# Assessing potential exposures to people in the post-closure period of a waste disposal facility

## IV. Option B: Modelling future climates and landscapes

**Gerhard Proehl**

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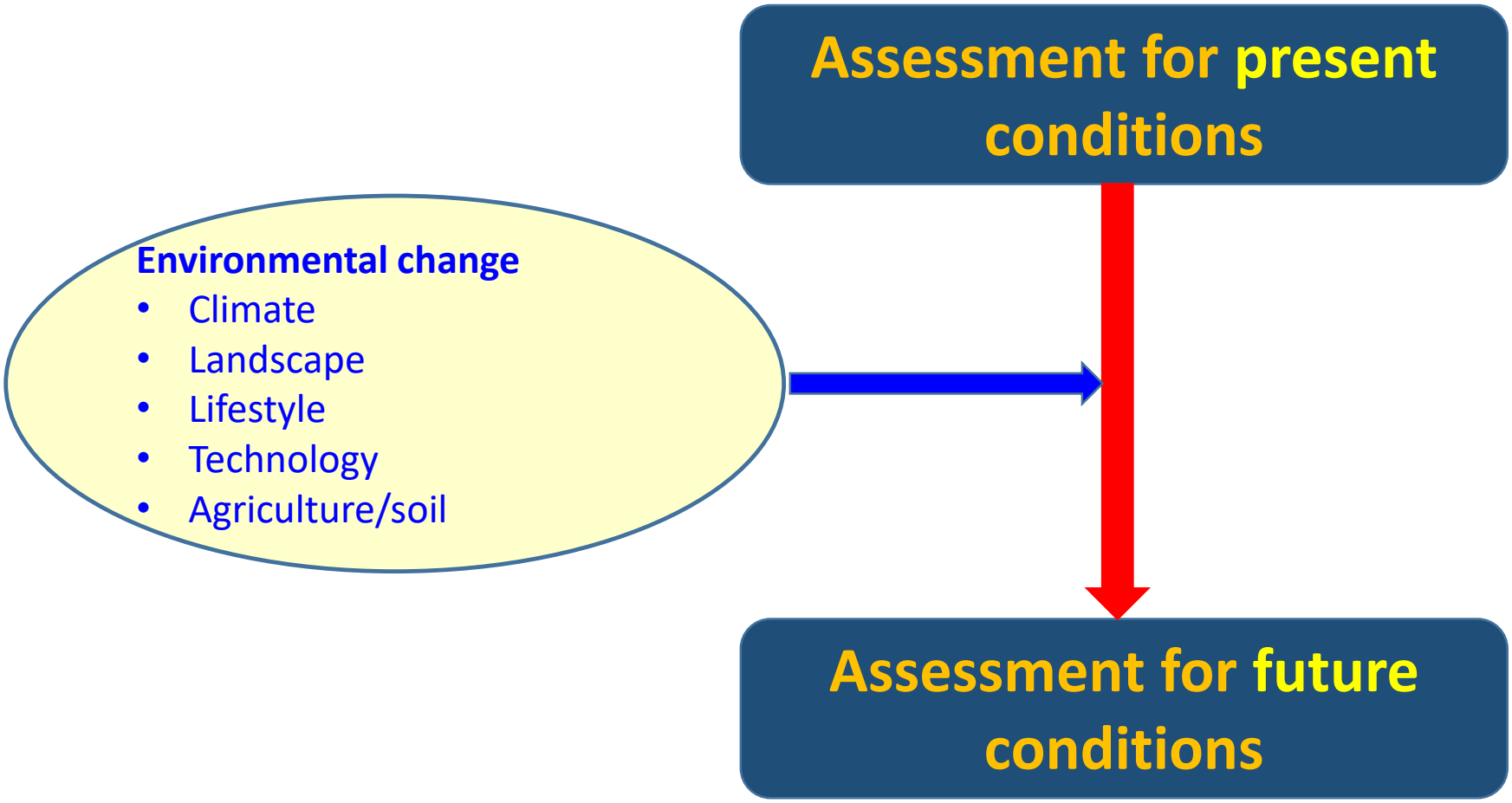
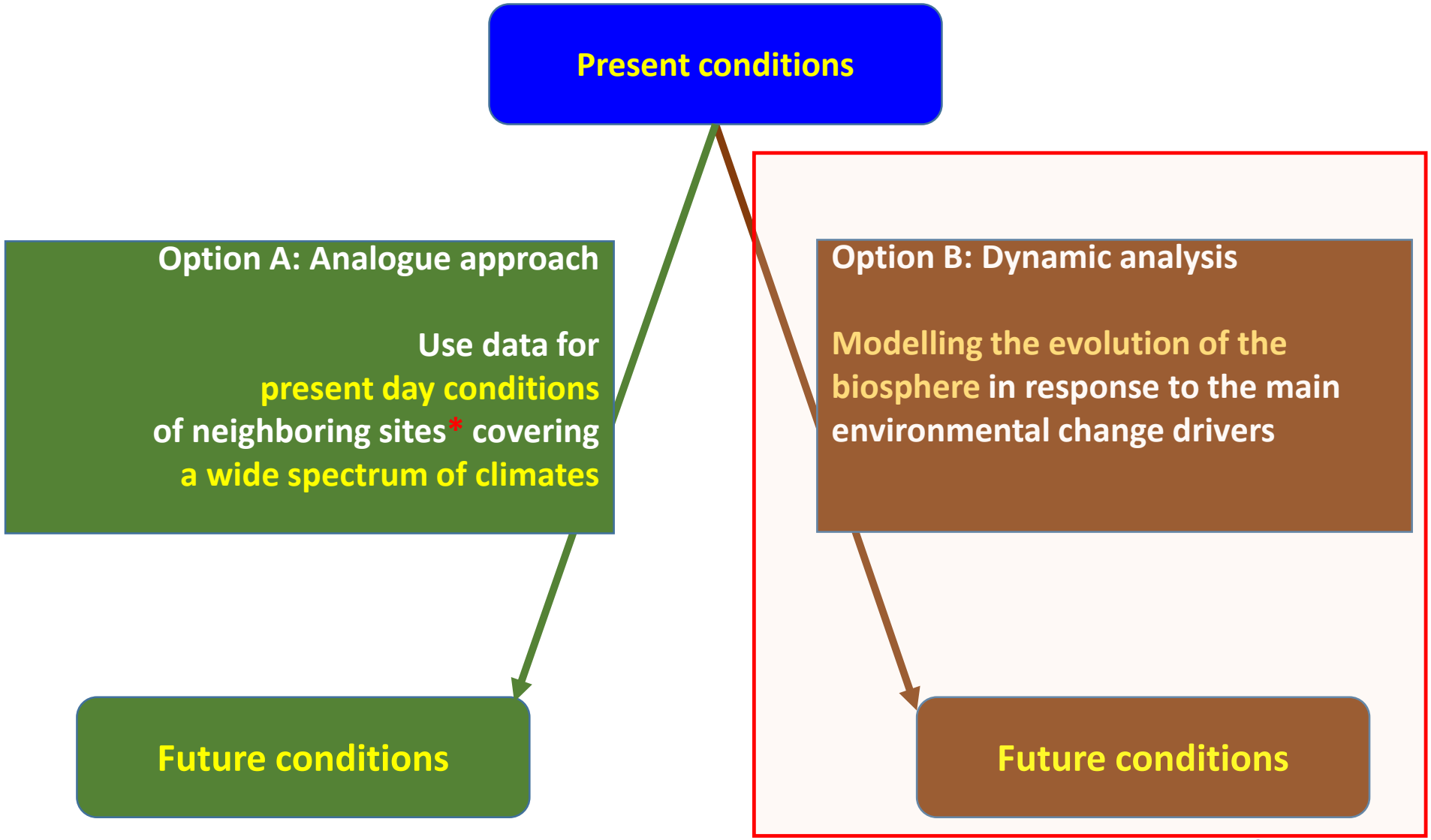
# From present to future conditions



# Options to reflect future developments




*Neighbouring sites: Selected from a radius of about 3000 km

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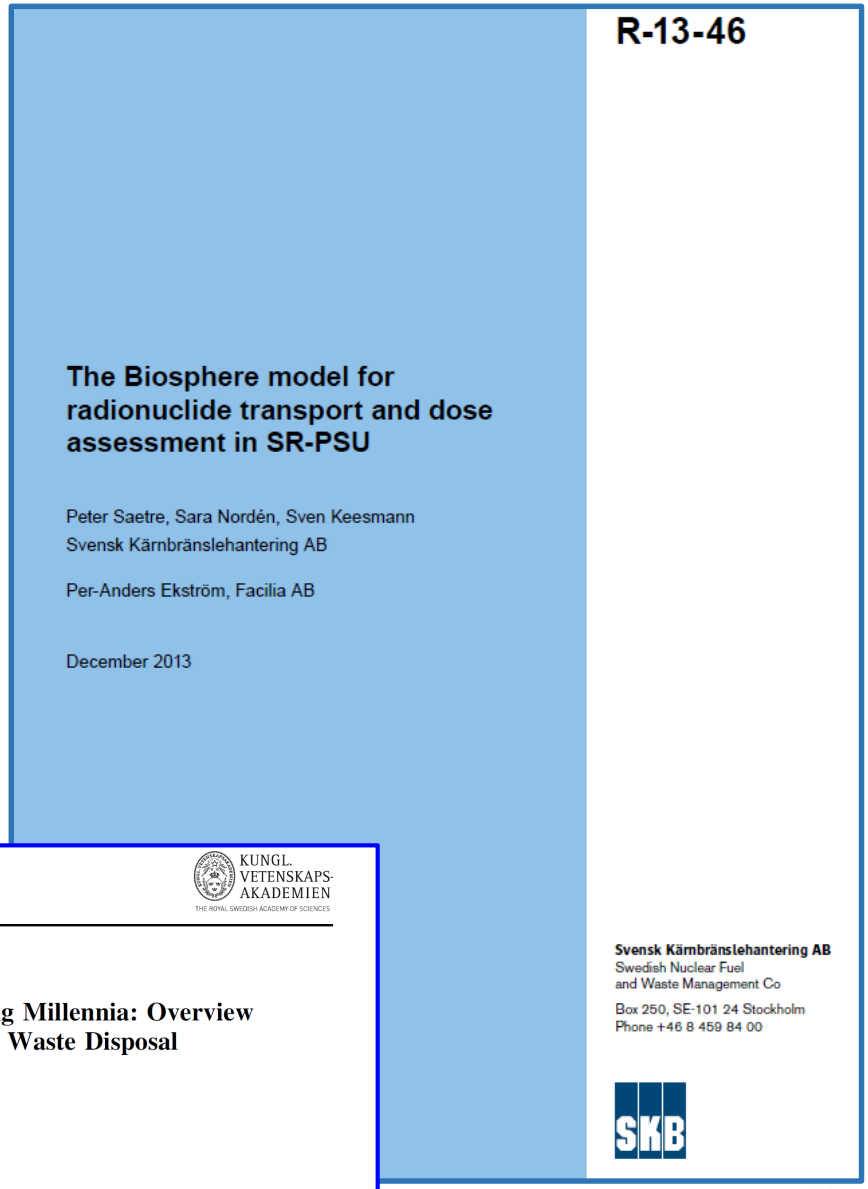
# Example for Option B



R-13-46

**The Biosphere model for radionuclide transport and dose assessment in SR-PSU**

Peter Saetre, Sara Nordén, Sven Keesmann
Svensk Kärnbränslehantering AB

Per-Anders Ekström, Facilia AB

December 2013

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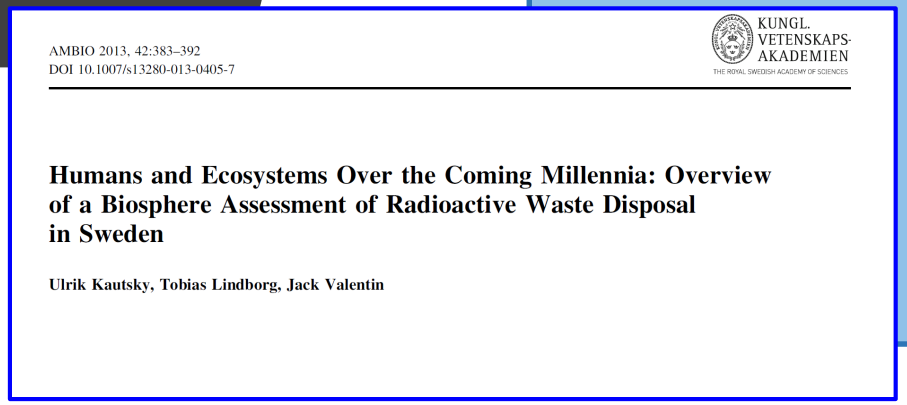

AMBIO 2013, 42:383–392
DOI 10.1007/s13280-013-0405-7

KUNGL. VETENSKAPS-AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

**Humans and Ecosystems Over the Coming Millennia: Overview of a Biosphere Assessment of Radioactive Waste Disposal in Sweden**

Ulrik Kautsky, Tobias Lindborg, Jack Valentin

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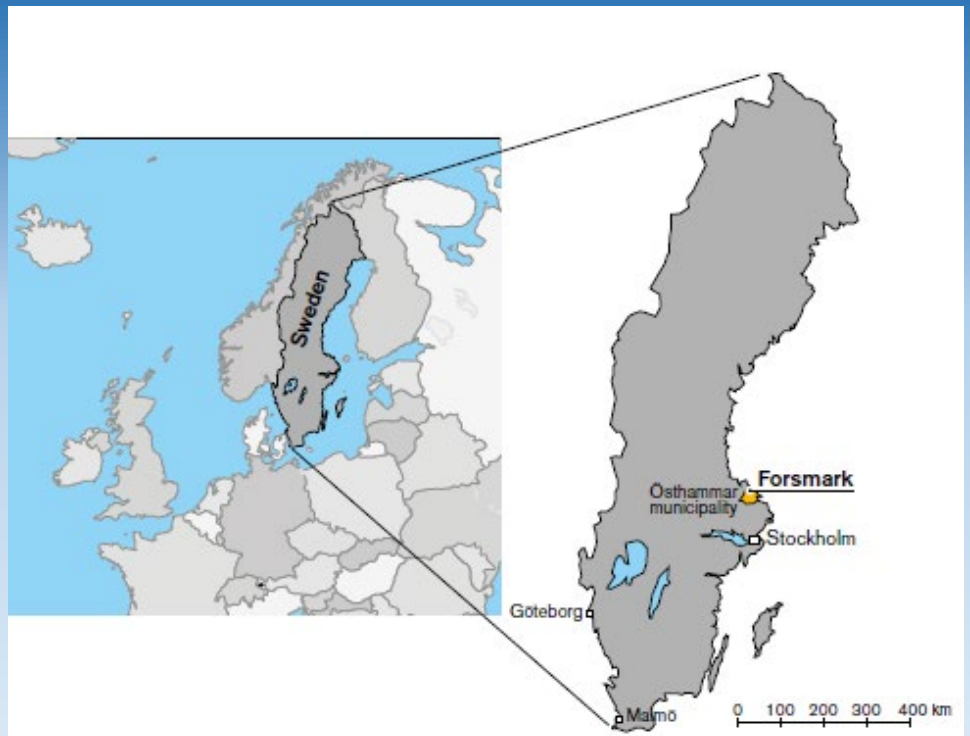
# A facility for high level waste in Sweden

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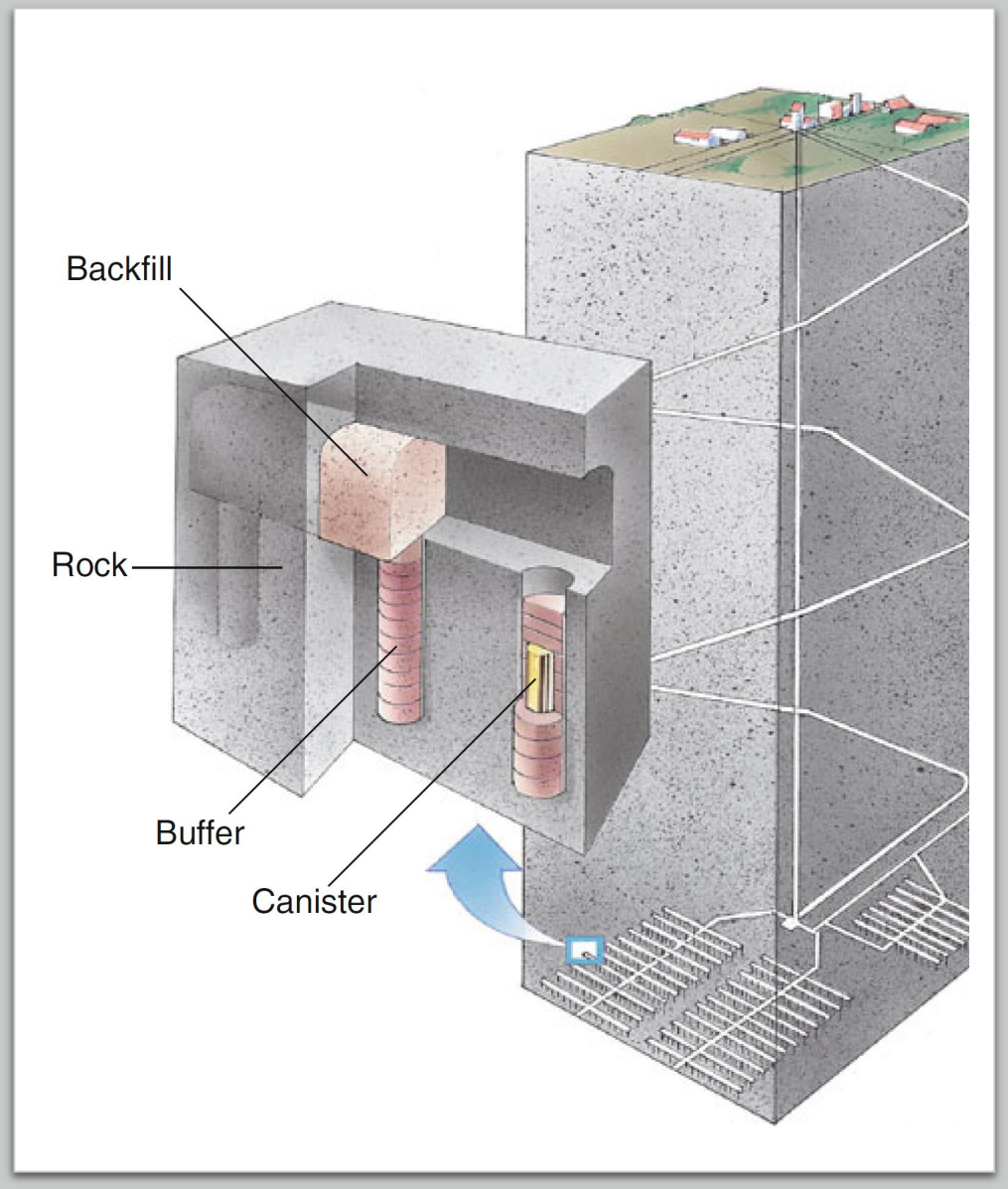


**General design of the facility**

- Spent nuclear fuel in copper canisters
- Surrounded by compacted bentonite clay
- Deposited at approximately 500 m depth
- In groundwater saturated, granitic rock

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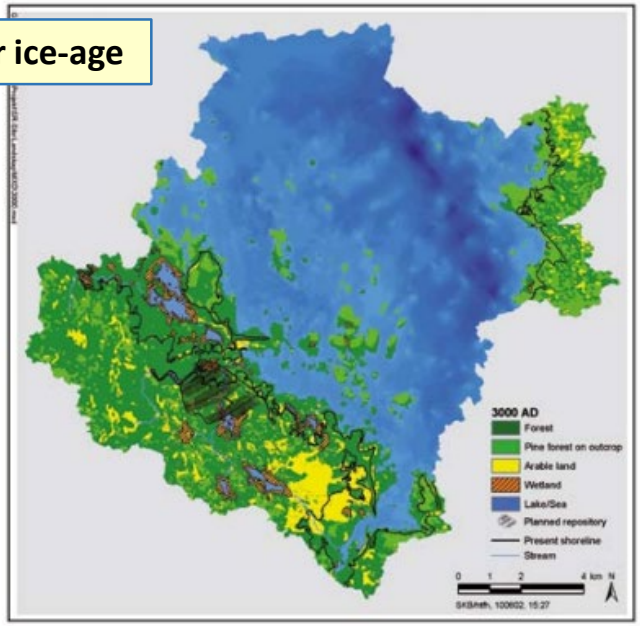
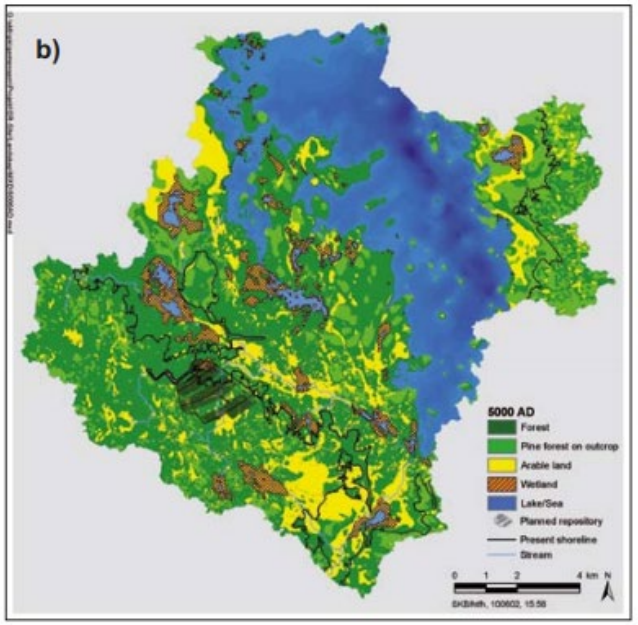
# Development of the landscape

- The site is at the shoreline of the Baltic Sea
- Since the end of the last ice-age (12000 years ago), the land is lifting,
  - The current lift rate is 6 mm/a
  - As a result, areas on the shore line, which are under water now, will dry out.
- The area develops in the order
  - **Sea**
  - **Lake**
  - **Wetland**
  - **Peat bog**
  - **Agricultural land**
- The land will develop as in the last 10000 years

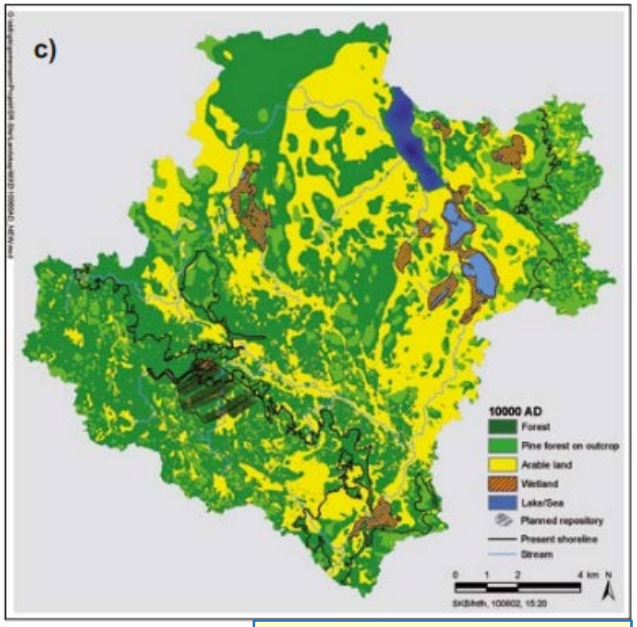
# Rise of land and change of topography at Forsmark




3000 y after ice-age




5000 y after ice-age




10 000 y after ice-age

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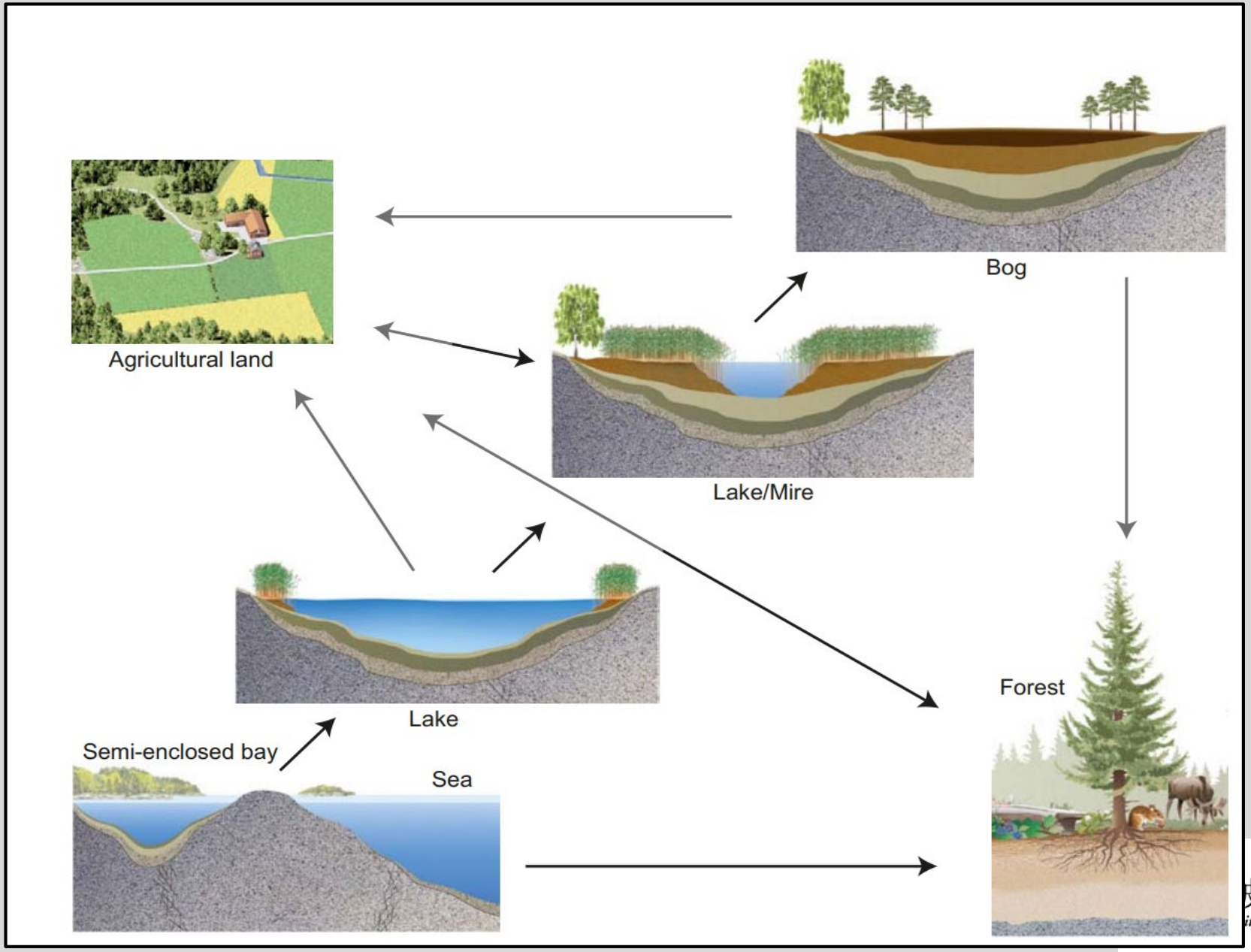
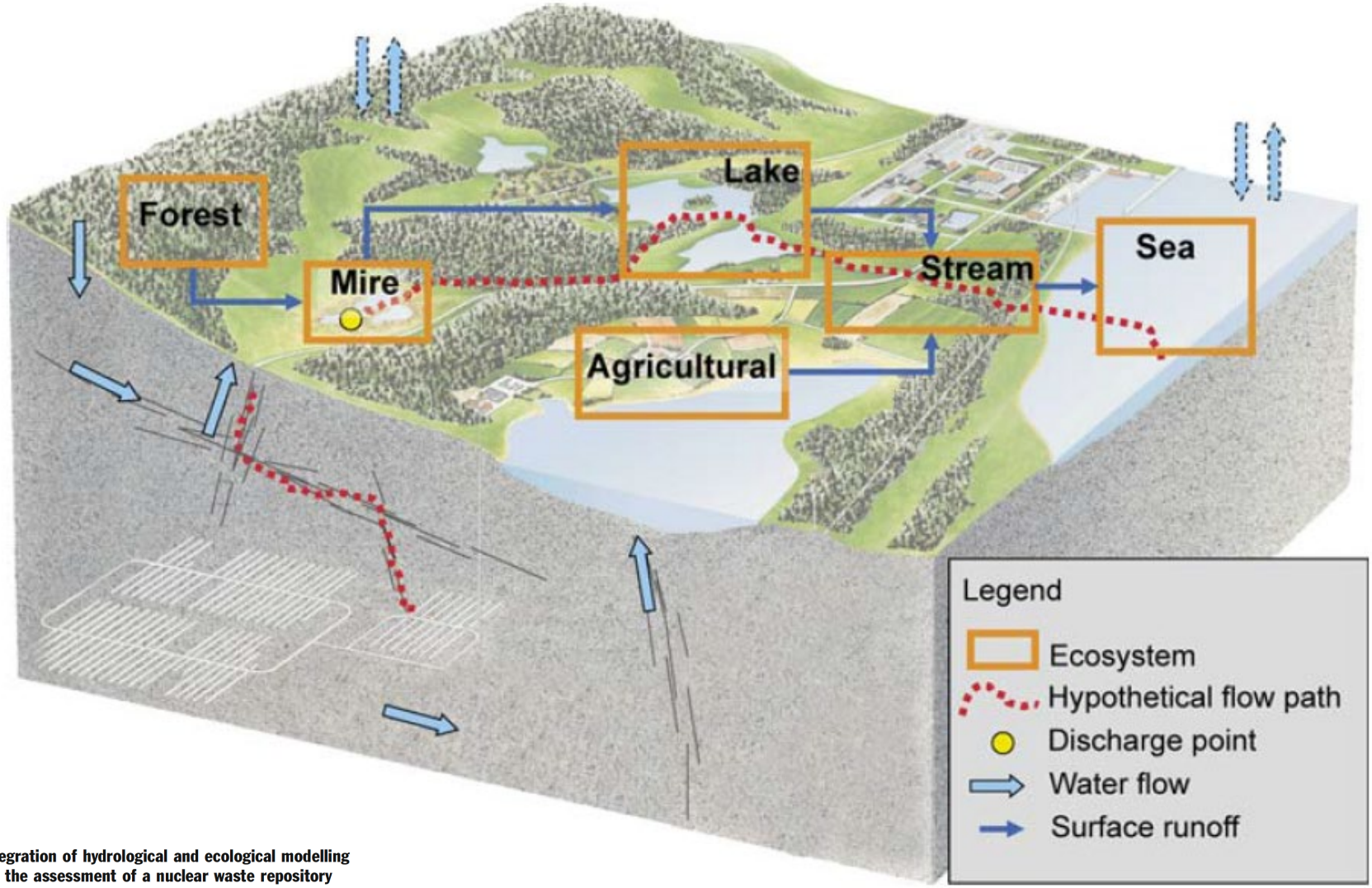
# The Forsmark site: From the sea to agricultural



# Ecosystems considered in the safety assessment




**Integration of hydrological and ecological modelling for the assessment of a nuclear waste repository**

Sten Berglund · Ulrik Kautsky · Tobias Lindborg · Jan-Olof Selroos

Hydrogeology Journal (2009) 17: 95–113

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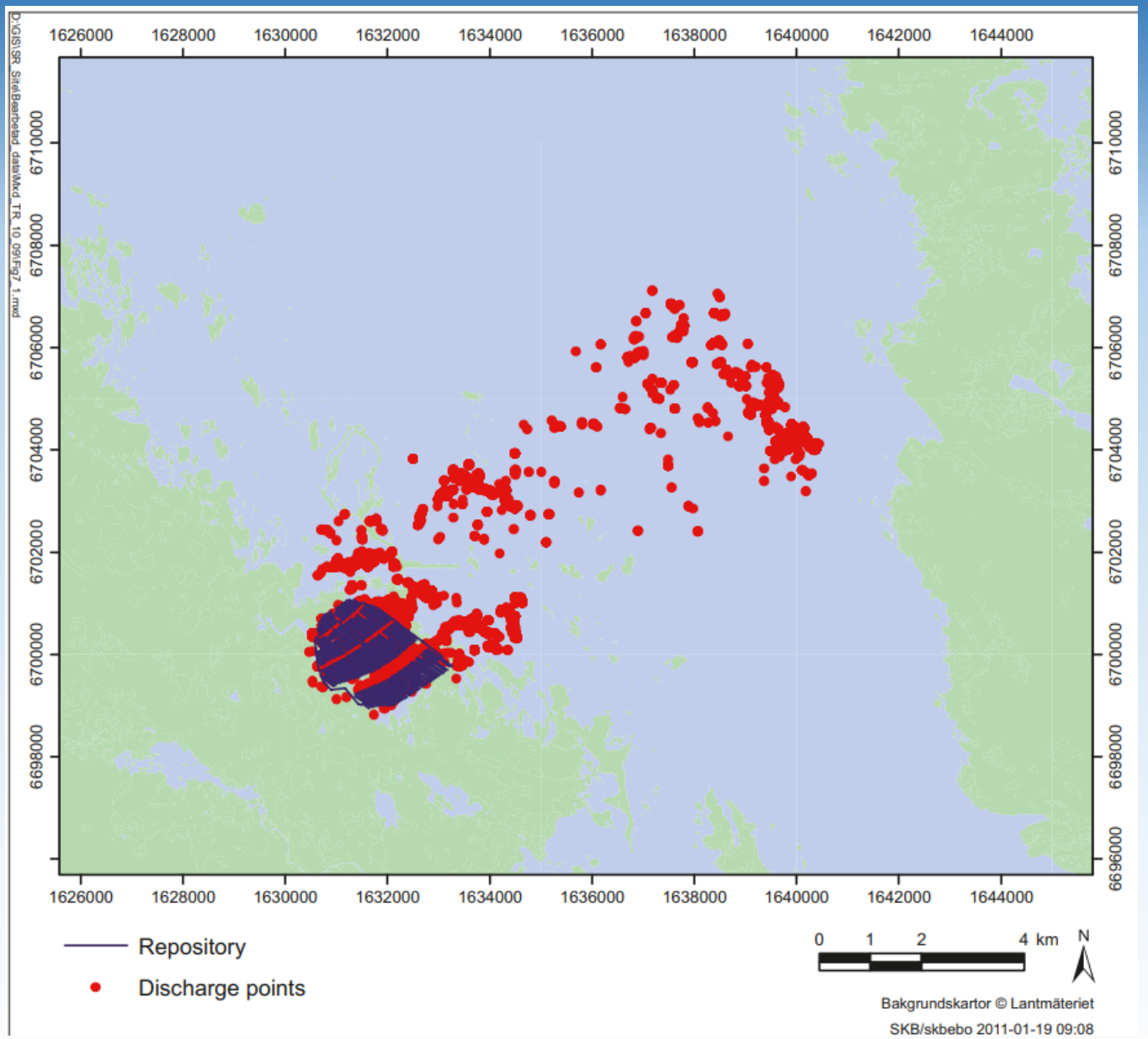
# The repository and the predicted points where radionuclides enter the biosphere

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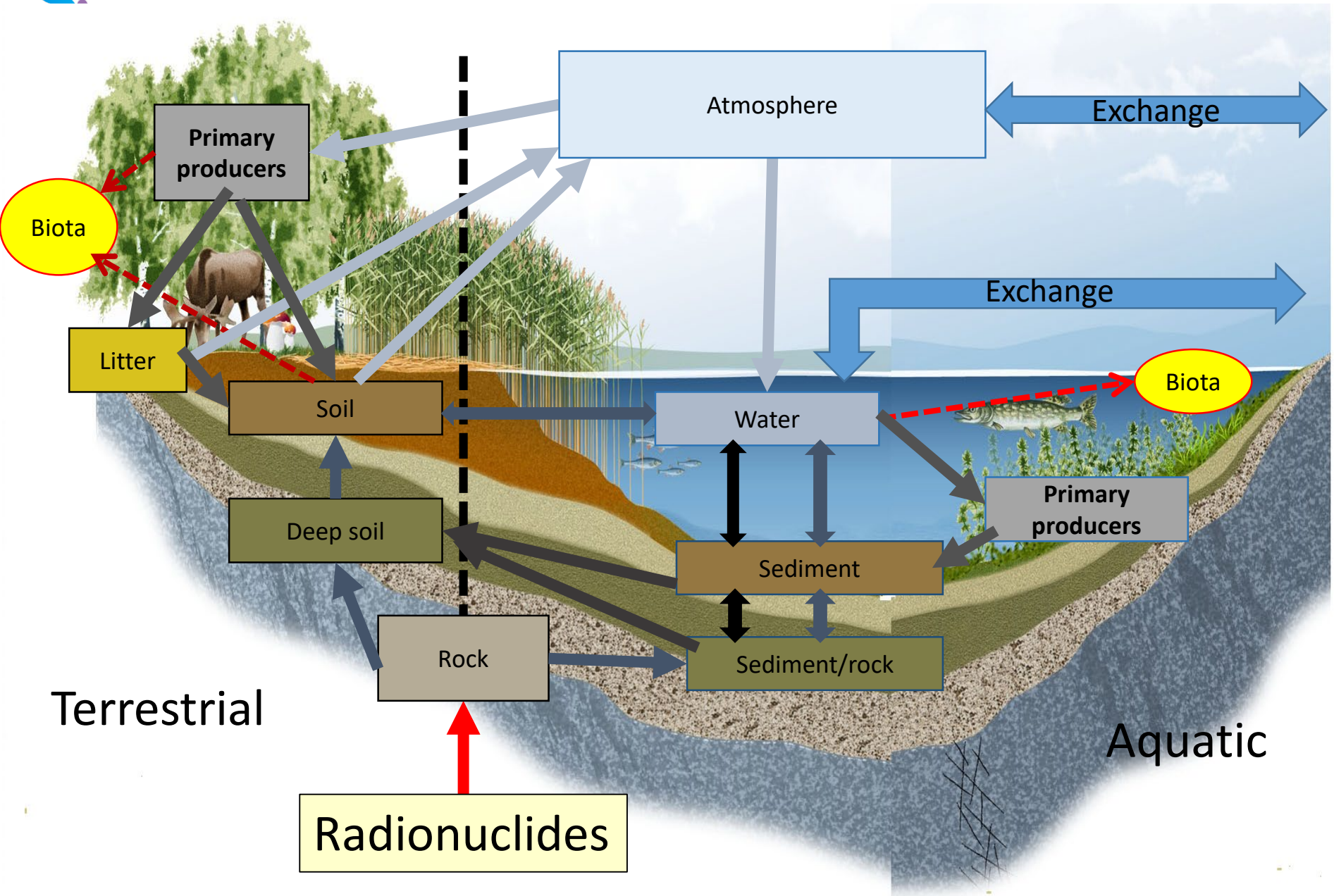
# The radionuclide model

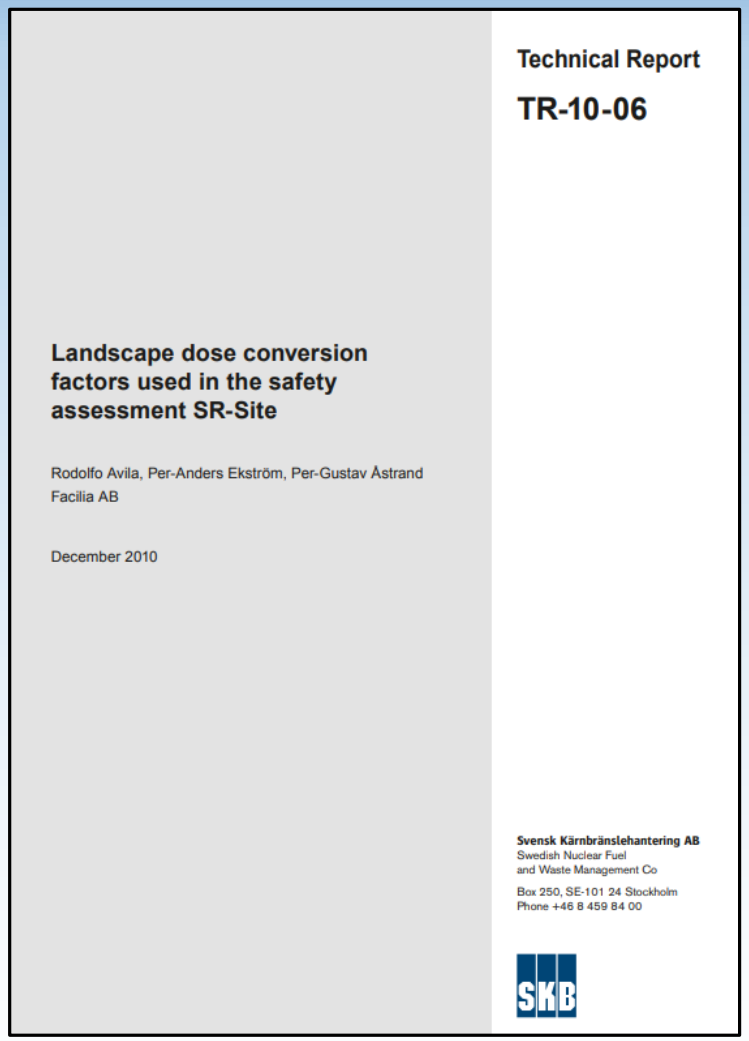



Modified from: T Lindborg, SKB, Sweden IAEA-EMRAS II annual meeting, Vienna 26 January 2011

# Exposure scenarios

- **The exposure is estimated for the land-use at the discharge point:**
  - Sea
  - Lake
  - Peat bog
  - Forest
  - Agricultural land
- **Production and collection of food on the landscape elements**
- **External exposure when staying on contaminated areas**

# Report describing the dose calculations at the Forsmark site



Technical Report

TR-10-06

**Landscape dose conversion factors used in the safety assessment SR-Site**

Rodolfo Avila, Per-Anders Ekström, Per-Gustav Åstrand
Facilia AB

December 2010

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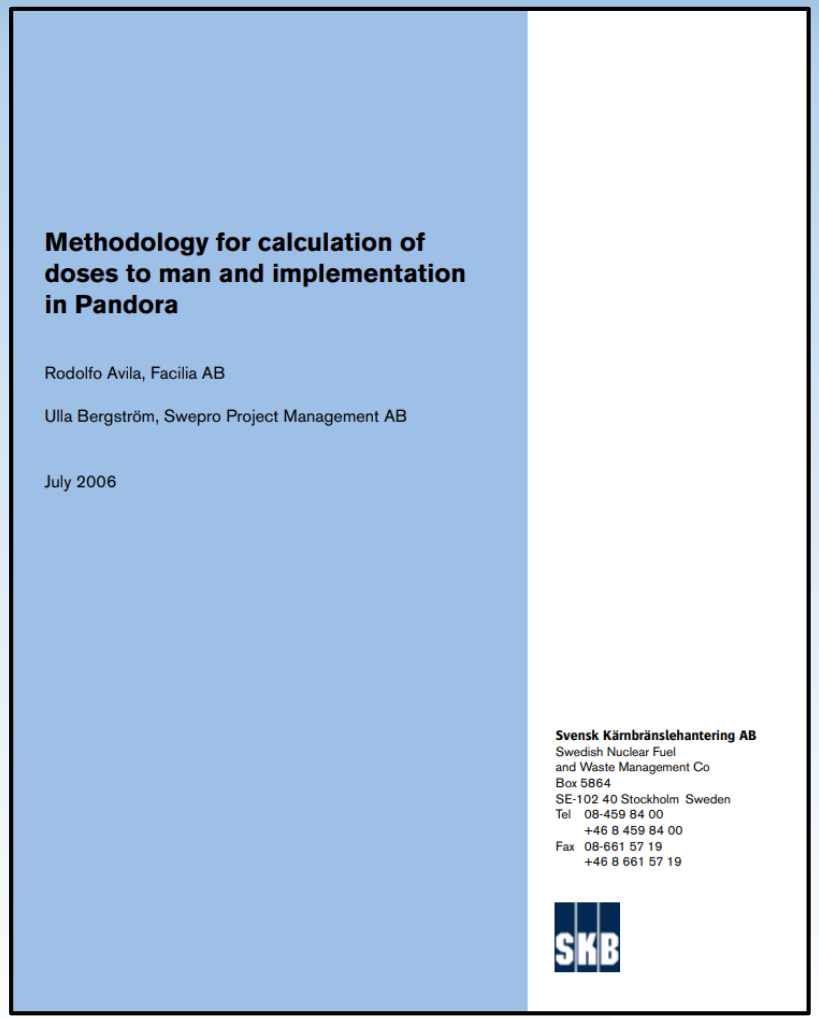

**Methodology for calculation of doses to man and implementation in Pandora**

Rodolfo Avila, Facilia AB

Ulla Bergström, Swepro Project Management AB

July 2006

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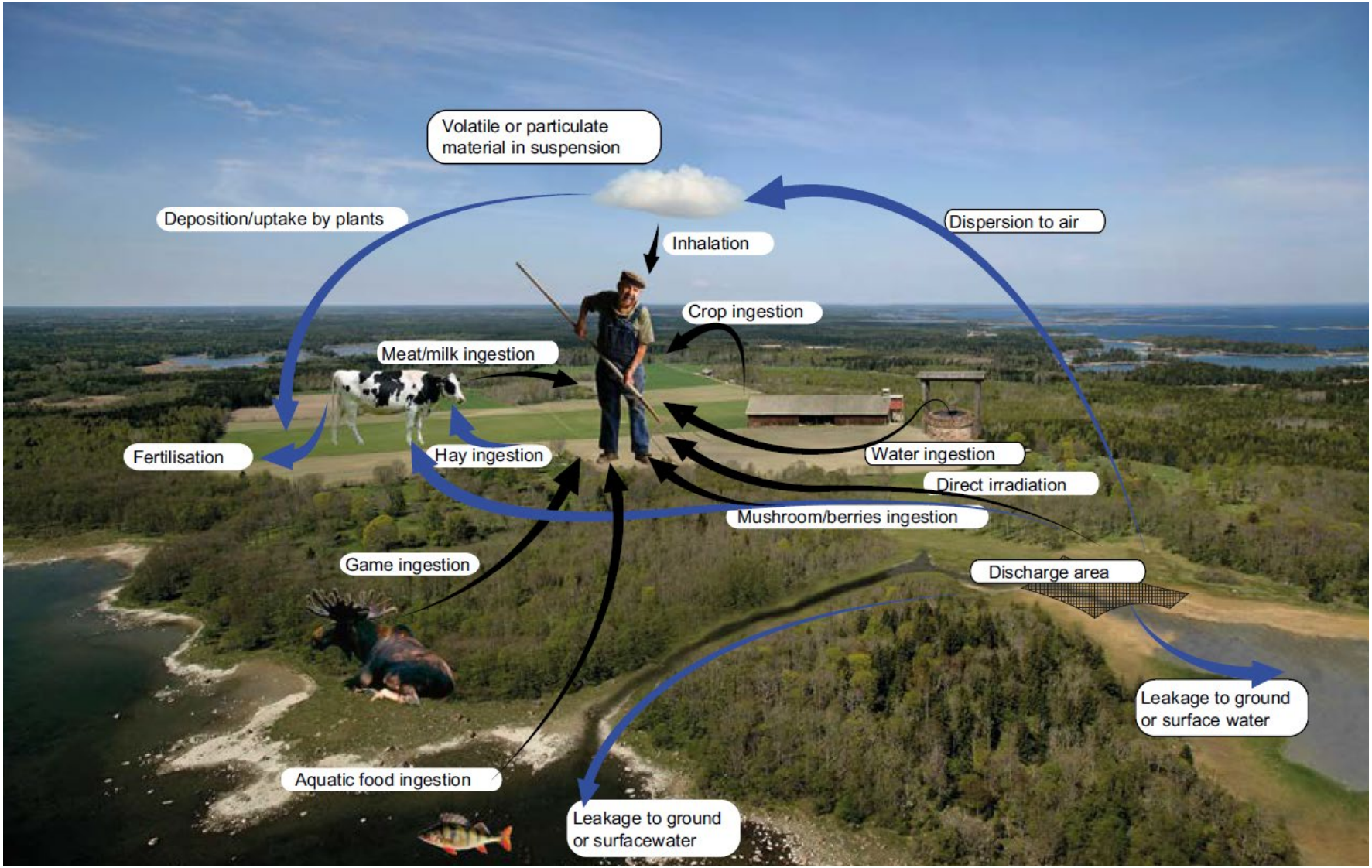
# Exposure pathways



# Exposure pathways

| Ecosystem | External exposure from the ground | Inhalation of soil dust | Cereals | Milk and meat | Mush-rooms, berries | Fish | Unintended intake of soil |
|---|---|---|---|---|---|---|---|
| Forest | x | x | | | | | x |
| Wetland (Mire) | x | x | | | | | x |
| Agricul-tural land | x | x | x | x | x | x | x |
| Lake | | | | | | x | |
| Sea | | | | | | x | |

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# Addressing the development of the climate

- Analysis of the past climate
- Implications of the greenhouse effect and global warming
- Extrapolation to the future
- Exploring  a range of climate paths

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# Climate cases considered in the safety assessment for the Swedish waste disposal facility

| Climate case | Development of climate |
|---|---|
| Global warming | • Temperate conditions until 50000 years AP (after present)<br>• Followed by natural variability and cooling of climate until 100 000 AP |
| Early periglacial | • Same as the global warming case<br>Except for a 3000 years period of periglacial conditions centred at 17000 AP |
| Extended global warming | • Temperate conditions until 100 000 AP |
| Weichselian glacial cycle | • Repetition of last glacial cycle conditions |

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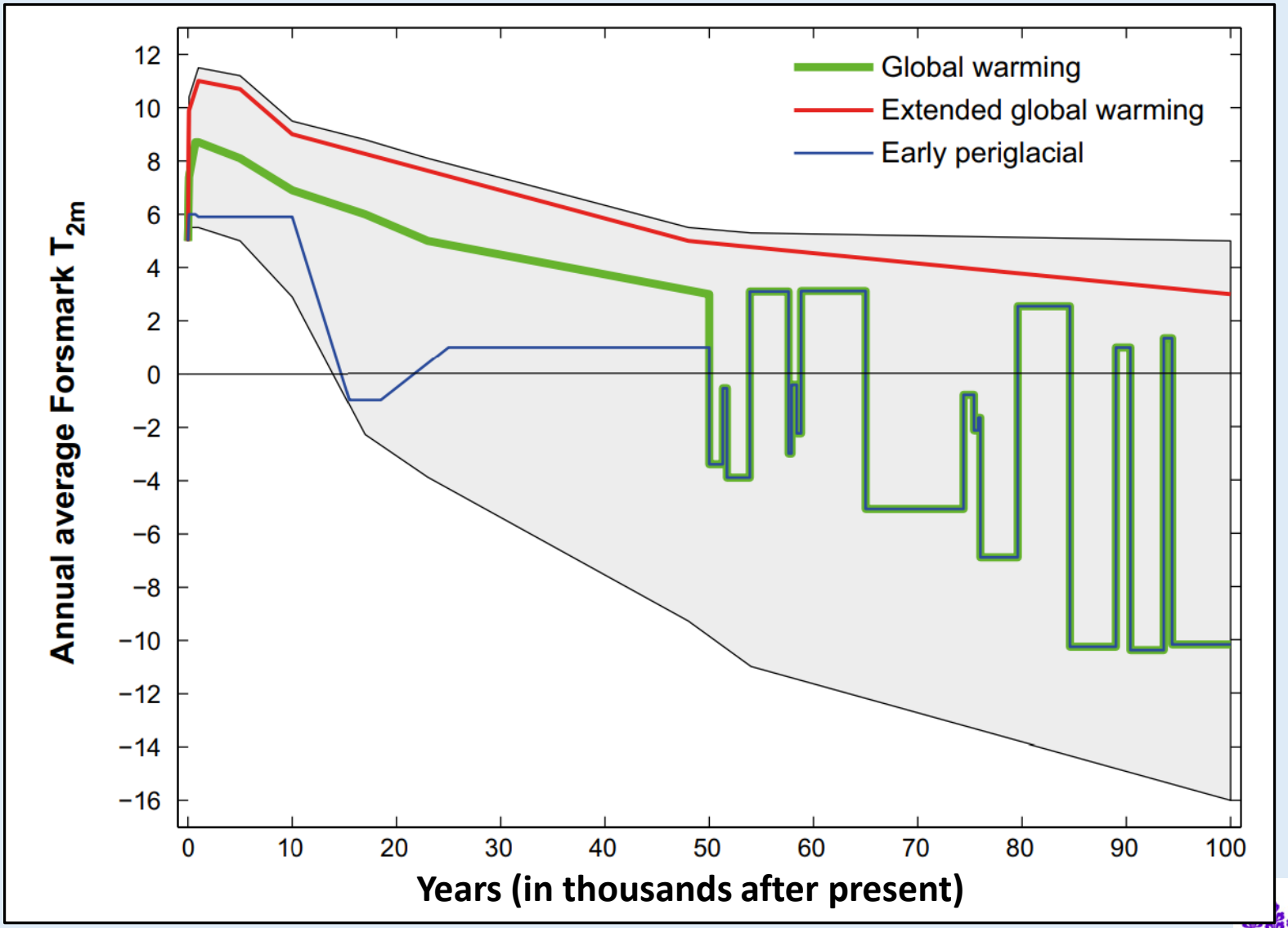
# Predicted generalized time evolution of annual average near-surface temperature (°C) in Forsmark

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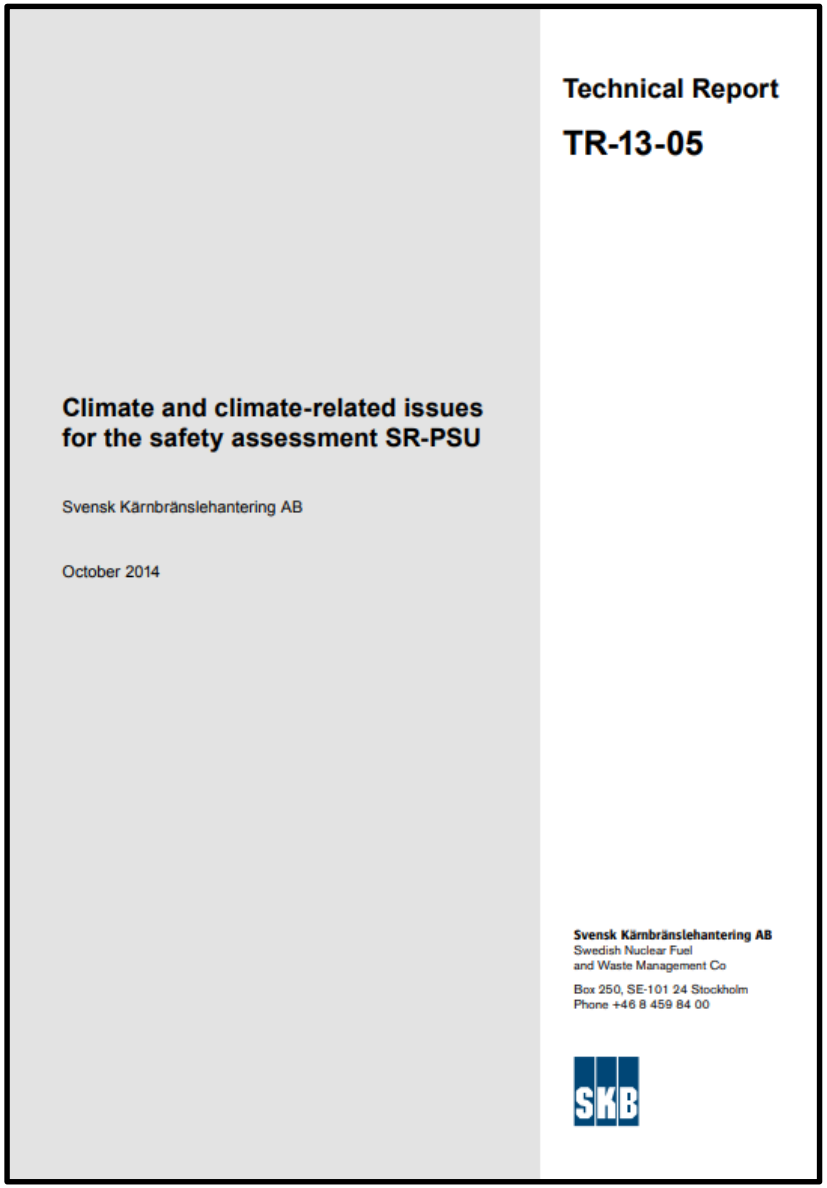


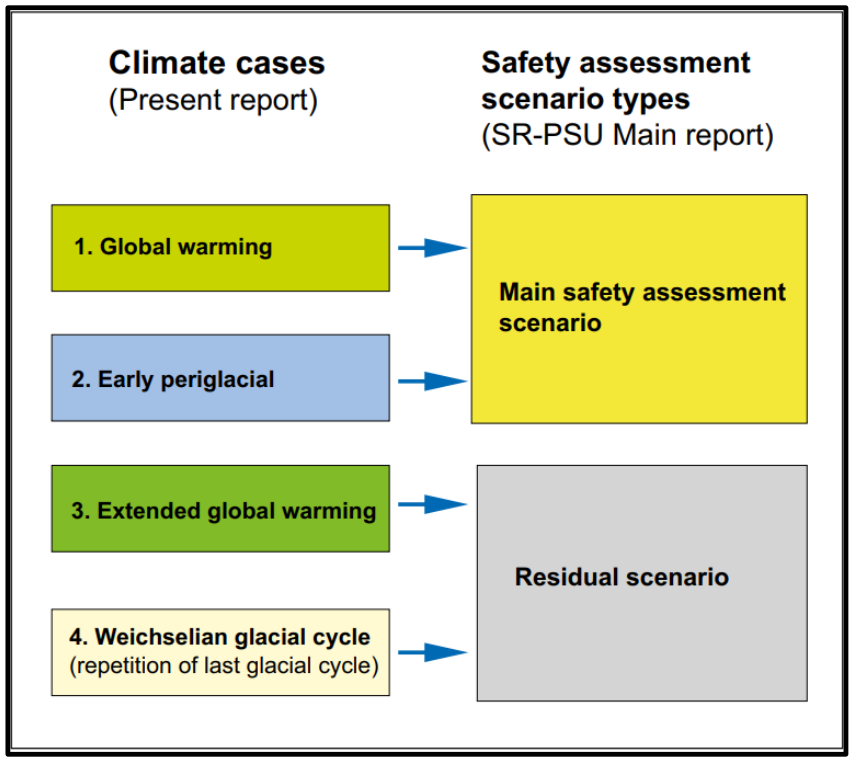


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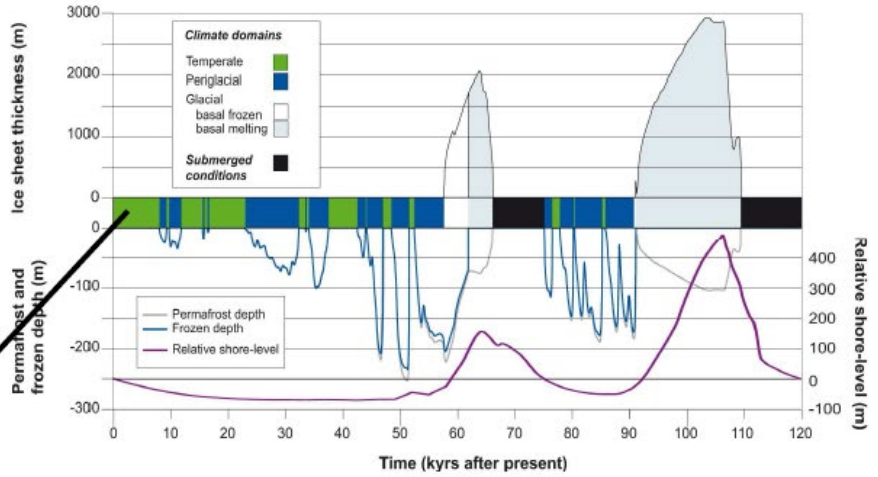
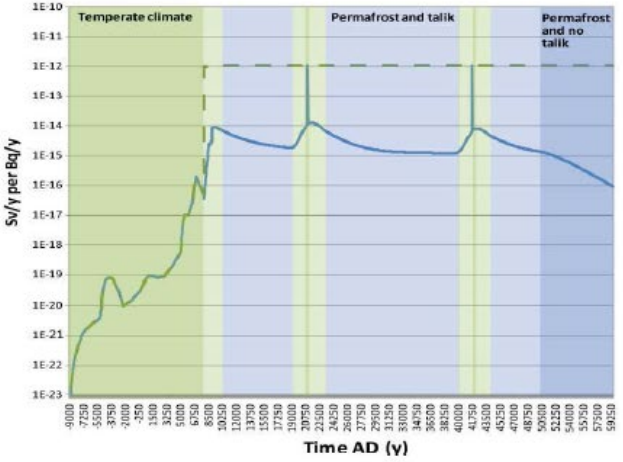
**From past to future climate**

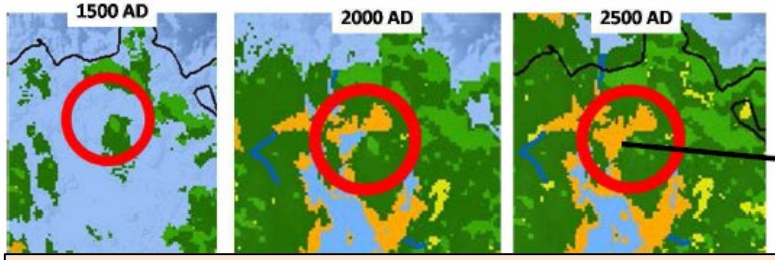
- Analysis of past climate cycles
- Green house effect
- Extrapolation to future climate cycles

## Climate




## Risk assessment

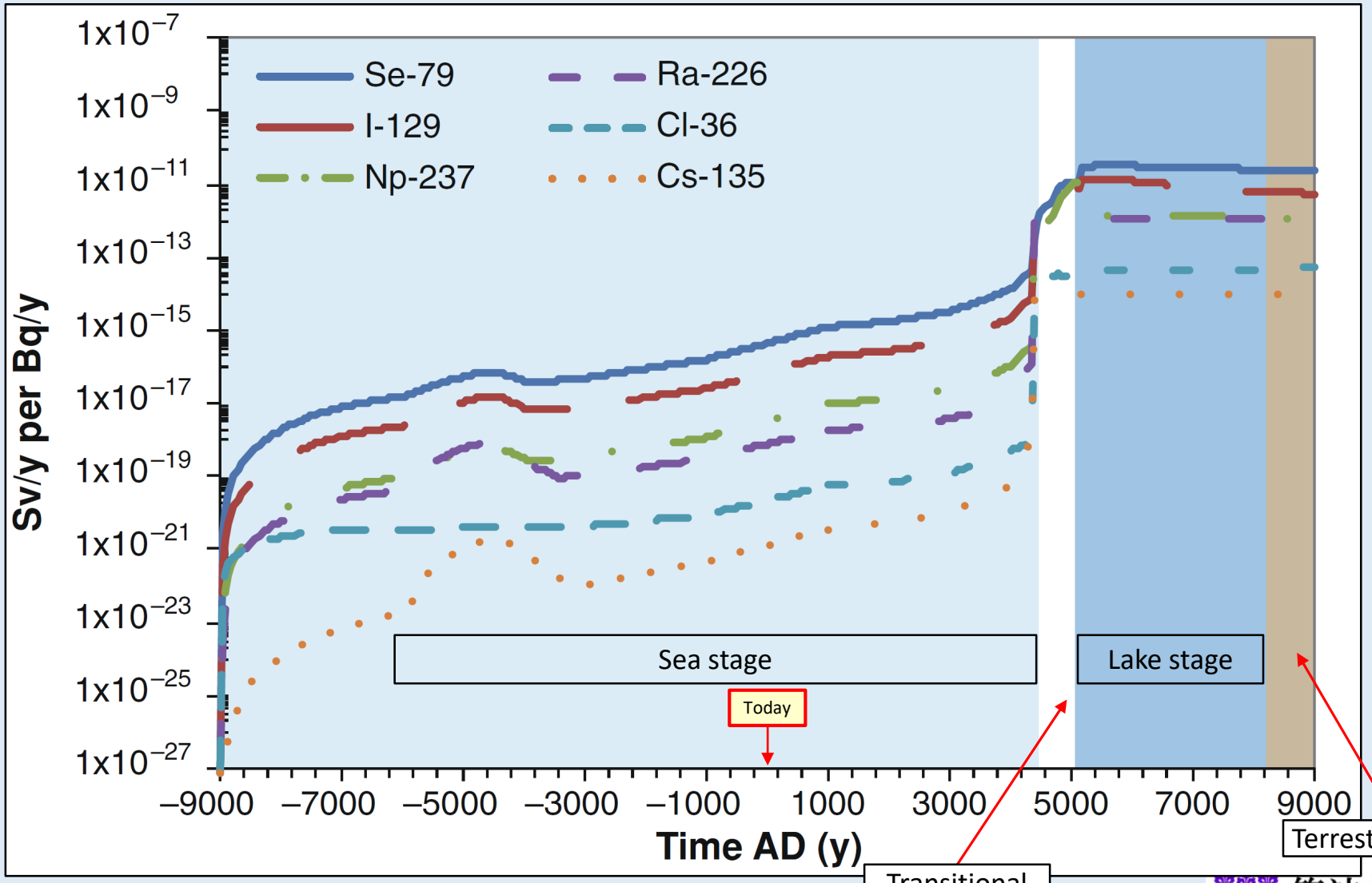



**From past to future landscape**

- Analysis of development in the past
- Extrapolation to the future (with glaciation)

# Simulation of the Dose per unit activity released for an biosphere object since the last ice-age:

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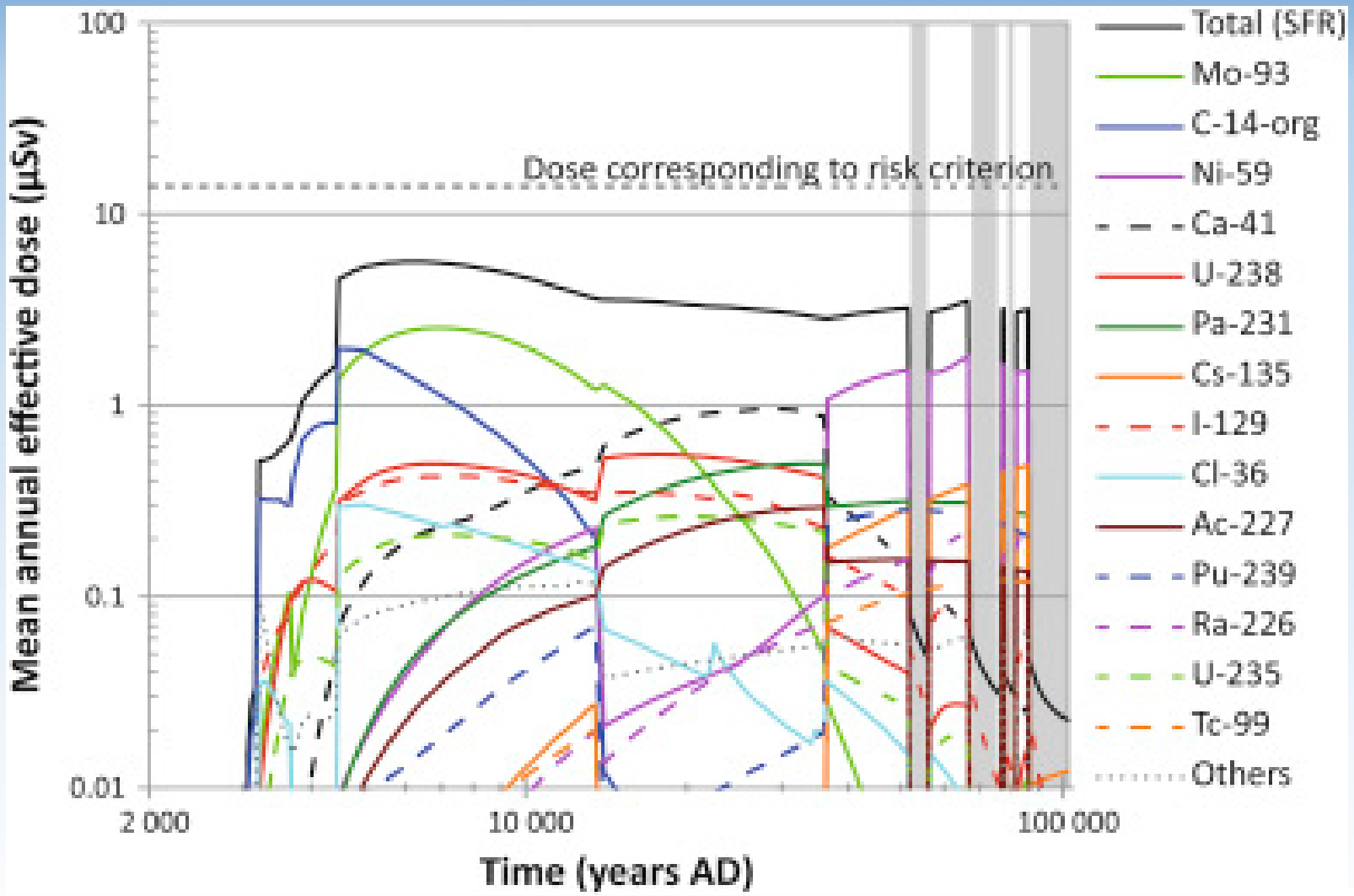
# Prediction of doses due to releases from the repository for high level waste



# SUMMARY

- **Environmental change is driven by**
  - Climate change
  - Change of the topography
- **Climate**
  - Analysis of past climate
  - Greenhouse effects
  - Extrapolation to the future
- **Topography**
  - Modelling of the annual uplift
  - Sea => Lake => Wetland => Peat bog => Agricultural land
- **The models reflect many interactions**
  - Climate and hydrology
  - Landform and hydrology
  - Release of radionuclides from the geosphere to the biosphere
- **Assessment of radiation doses**
  - Migration to the landscape elements
  - Accumulation of radionuclides and land-use
  - Dose to people
- **Data requirements and validation**
  - Enormous data requirements to quantify all processes
  - Complexity of the system is an inherent source of uncertainty
  - The land lift model can be validated by the past development
  - Predicting future conditions may be considered speculative,
  - Addressed by consideration of “alternative development”