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Overview of Remediation Technologies for Radionuclides in Soil and Groundwater

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Context

- Remediation technologies operate at the intersection of
  - radionuclide characteristics
  - the target problem
  - remedy functionality
  - remediation objectives

Outline

- Radionuclide characteristics related to remediation
- Considering end states and attenuation in remedy decisions
- Remedy technologies and approaches
- Remedy implementation

- Discussion focused on
  - Uranium, Tc-99, Sr-90, I-129, tritium
  - Groundwater protection and groundwater remediation

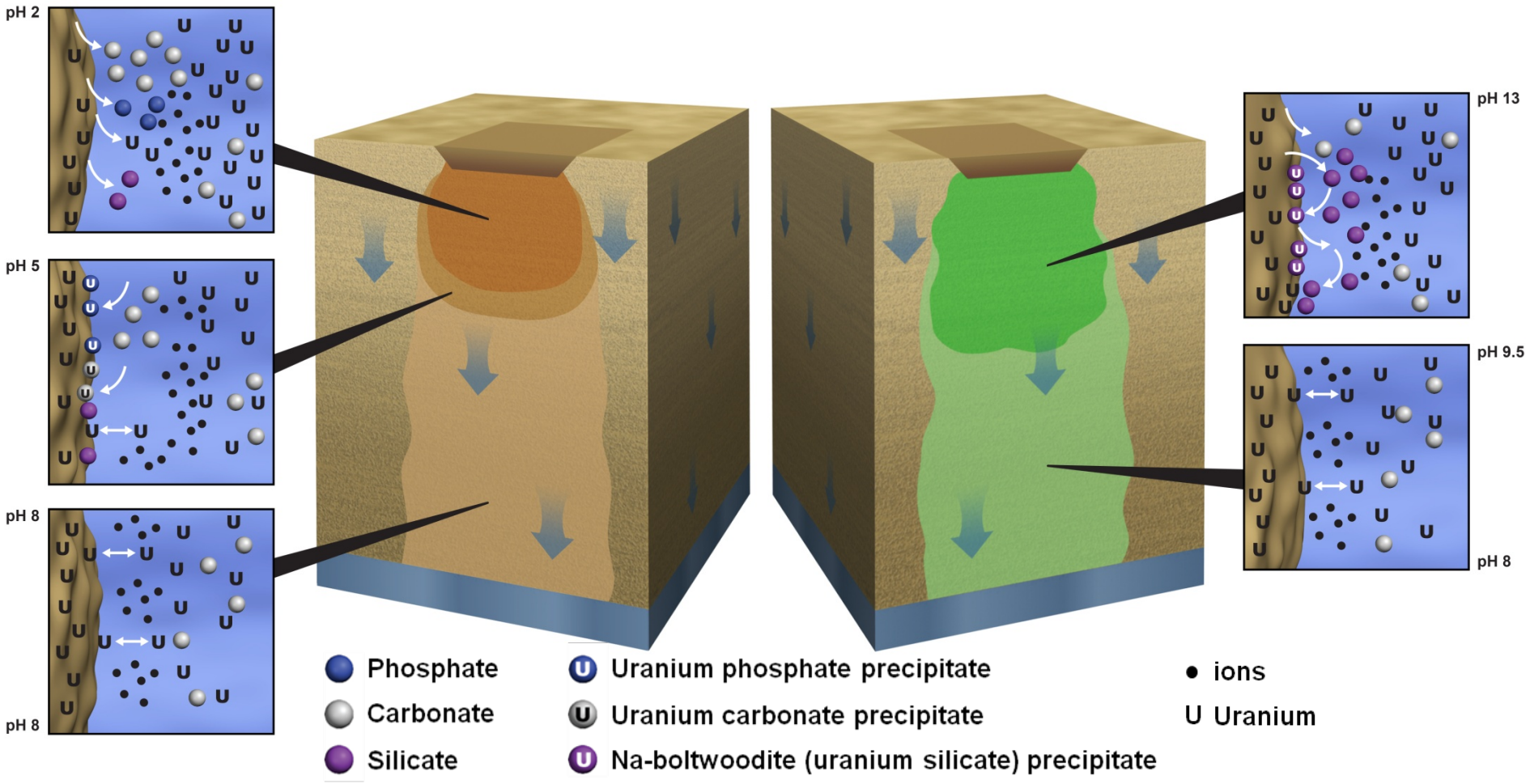
Radionuclide Characteristics (Friend or Foe)

- Half-life
  - Shorter is better (when exposure is controlled)
    - Sr-90 or tritium compared to uranium, I-129, or Tc-99
- Mobility (sorption)
  - Very low mobility generally good
  - Medium or high mobility - depends on the situation
    - Attenuated transport can be helpful (vadose zone contamination) or problematic (P&T)
    - Secondary sources are problematic unless balanced by attenuation

Radionuclide Characteristics (Friend or Foe)

- Biogeochemical interactions
  - Helpful
    - Uranium and Sr-90 interactions with phosphate
    - Uranium silicate precipitates
  - Mixed
    - Uranium and I-129 (and Cr) interactions with carbonate
      - Depends on location/extent
    - I-129 species transformation
      - Depends on change in mobility and potential for attenuation/sequestration
    - Uranium and Tc-99 redox
      - Depends on setting and role in a remedy
  - No interactions
    - tritium

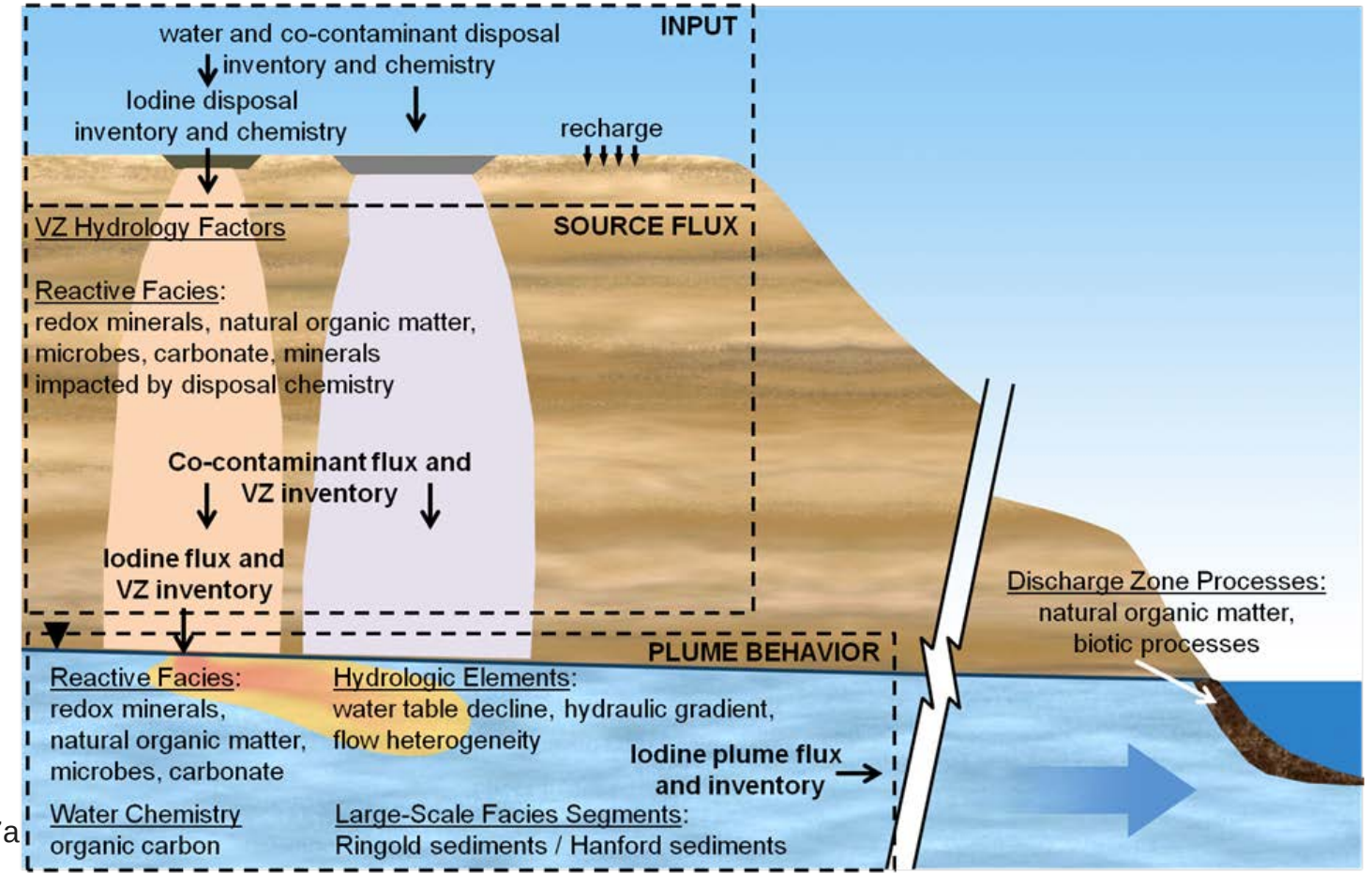
Disposal Chemistry



Szecsody et al. 2013
Truex et al. 2014

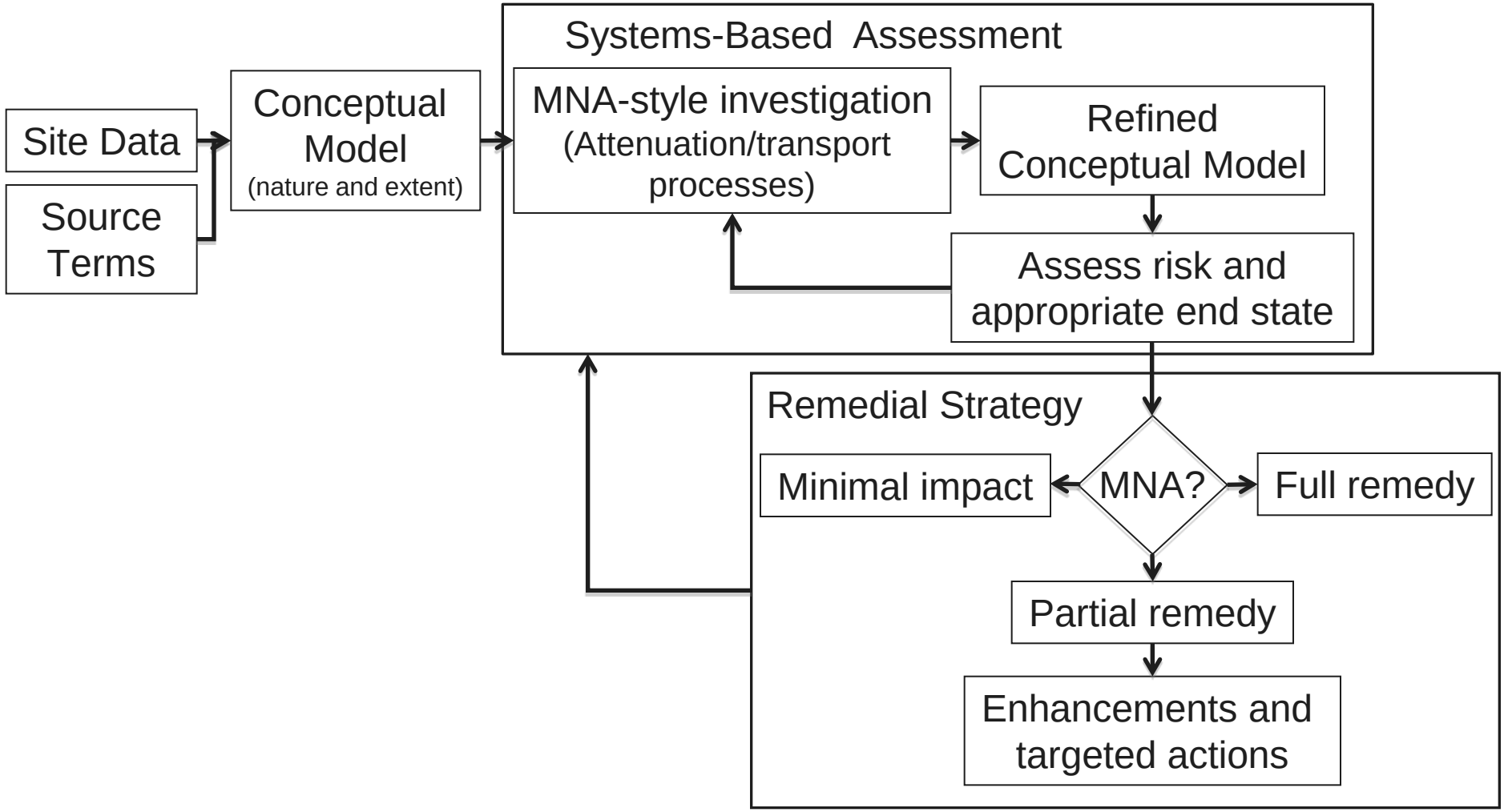
Radionuclide Characteristics (Friend or Foe)

- The Conceptual Site Model helps us decide:
  - Friend or foe for risk and transport
  - Friend or foe for remediation



Truex et al. 2017a

Considering End States and Attenuation in Remedy Selection

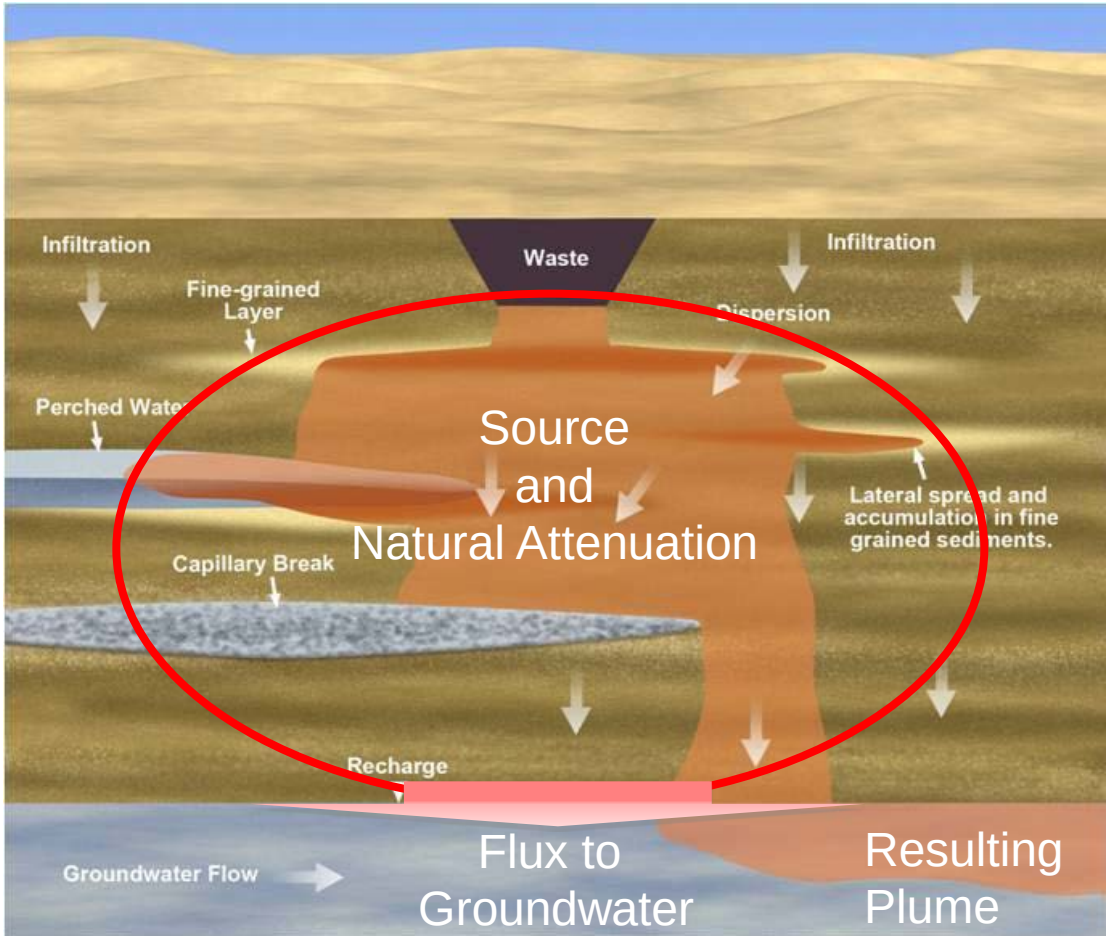


Remedy Technologies and Approaches

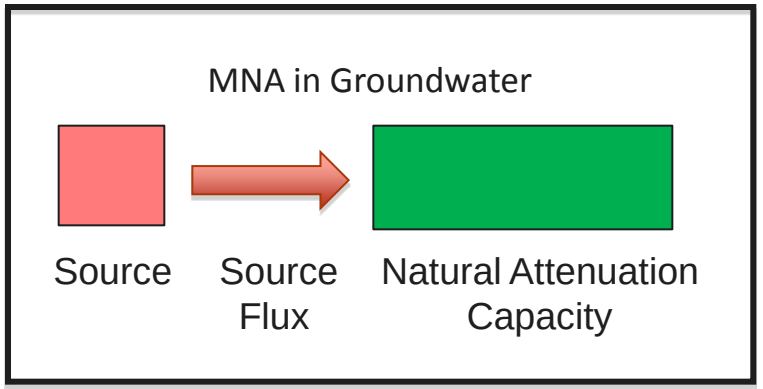
- Vadose zone
  - Attenuation
    - Consider transport processes in the vadose zone
  - Flux control (enhanced attenuation)
    - Physical stabilization
    - Hydraulic control
    - Biogeochemical stabilization
  - Extraction (e.g., excavation, soil flushing)
    - Cost/benefit
  - Groundwater treatment (e.g., phosphate)
    - Consider vadose zone source characteristics for groundwater impact

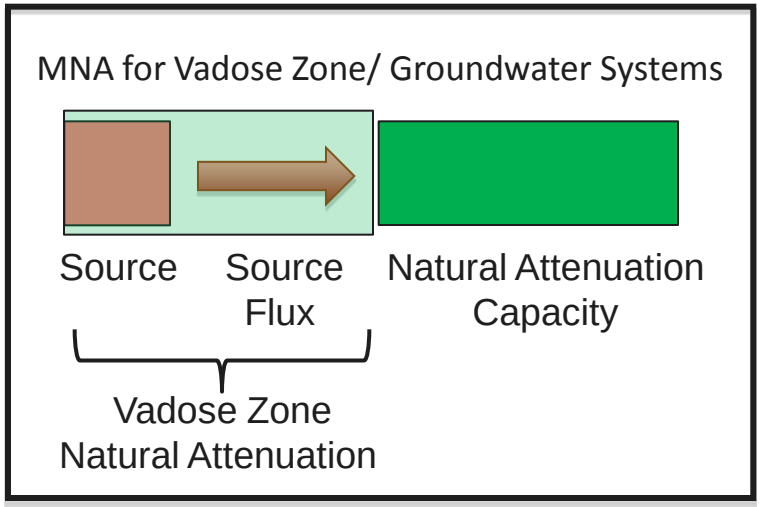
Dresel et al. 2011

Attenuation



Adapted from Dresel et al. 2011

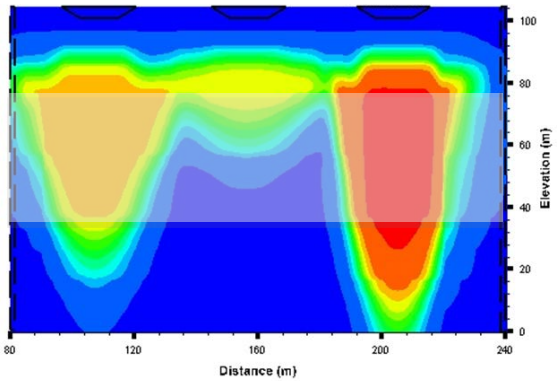


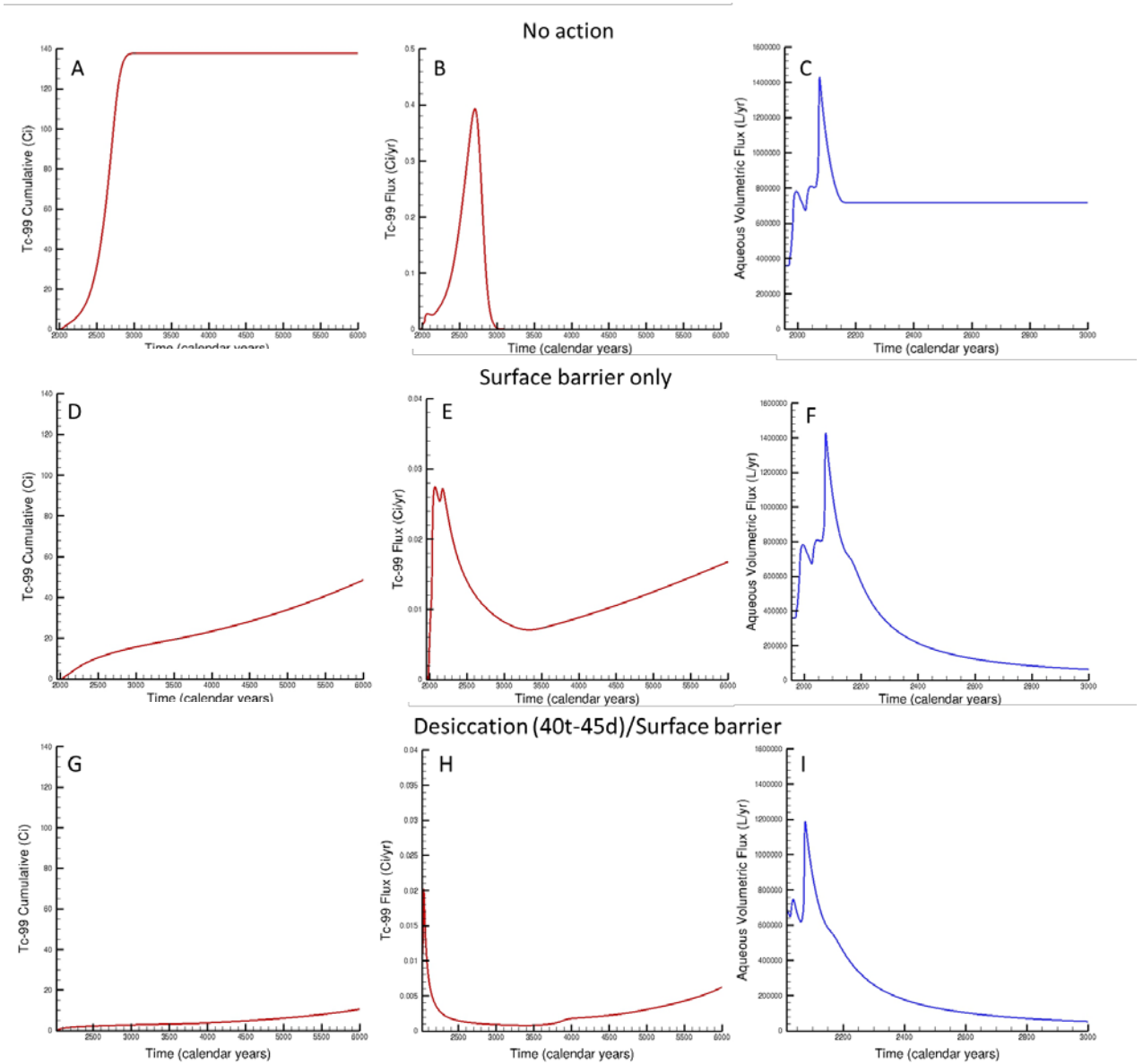


Truex and Carroll 2013
Truex et. al 2015a
Oostrom et al., 2016

Desiccation

- Desiccation as hydraulic control

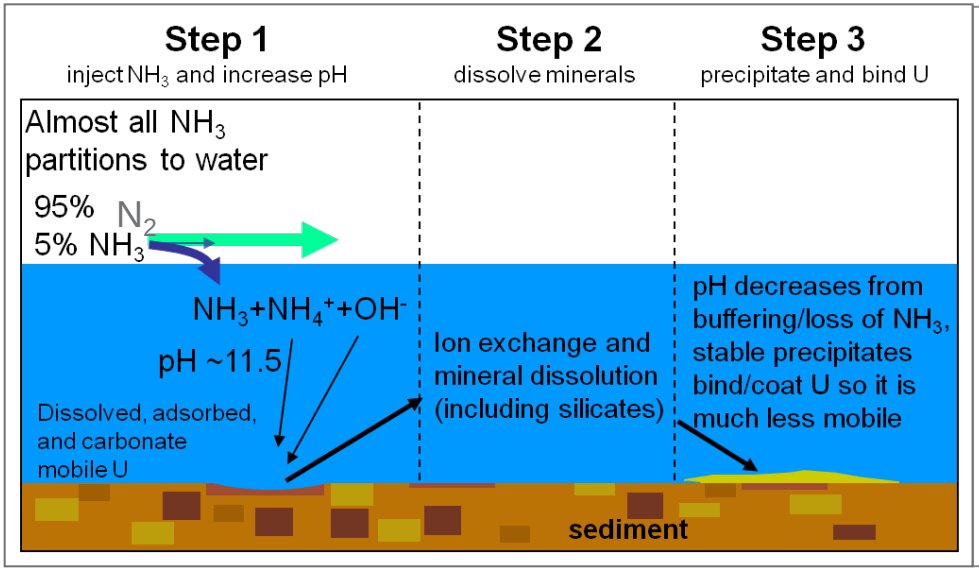


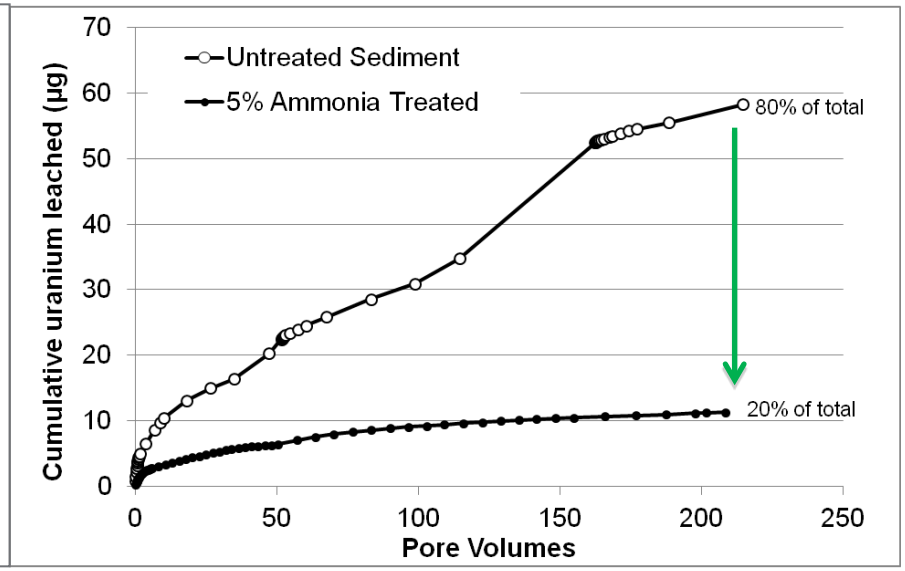


Truex et al. 2017b

Geochemical stabilization – vadose zone

- Ammonia gas for uranium sequestration

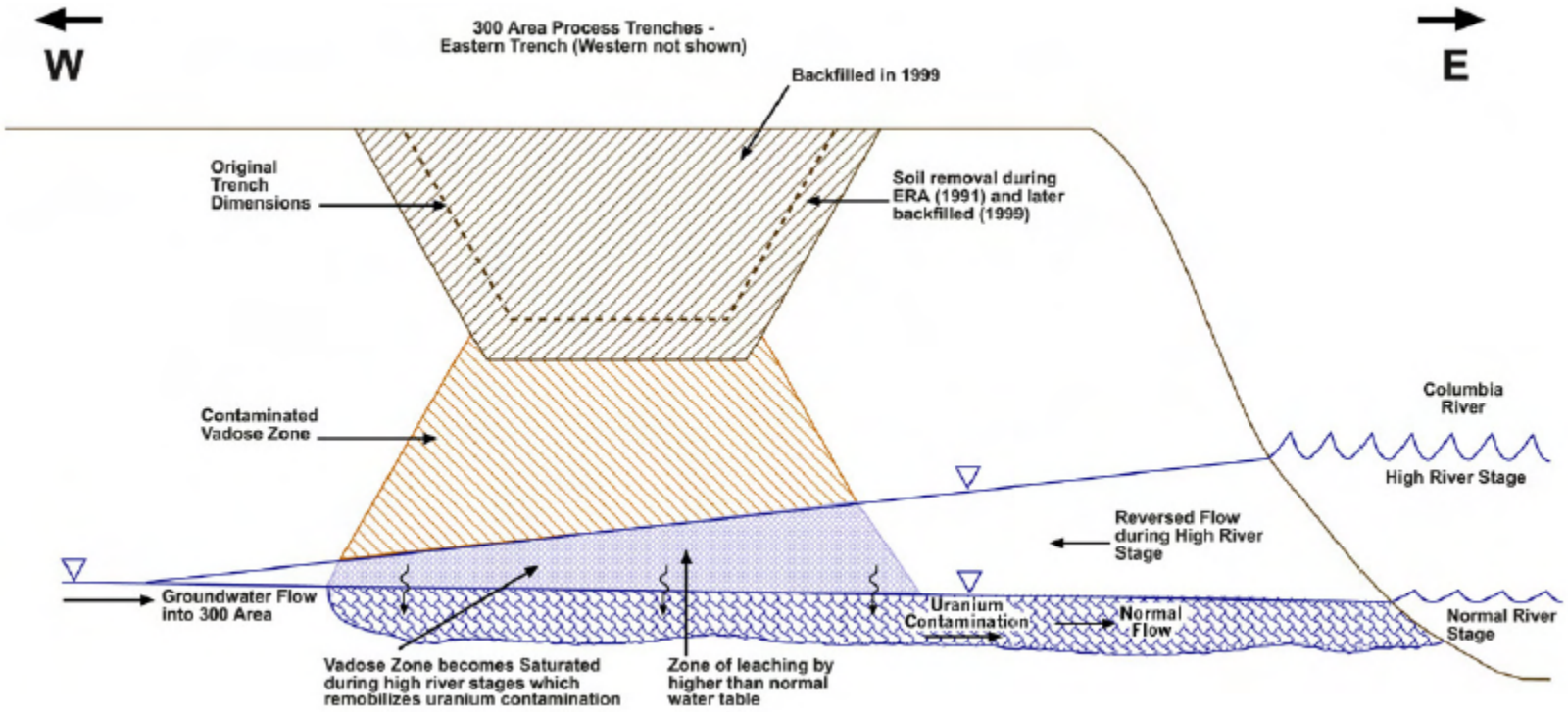




Szecsody et al. 2012

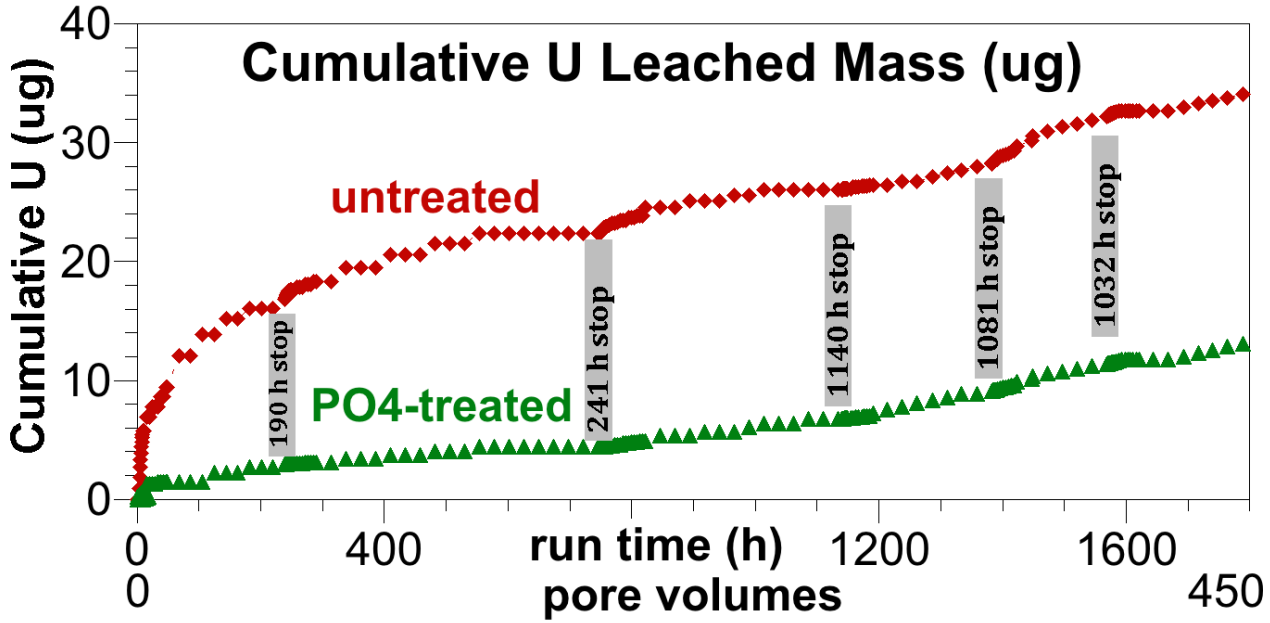
Uranium source zone

- Periodically rewetted zone



Geochemical stabilization – periodically rewetted zone

- Phosphate treatment for uranium

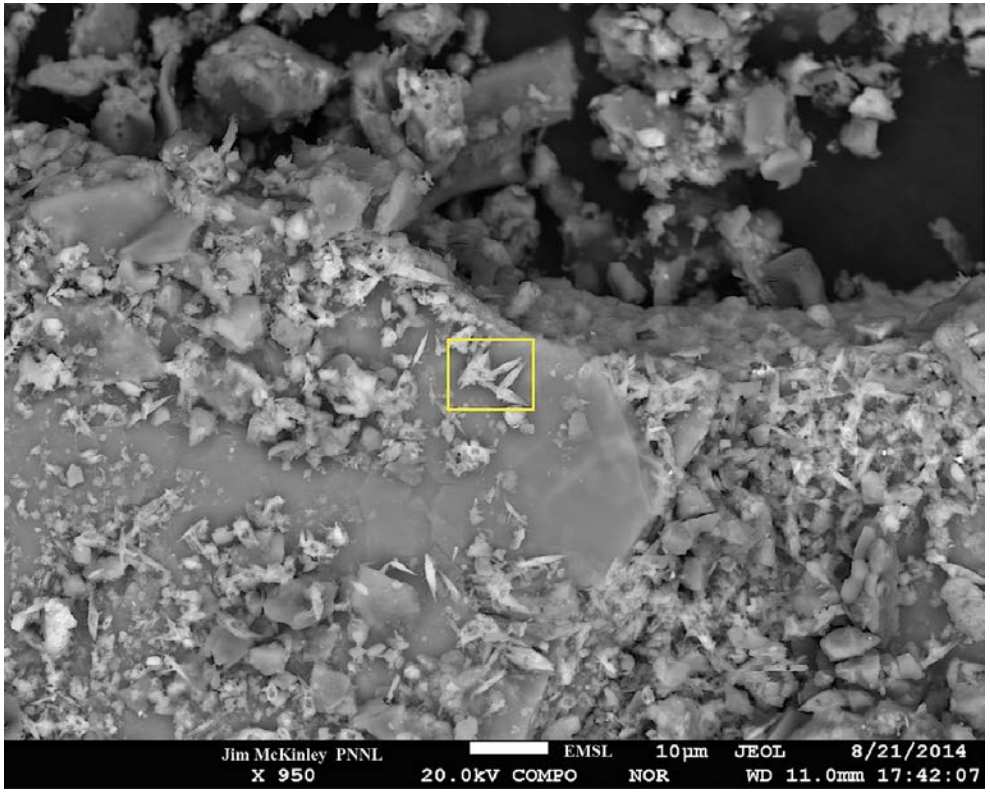


Remedy Technologies and Approaches

- Groundwater
  - Attenuation
    - EPA guidance
  - Enhanced Attenuation and Source Control
    - Physical stabilization
    - Hydraulic control
    - Biogeochemical stabilization
  - Extraction (P&T)
    - Cost/benefit
  - Volumetric Treatment/Permeable Reactive Barriers
    - Scale, transport, attenuation

Carbonate interactions

- Uranium, iodate, and chromate co-precipitates with calcite

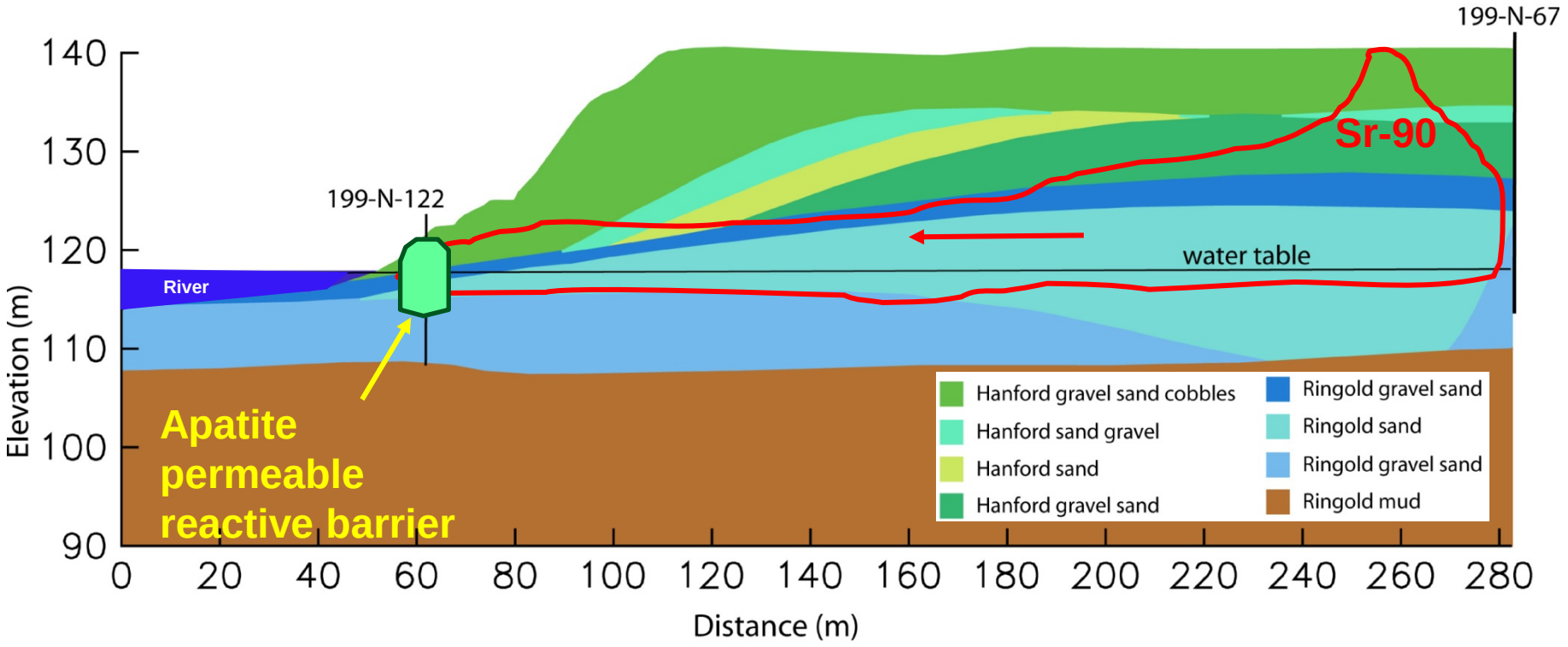


Cr-calcite observed in a Hanford field sediment

Truex et al. 2015b

100-N Strontium

- Only near-river strontium is a risk to the river
- Monitoring linked to remedy approach



Remedy Implementation

- Amendment distribution
  - Vadose zone gas phase
  - Phosphate mobility
  - Particles
  - Bioremediation amendments

Reductants

- ZVI
- SMI

Truex et al. 2011a
Truex et al. 2011b

Remedy Implementation

- Adaptive Site Management
  - National Research Council
  - ITRC
    - Remediation Management of Complex Sites
    - http://rmcs-1.itrcweb.org/
- Exit Strategies (P&T)
  - http://bioprocess.pnnl.gov/Pump-and-Treat.htm

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