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Uranium ISR Mine Closure – General Concepts and Model-based Simulation of Natural Attenuation for South Australian Mine Sites

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UIT UMWELTLEISTUNGEN

HEATHGATE

Beverley and Beverley Four Mile

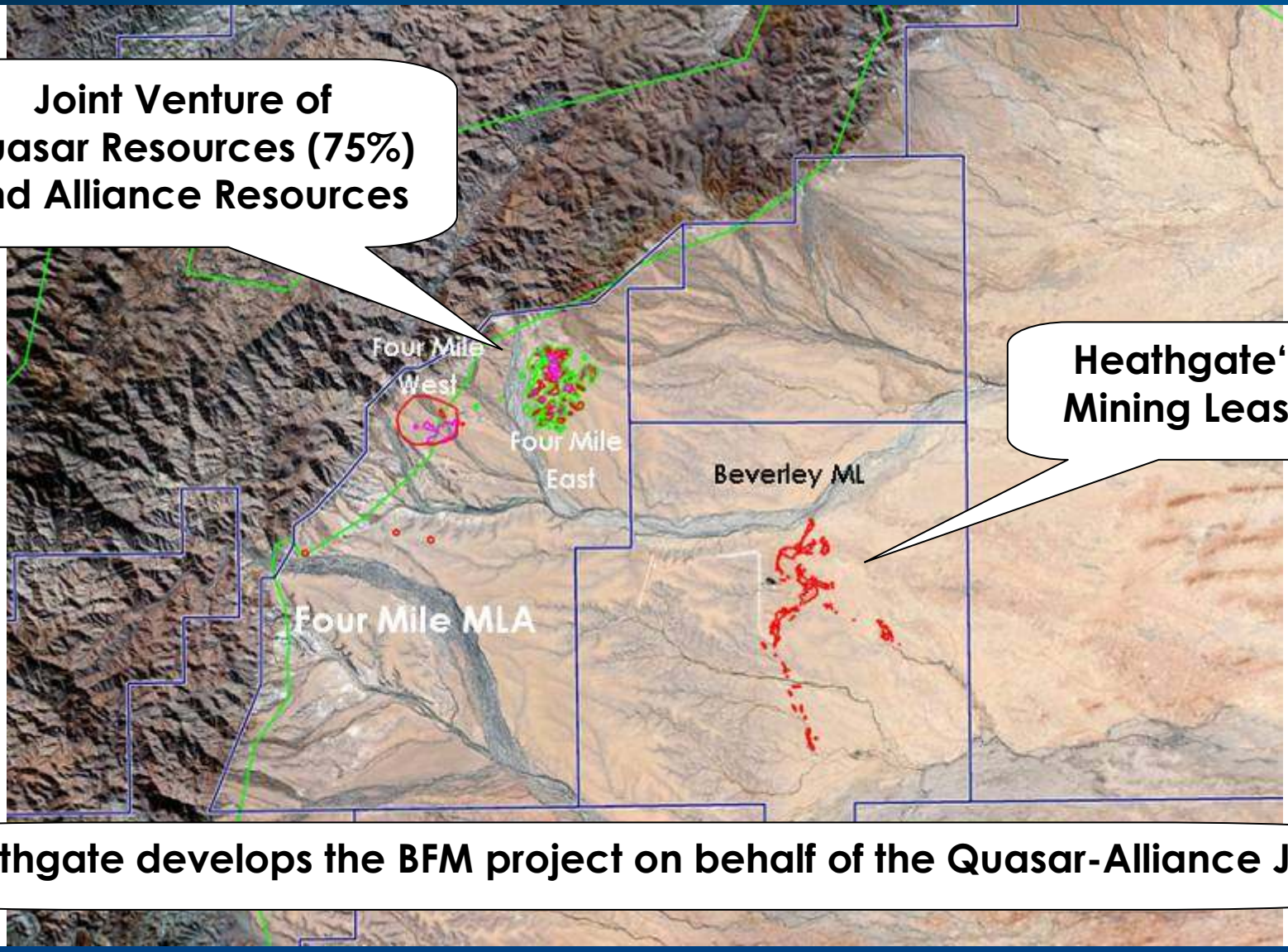
Beverley Four Mile

Discovered in 2005 (~100 mlbs)
Mine project development from early 2008
PER submitted in Jan 2009
Production from early 2010

Beverley Plant

Best-practice ISR (optimized under local circumstances)

Beverley and Beverley Four Mile



Heathgate develops the BFM project on behalf of the Quasar-Alliance JV

Overview

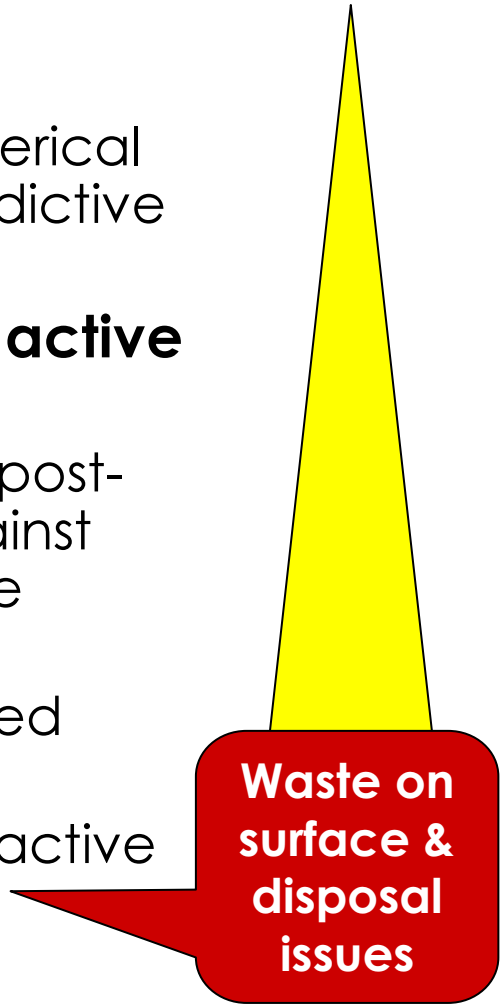
- **Introduction**
  - Mine closure and groundwater remediation
  - MNA/ENA options
- **Evidence of NA effects at Beverley mine**
- **Beverley Four Mile Project**
  - Outline
  - Mine closure and groundwater remediation concept
  - Baseline conditions
- **Reactive transport model simulation of NA/ENA**
  - Numerical model
  - Geochemical lab tests for model calibration
  - NA/ENA scenarios and results
- **Summary**

ISR Mine Closure and Groundwater Remediation

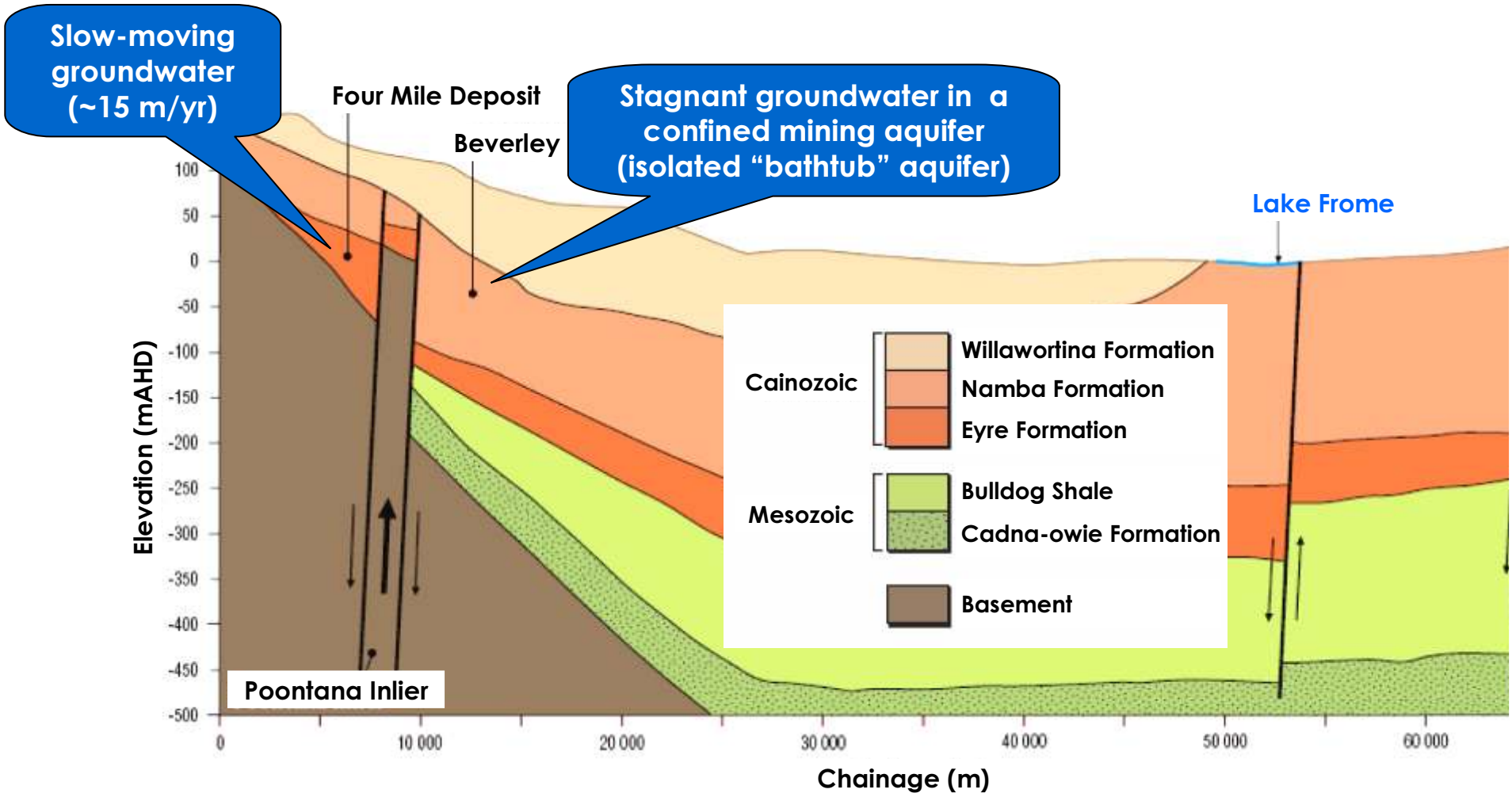
- **Major ISR advantages**
  - Minor surface disturbance
  - No tailings
  - Low radioactivity levels on surface
- **Main regulatory issue: groundwater remediation**
- **Conditions include:**
  - Principle: Minimize environmental impacts
  - Restore groundwater use category
  - Consider waste generation and disposal, energy consumption, surface impacts and costs to minimize impacts in a complex manner
  - Strongly dependent on local circumstances

MNA/ENA Options

- **Monitored natural attenuation (MNA)**
  - Established at Beverley by an extensive monitoring program in conjunction a numerical hydrological/geochemical models as predictive tools
- **Enhanced natural attenuation (ENA) and active remediation including**
  - Groundwater sweep by the exchange of post-mining solution in mined-out wellfields against the fresh groundwater from wellfields to be started up
  - In-situ treatment (e.g. reductants, stimulated bioremediation)
  - Groundwater sweep in combination with active water treatment (e.g. RO, neutralization)
  - Others

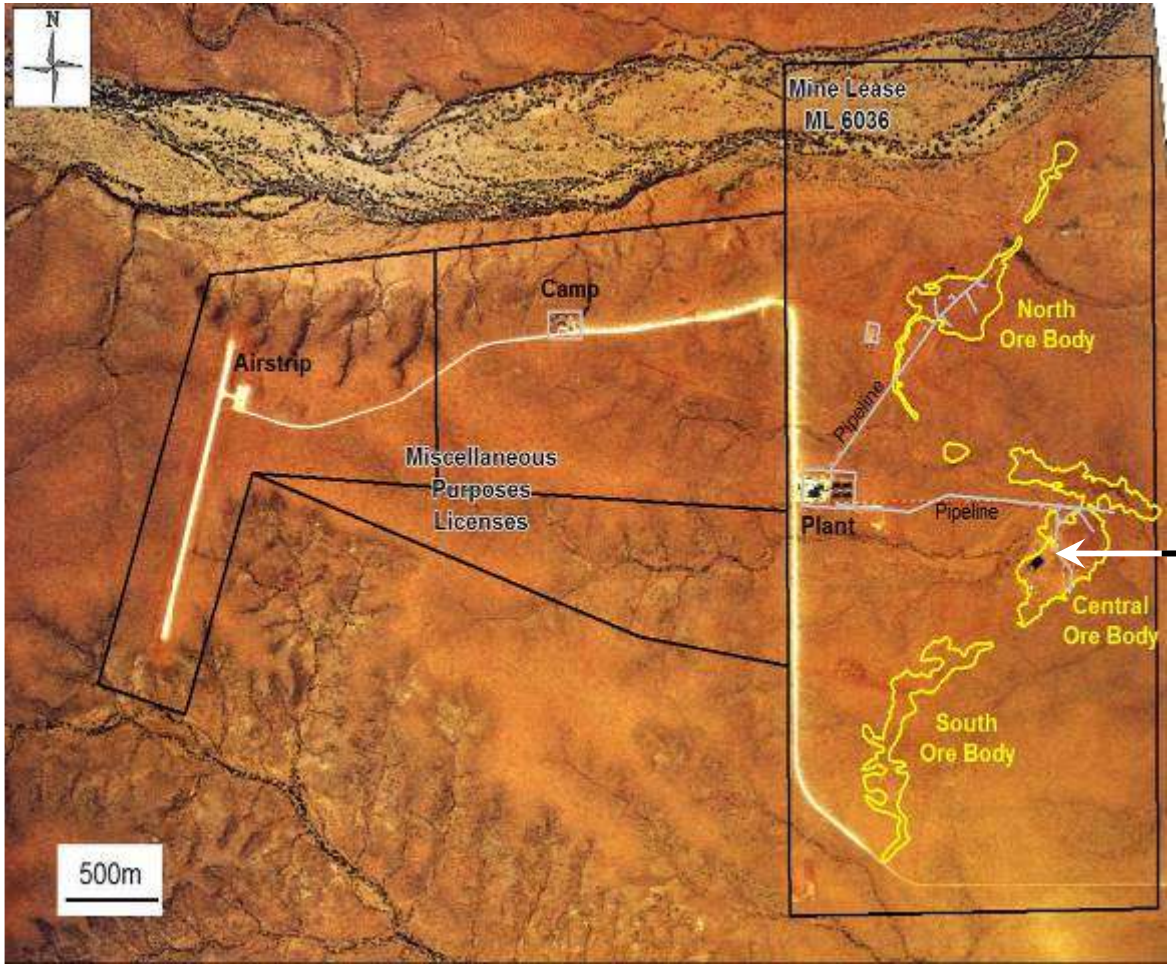


Hydrogeology at Beverley/Four Mile



- **Evidence of NA effects at Beverley**

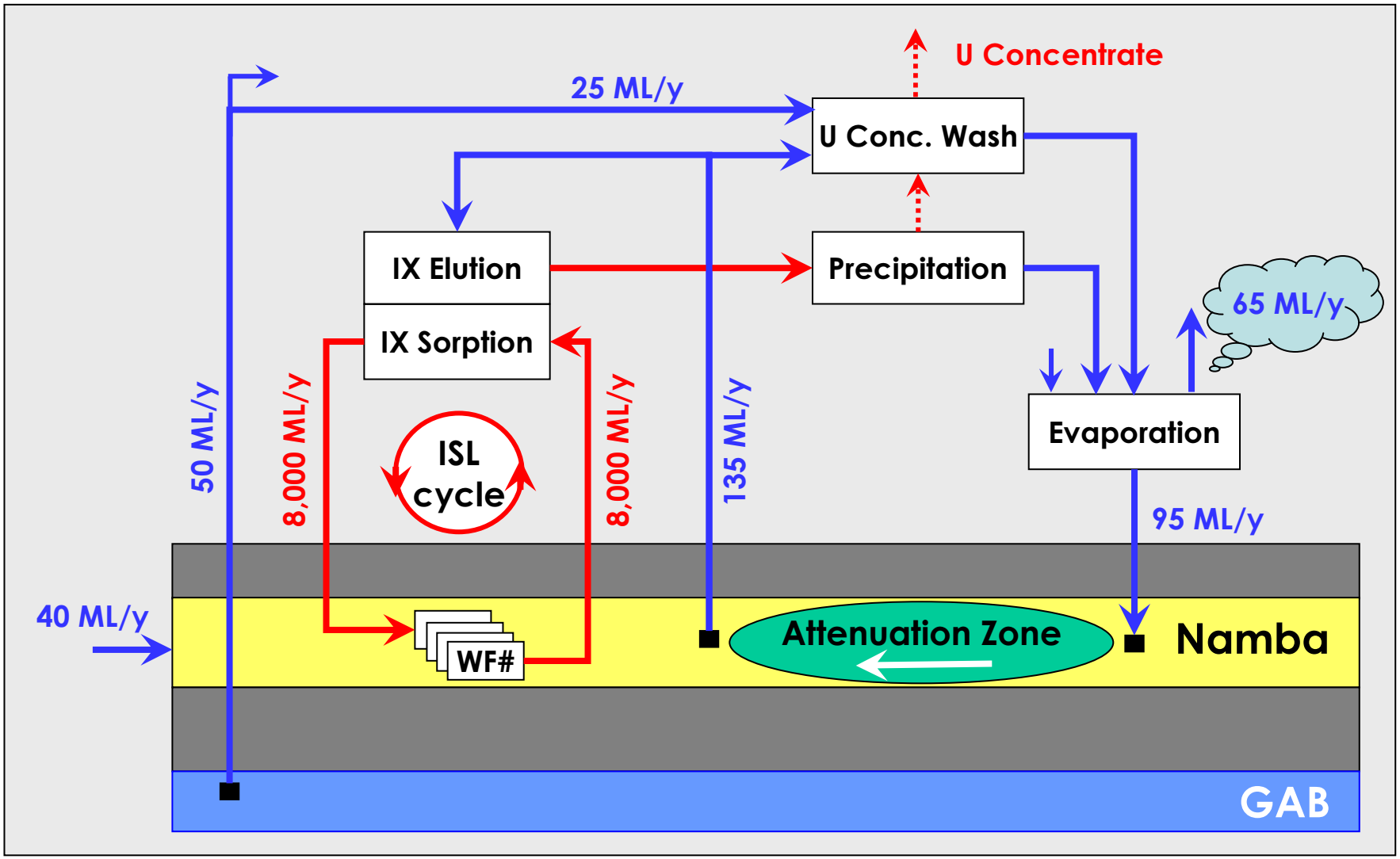
First Evidence of NA at Beverley



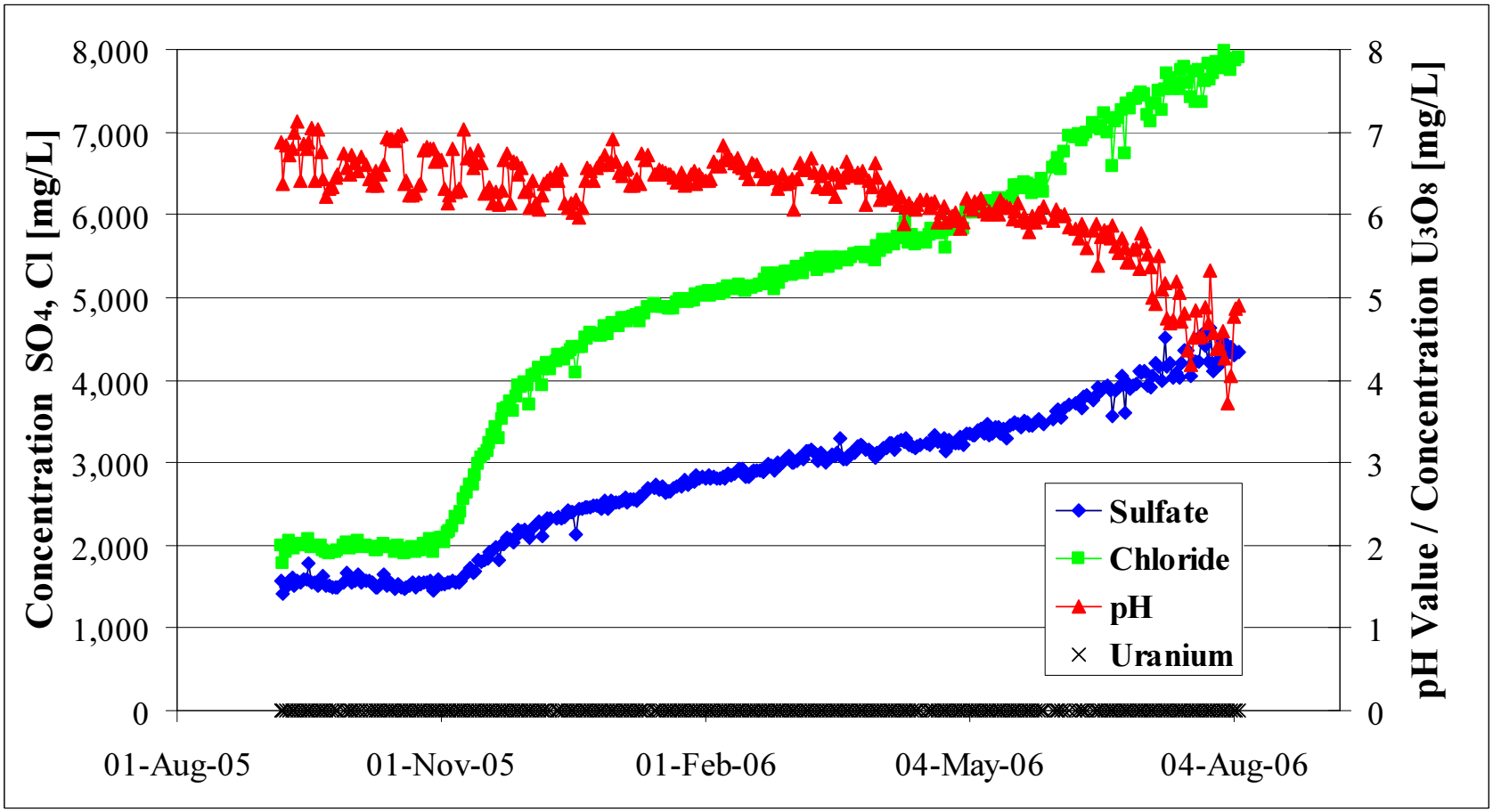
- Field leach trials (FLT) performed in 1998
- Second FLT in the central ore body were ISR commenced in 2004

- Between 1998 and 2004, pH of the FLT mining fluid increased from 2 to 3.2

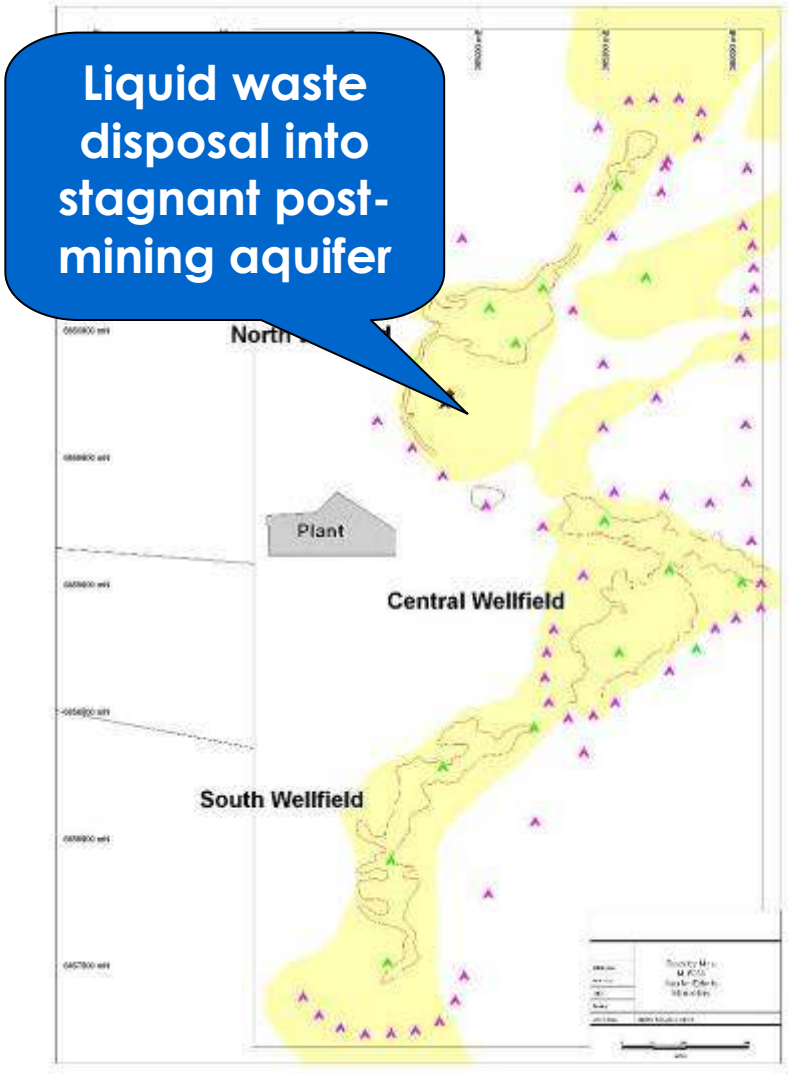
Second Evidence: NA at Beverley North



Breakthrough of Mine Water at Beverley North



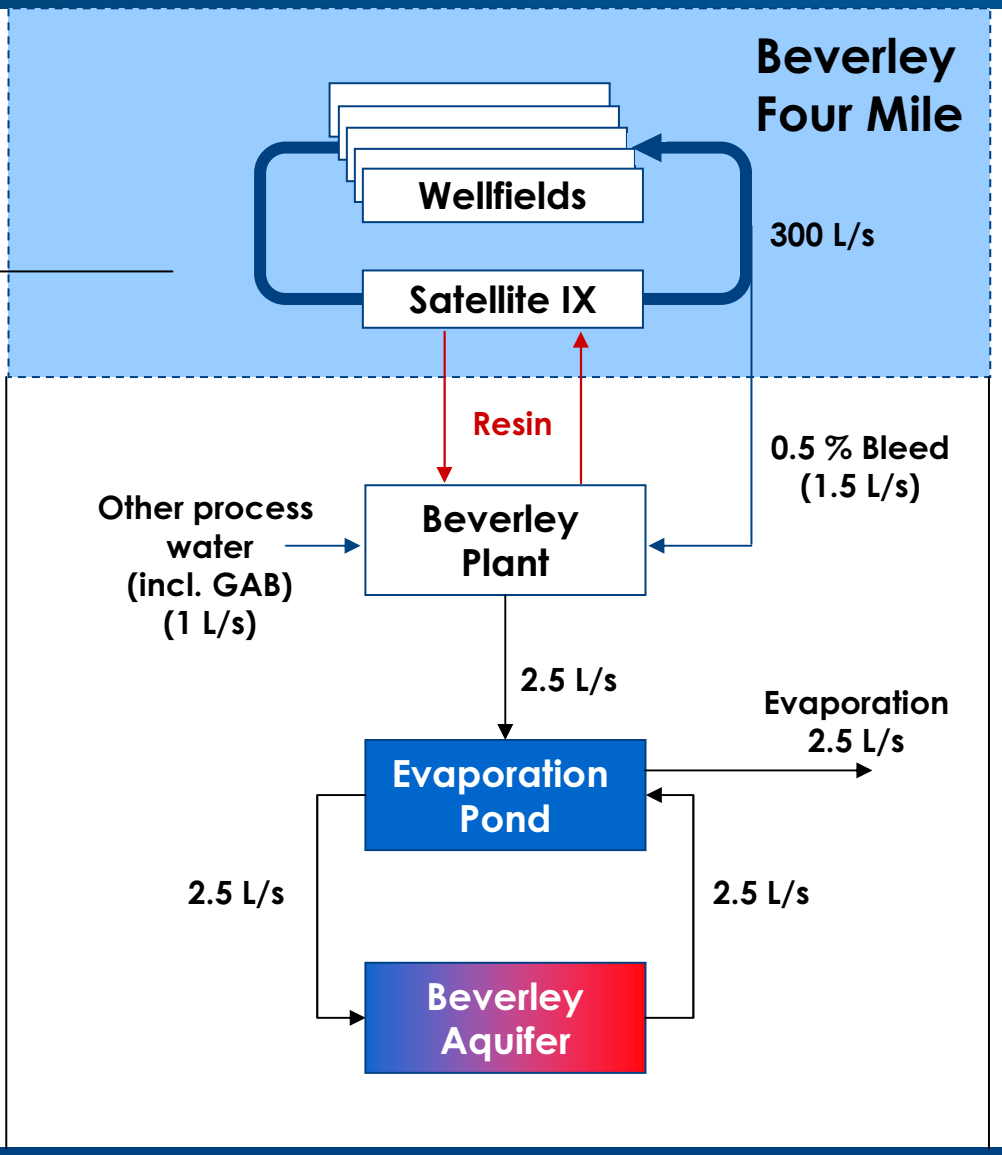
Liquid Waste Disposal and Regulatory Monitoring



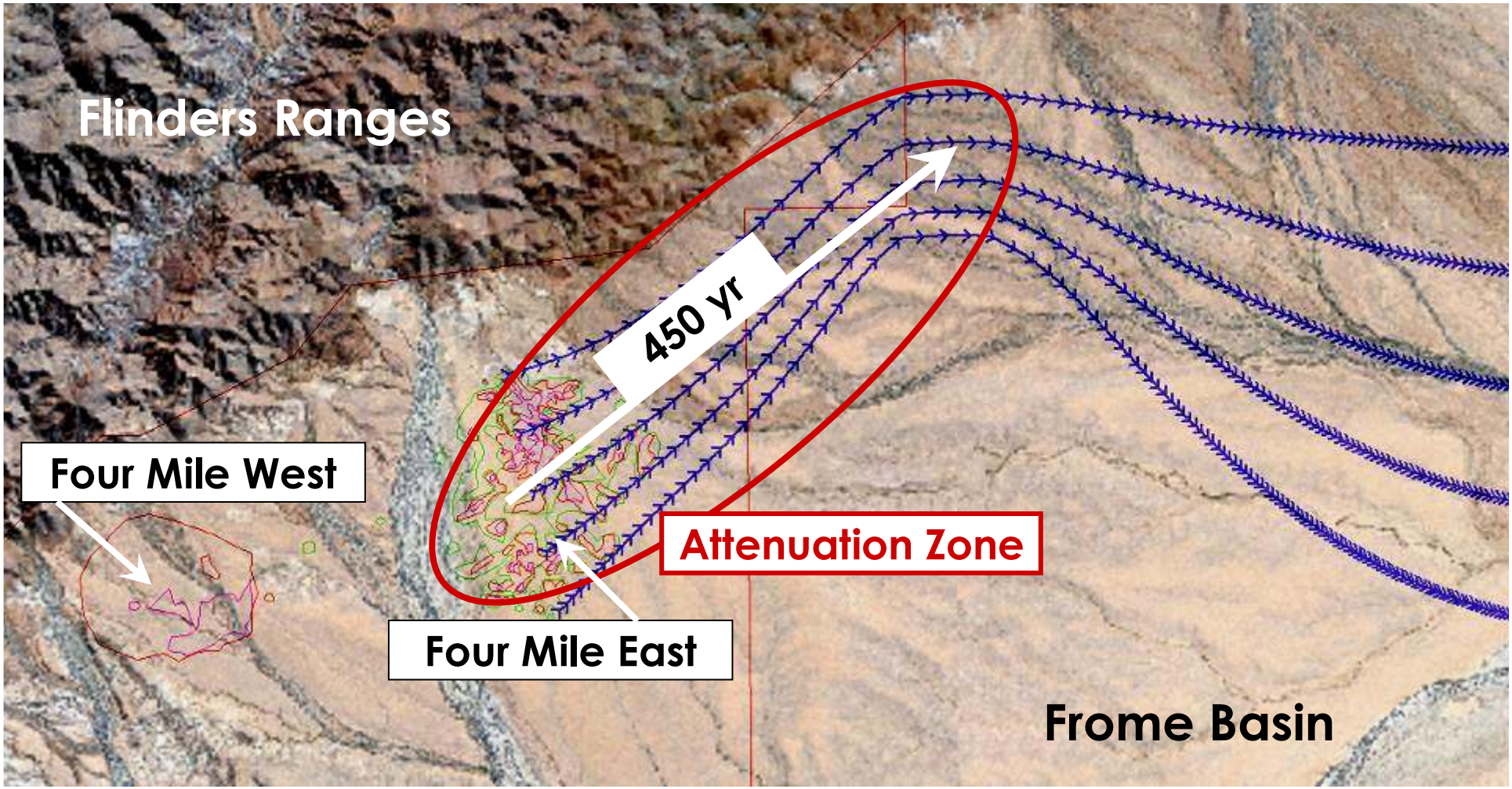
Groundwater monitoring serves a production optimization role as well as an environmental role

- **Beverley Four Mile Project**

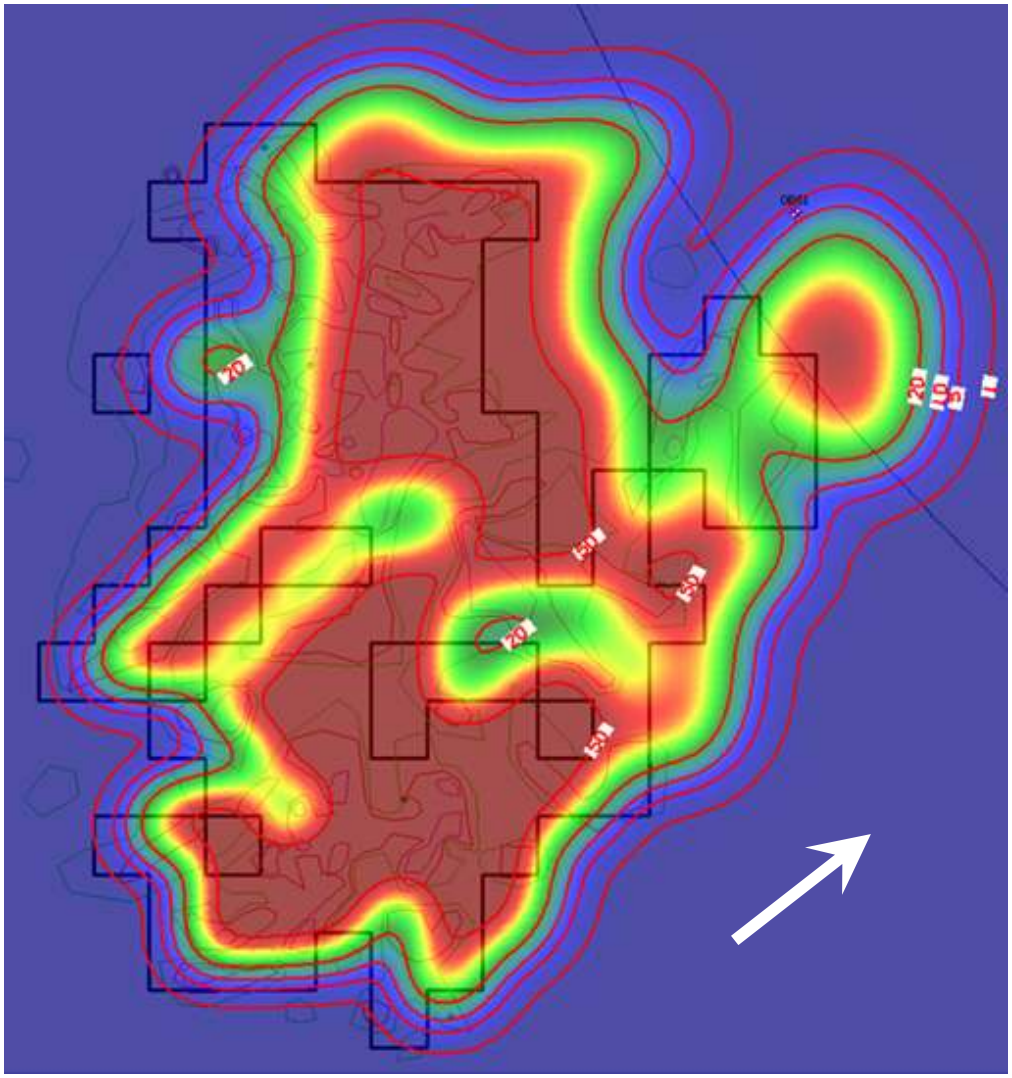
BFM Project/Water Balance/Waste Water



Hydrology and Mine Closure – Attenuation Zone



BFM Groundwater Flow within 10 Years



- Illustrative flow pattern of the mining fluid plume within 10 years after ISR against mining zone (black line)
- 15 m/yr flow to NE

BFM Groundwater – Baseline Conditions

- **Groundwater quality parameters within mining and attenuation zone:**
  - Salinity (TDS): 1.9-4.1 g/L
  - Uranium: up to 0.09 mg/L
  - Radium: up to 239 Bq/L
  - Fluor: 2-18 mg/L
- **According to ANZECC limits, not suitable for**
  - Potable use
  - Irrigation use
  - Stock use

- **No use category!**
  (refers to both Beverley and Beverley Four Mile)

Staged Groundwater Management Program

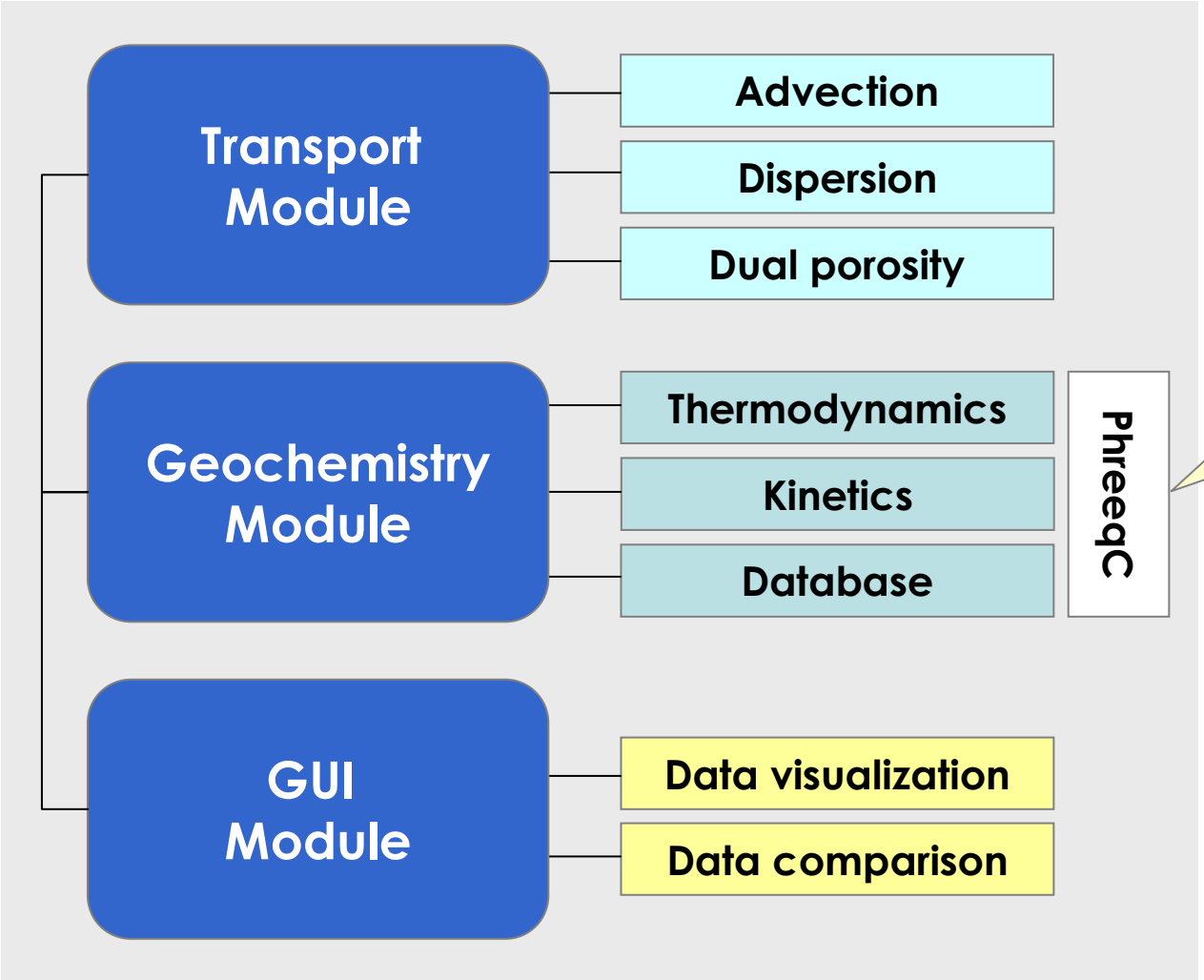
- **Stage 1 (pre-mining)**
  - Site investigations and assessment
  - Develop a calibrated NA/ENA model (reactive transport) → approval process
- **Stage 2 (during mining)**
  - Operational monitoring
  - Validate and adjust model for improved predictions
  - Implement adequate ENA measures
- **Stage 3 (post mining)**
  - Post-mining monitoring
  - Advanced model predictions
  - Implement (optional) ENA measures if required

- **Stage 1: NA/ENA Model Predictions**

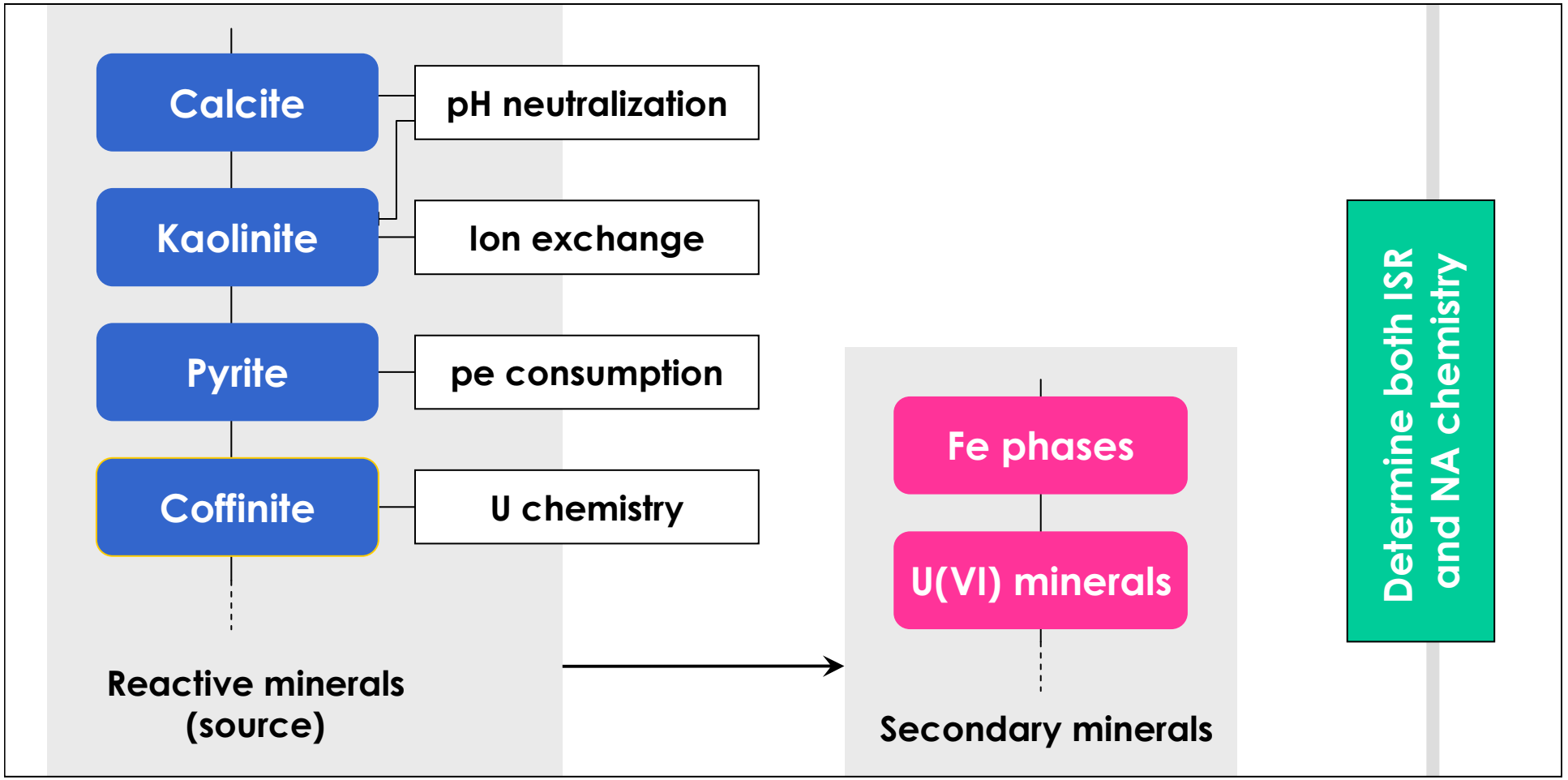
Stage 1 – Site Investigations / Model Simulation

- **Deposit investigations and assessment**
  - Hydrological (permeability)
  - Mineralogical (identify reactive minerals)
  - Geochemical (quantify thermodynamics and kinetics)
- **Model development**
  - Reactive transport model / dual porosity approach
  - Lab tests (batch/column) with core material and mining solutions (ANSTO)
  - Calibrate model
- **Upscale to simulate mining/post-mining groundwater scenarios**
  - Pure natural attenuation (NA)
  - ENA options

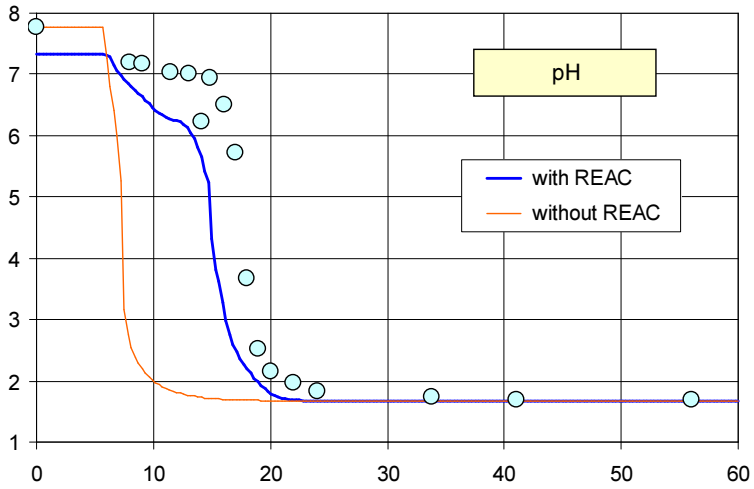
Reactive Transport Model (UIT-code TRN)

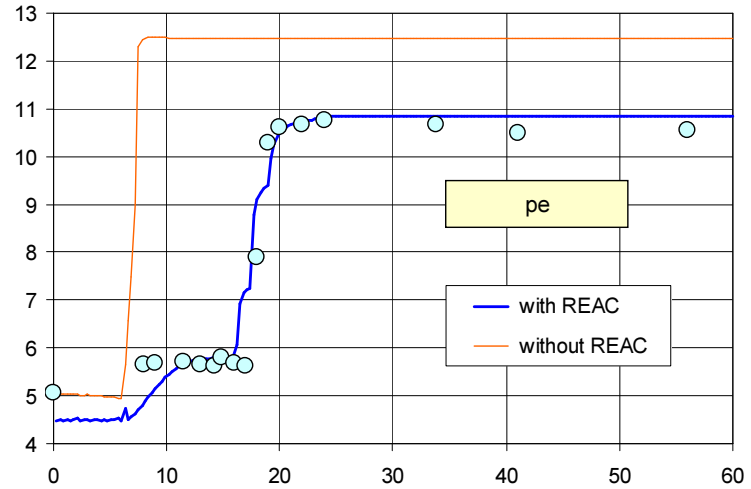


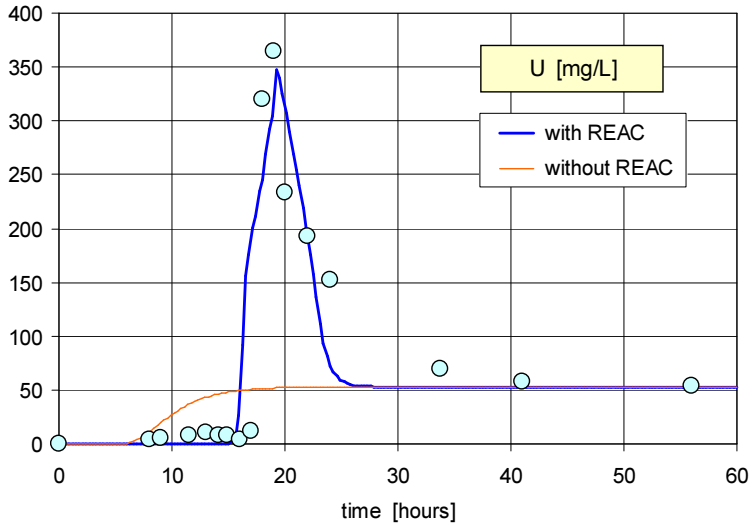
Primary Mineral Phases (Beverley&Beverley Four Mile)

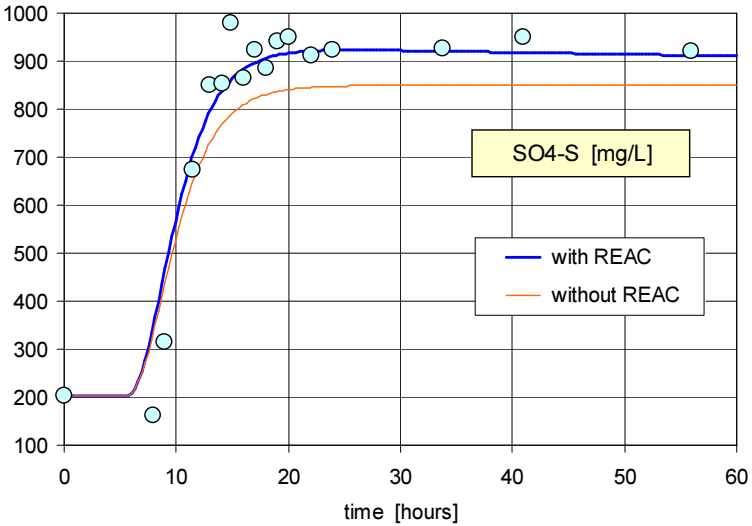


Model Calibration against Column Test Results







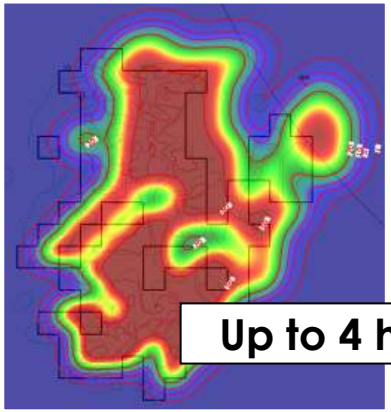


NA/ENA Scenarios Considered

- **Scenario 1a:** Continuous 1 km ISR zone
  → Pure NA

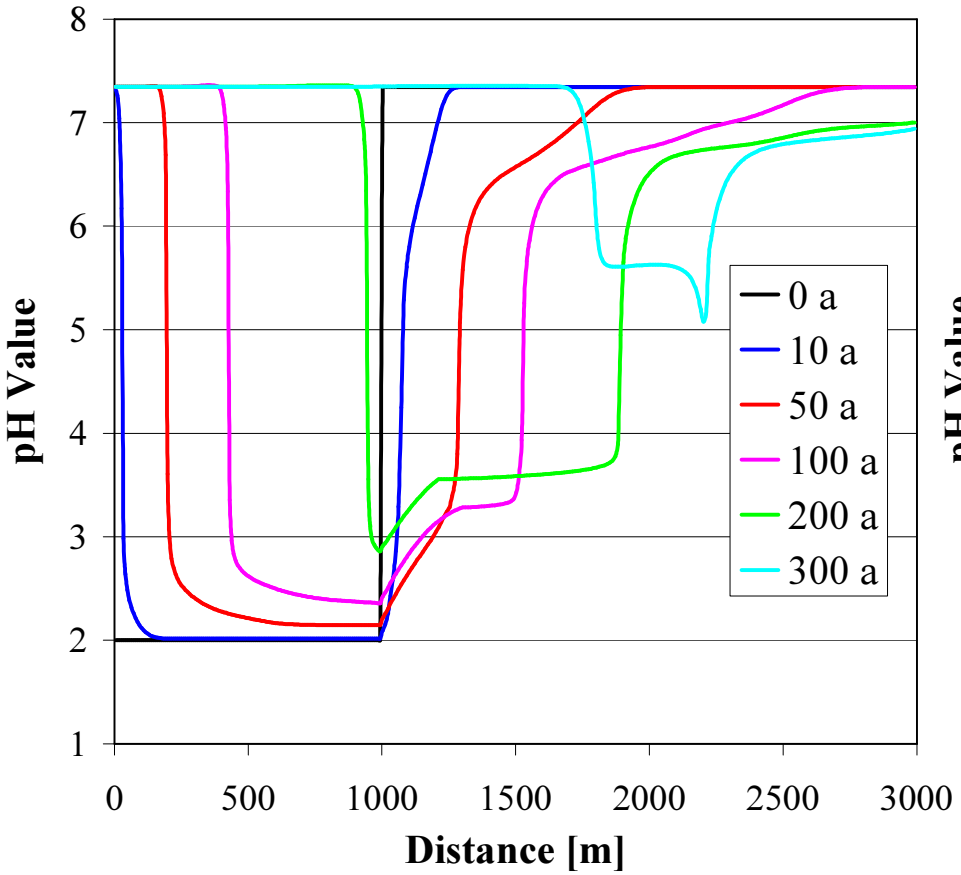
- **Scenario 1b:** Same,
  but with groundwater sweep
  (one pore volume exchange)
  → Preferred ENA option

- **Scenario 2:** Patchy ISR zone
  → Pure NA

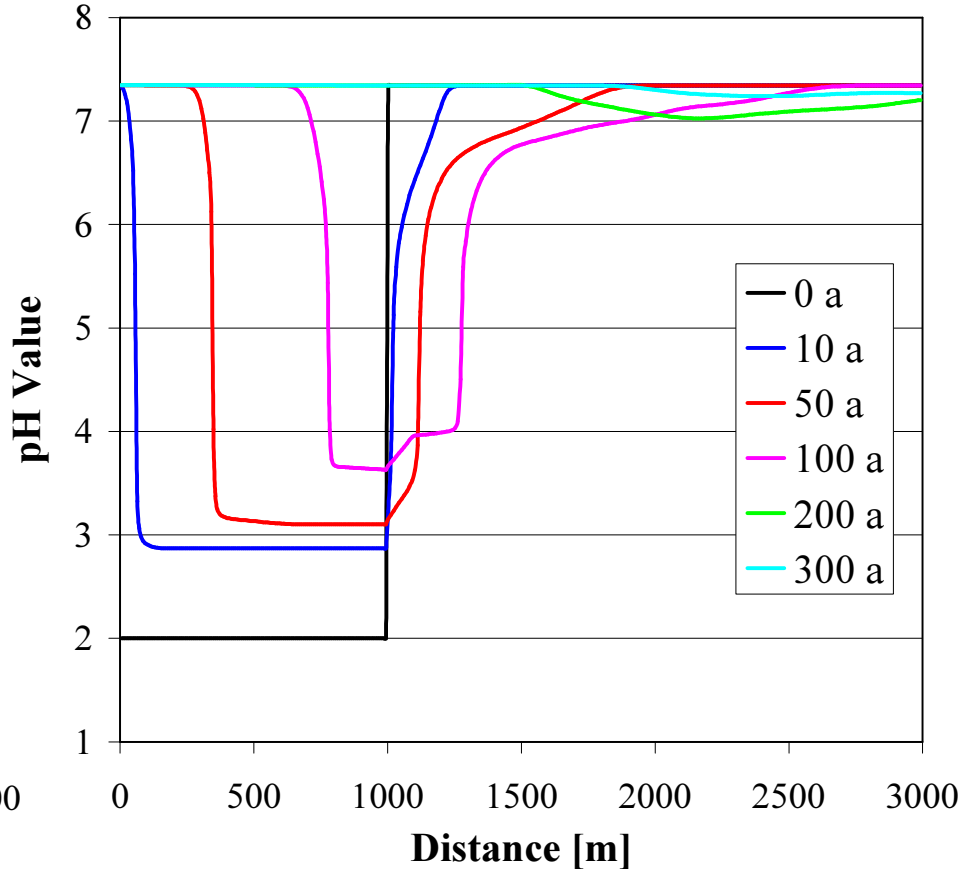


Scenario 1 (1 km ISR zone) – pH Value

Pure NA

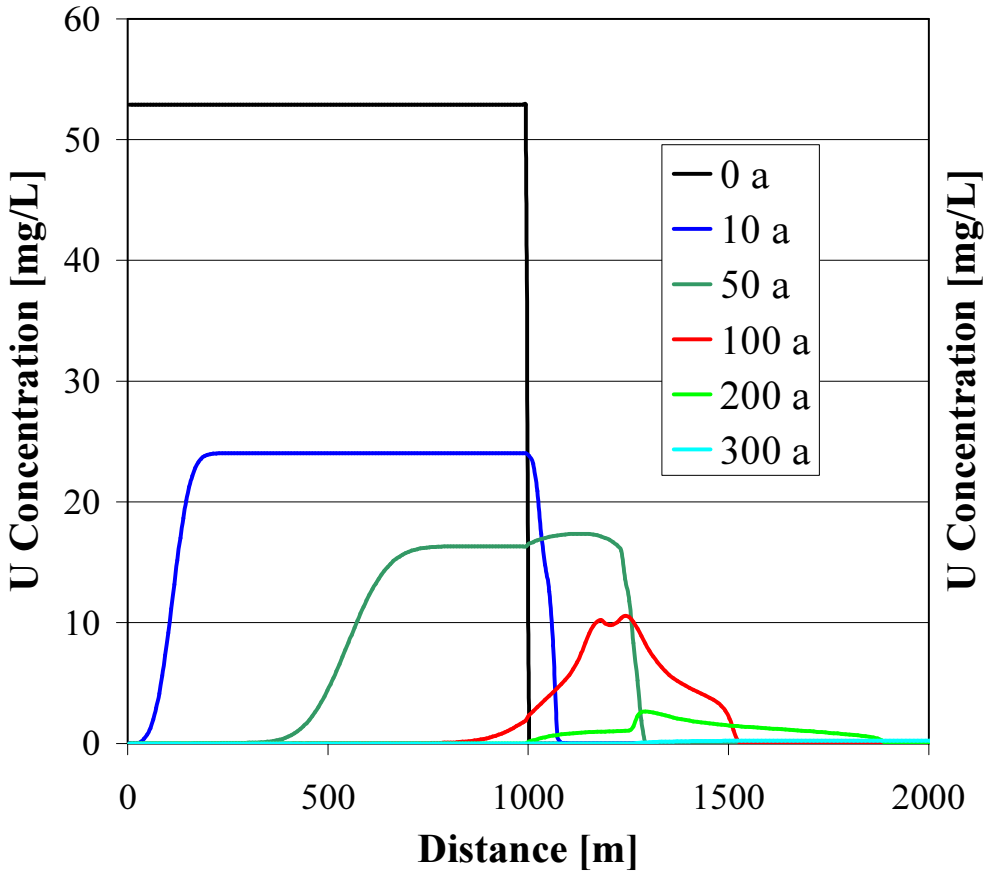


ENA: Groundwater sweep

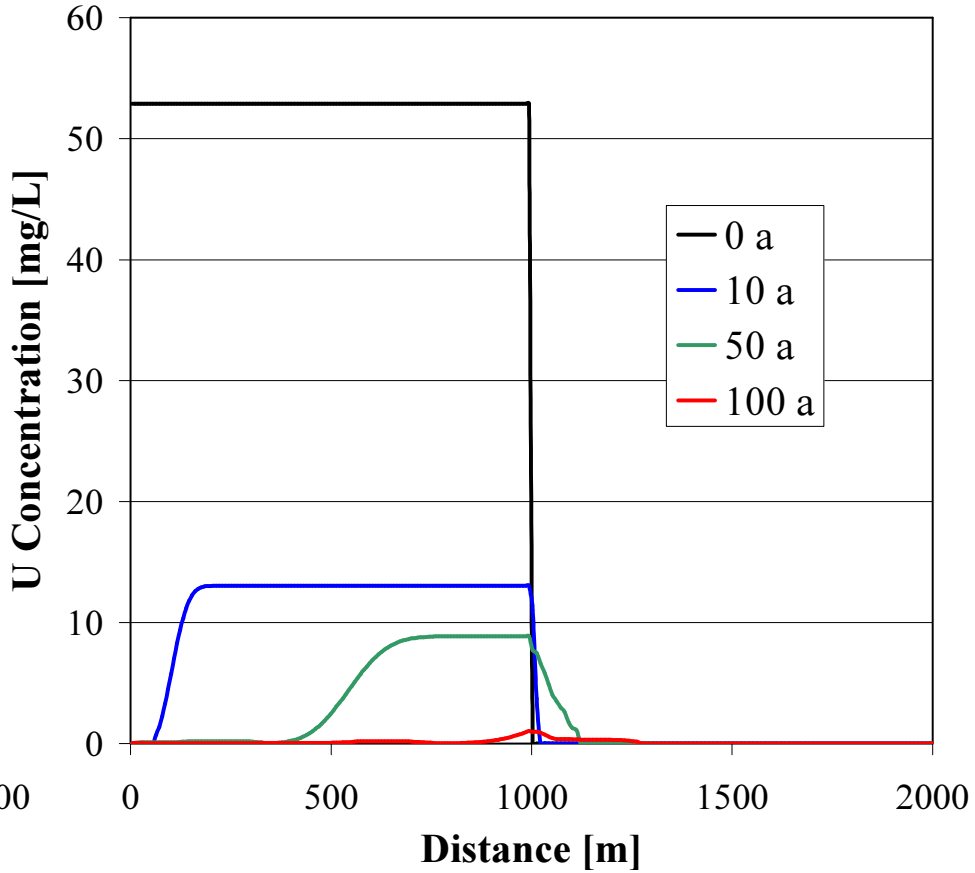


Scenario 1 (1 km ISR zone) - Uranium

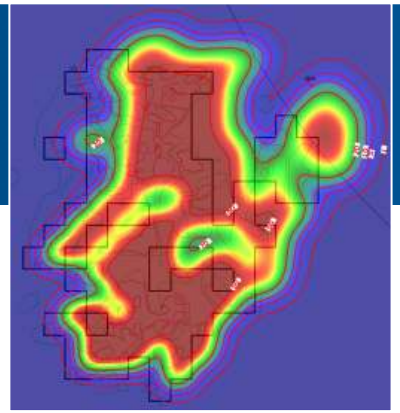
Pure NA



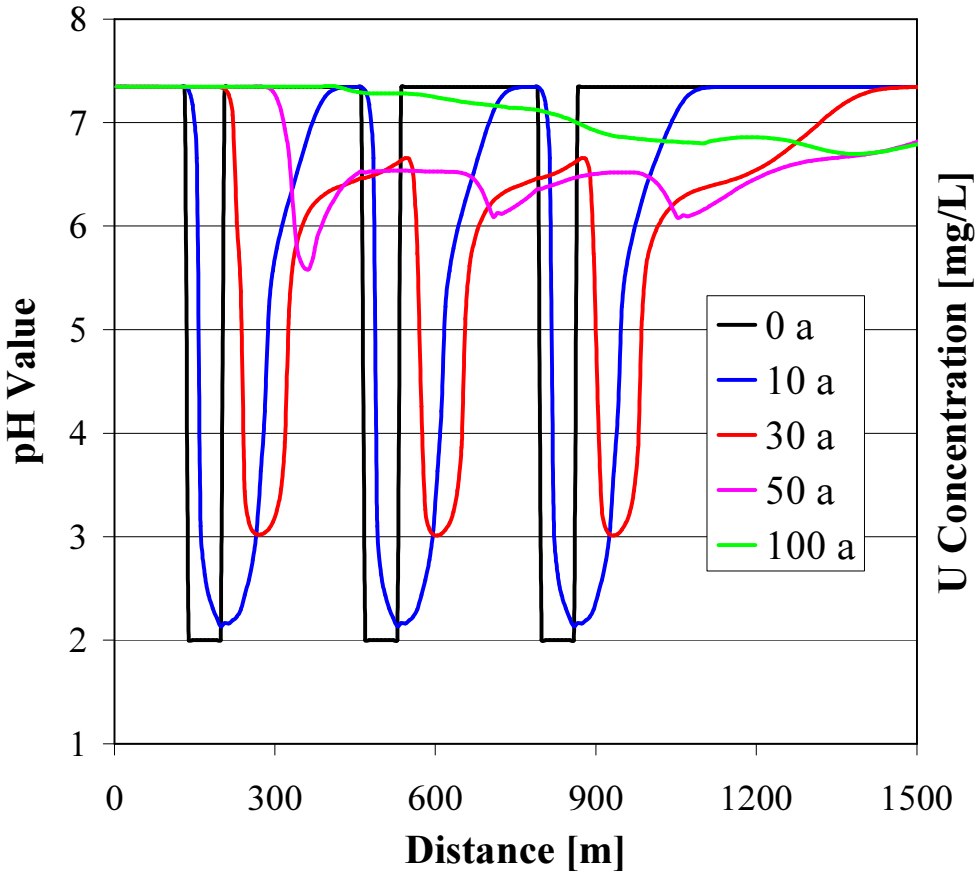
ENA: Groundwater sweep

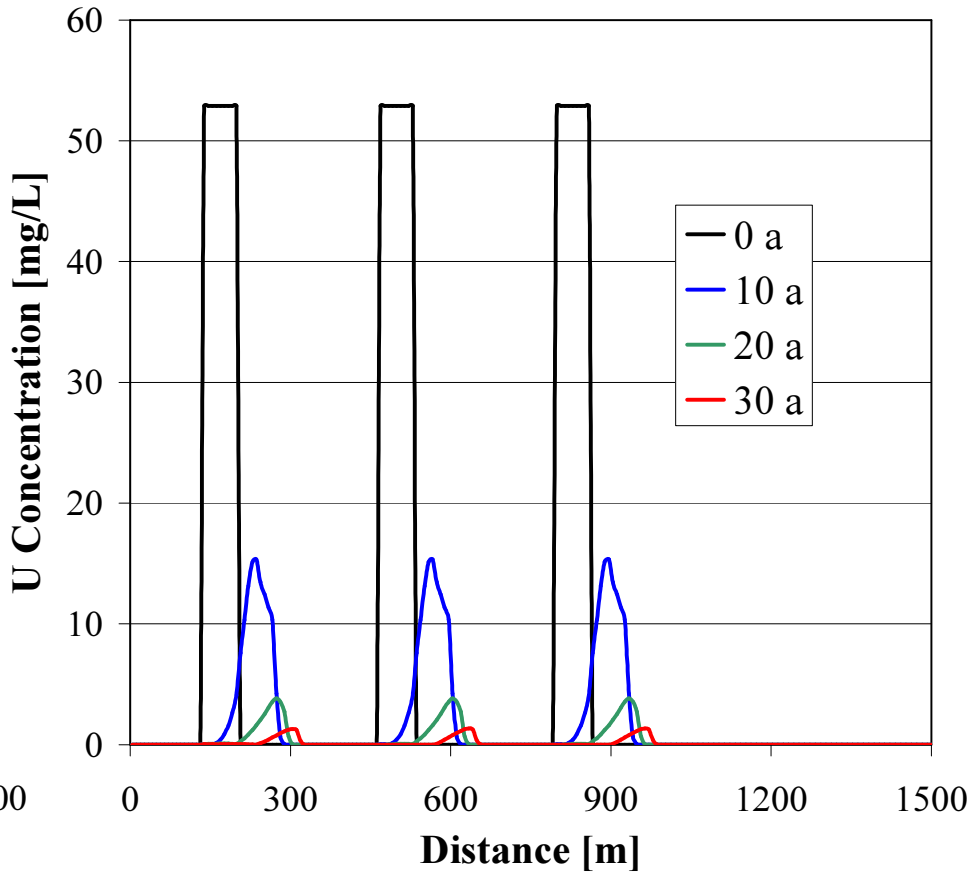


Scenario 2 (Patchy Mine Zone, NA)



Patchy ISR zones - pure NA





Summary

- **BFM mine closure plan:**
  - ENA (→ groundwater sweep by exchange between wellfields) in combination with extensive regulatory monitoring program
  - Consistent with world's best practice under specific local circumstances
  - To be implemented in a staged (iterative) approach
- **Groundwater use category unchanged**
- **NA/ENA model predicts limited impact within attenuation zone with a range of acidity and contamination considerably less than length of attenuation zone**
- **Reactive transport model refines 2007 U.S.G.S. study on ISR impacts on groundwater by**
  - Well-calibrated model (core-test based)
  - More realistic model space
  - Higher resolution
  - Flexibility (incl. simulation of ENA)

View from Flinders Ranges on Beverley Four Mile