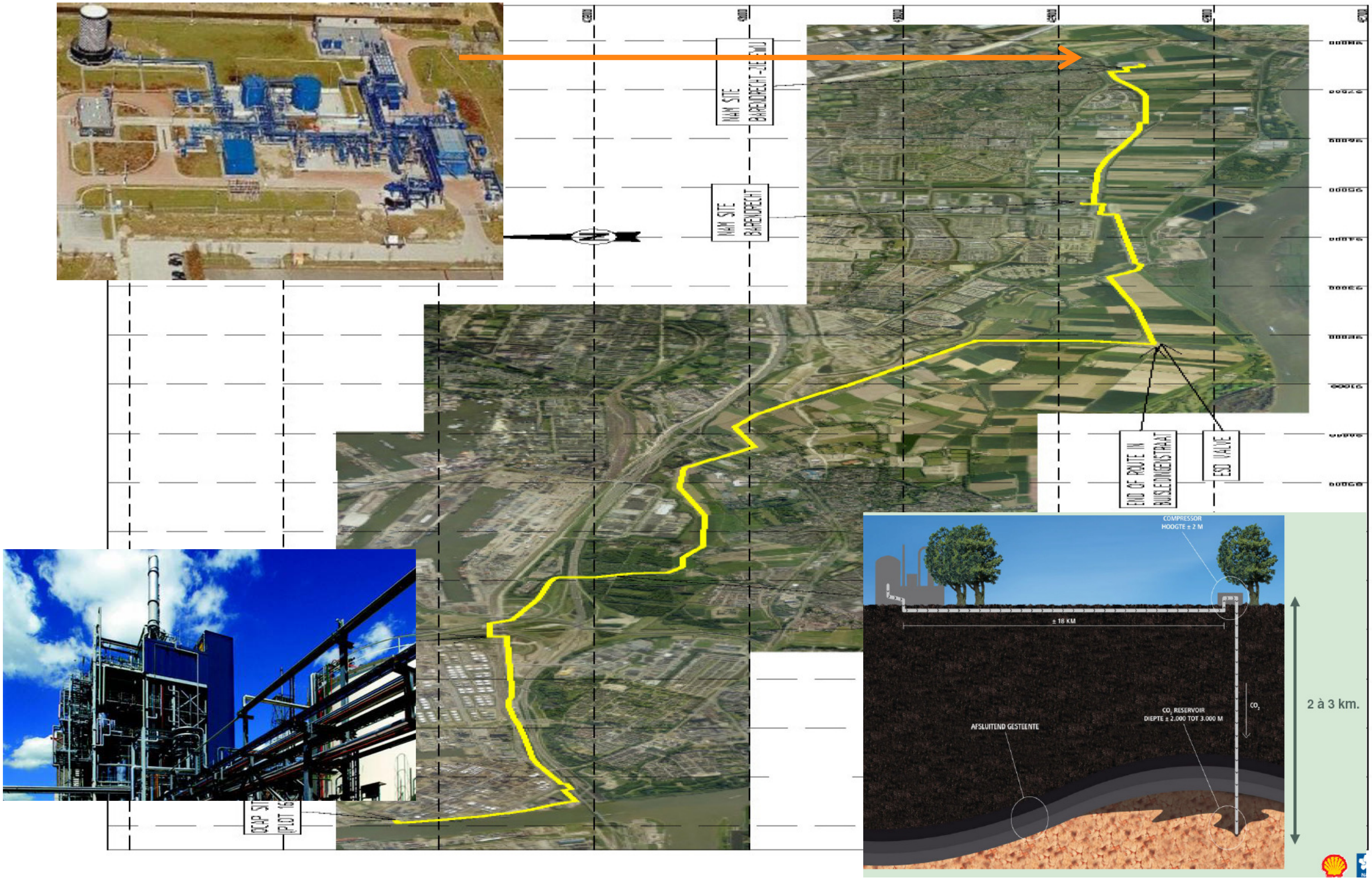
Barendrecht project scope

Pernis Refinery:
Almost 1 million tonnes of pure CO_2 annually

Winter:
400,000 tonnes CO_2 in Barendrecht reservoirs

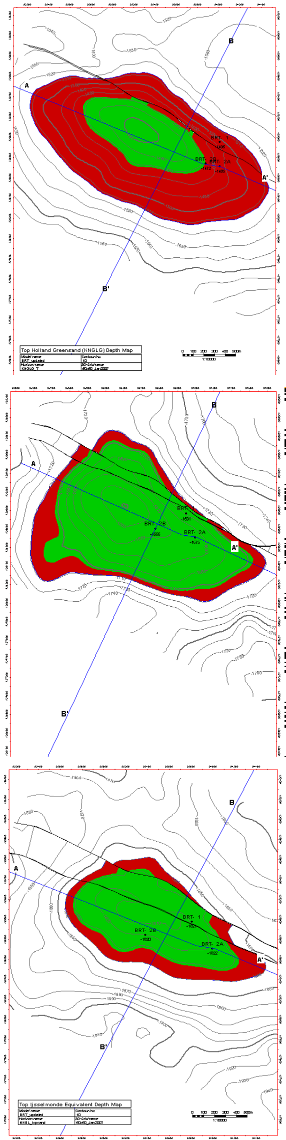
Annually:
150,000 tonnes of CO_2 to soft drinks industry

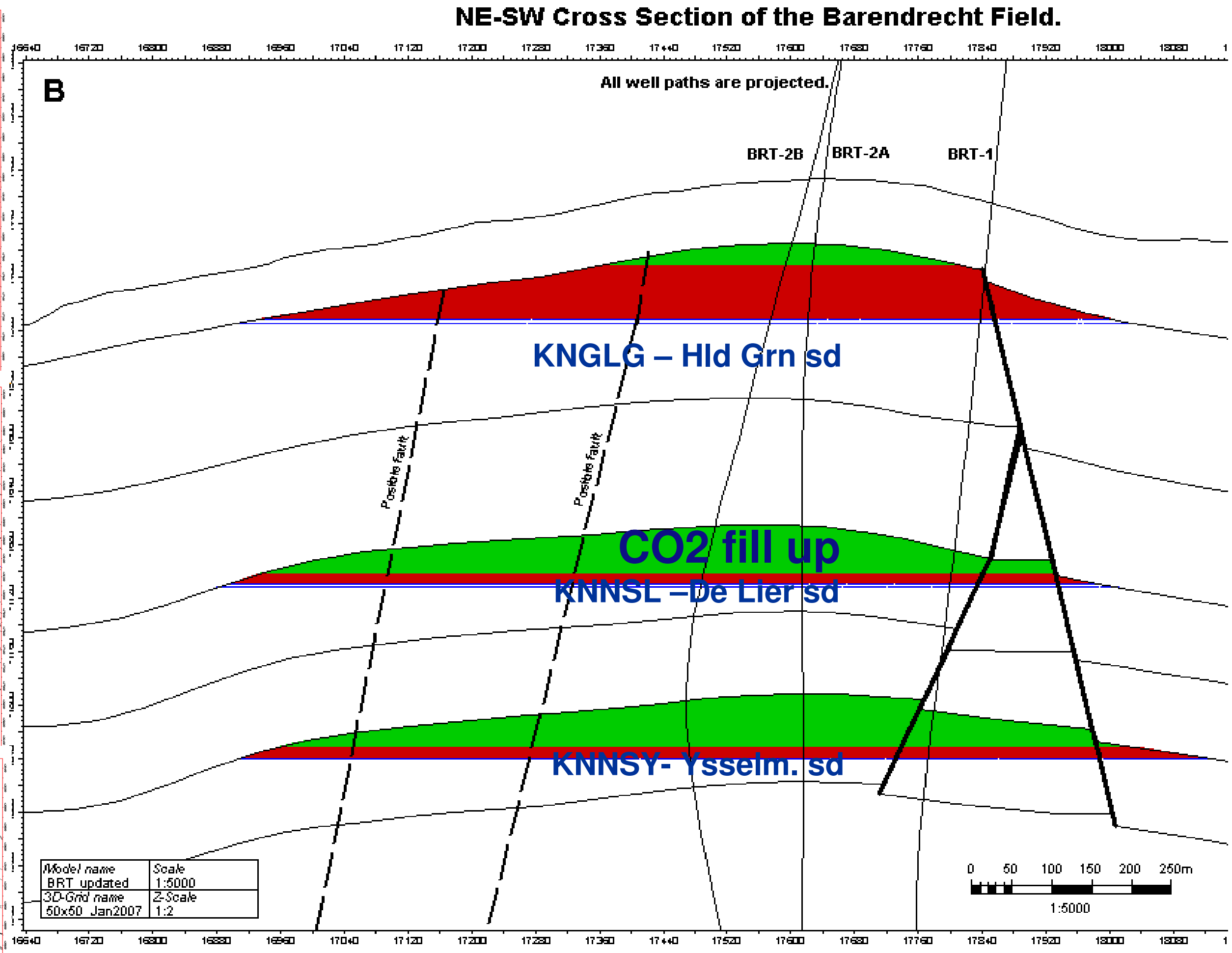
Summer:
380,000 tonnes of CO_2 to greenhouses


NAM SITE BARENDRECHT
ESD VALVE
COMPRESSOR
± 18 KM
AFSLUITEND GESTEENTE
2 à 3 km.


BARENDRECHT
BARENDRECHT-1
BARENDRECHT ZIEDEWIJ
BARENDRECHT-ZIEDEWIJ-1

Barendrecht Field

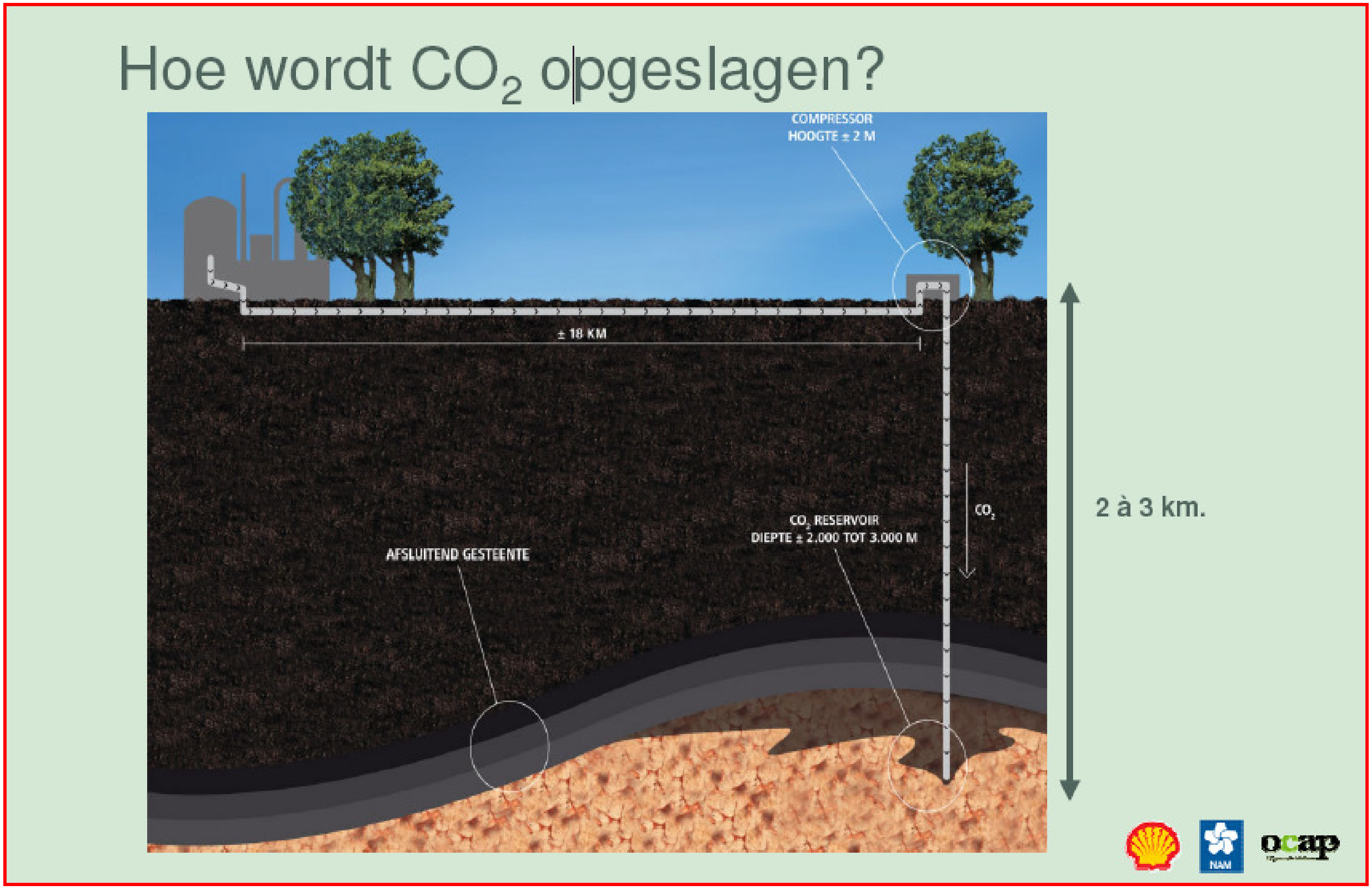




What makes Barendrecht so suitable?

- Relatively unique situation:
  - Available in short term
  - Suitable CO_2 source (>99% purity)
  - Suitable field reservoirs (safe, almost fully depleted)
  - Learnings on entire life cycle would be quickly available
  - Short distance to CO_2 source
  - Region where people take climate problem seriously and are keen to develop a CO_2 infrastructure (Rotterdam Climate Initiative)

Public misinterpreted size of trees vs depth



Barendrecht field located under populated area. Many worries not based on facts

Barendrecht-velden

Thank you!