Performance Assessment for the Energy*Solutions* LLW Disposal Facility at Clive, Utah

Neptune and Company, Inc.

Presenters

Paul Black, PhD	PA process
John Tauxe, PhD, PE	PA modeling
Katie Catlett, PhD	Near-field processes
Ralph Perona, DABT	Far-field and dose
Mike Balshi, PhD	Deep time scenarios

Presentation Outline

- Performance Assessment Development
- The Clive Depleted Uranium PA
  - Features, Events, Processes (FEPs)
  - Conceptual Site Model

PA Development

- Performance assessment objectives
- ***Features, events, processes***
- ***Conceptual models***
- Mathematical models
- Computer model
- Model evaluation

Periodically revisit the PA model.

PA Objectives

- Evaluate future performance of a radioactive waste disposal system.
- Evaluate compliance with regulatory performance objectives (*e.g.*, dose).
- Consider design alternatives that could help keep doses ALARA*.

*as low as reasonably achievable

PA Conditions

Spatial extent:

- Waste disposal configuration
- Exposure areas
- Groundwater and atmosphere

Waste inventory:

- Physical characteristics
- Radiological characteristics
- Chemical characteristics

PA Conditions: Time

Near time (within 10,000 y):

- Project current conditions/knowledge (society, technology)
- Estimate radiation doses

Deep time (peak activity after 10,000 y):

- Consider changes in climate

Potentially-Exposed Individuals

Based on current land use and activities:

- Persons who may gain access to the site following loss of institutional control
- Persons who may be exposed at off-site locations

Features, Events, and Processes

Features are characteristics of the Site, e.g., soil, geology, water, air, waste

Events might occur in the future, e.g., earthquakes, volcanoes, tsunamis, meteors, ice ages

Processes are ongoing actions, e.g., subsidence, erosion, biotic mixing, hydrology, geochemistry

Features, Events, and Processes

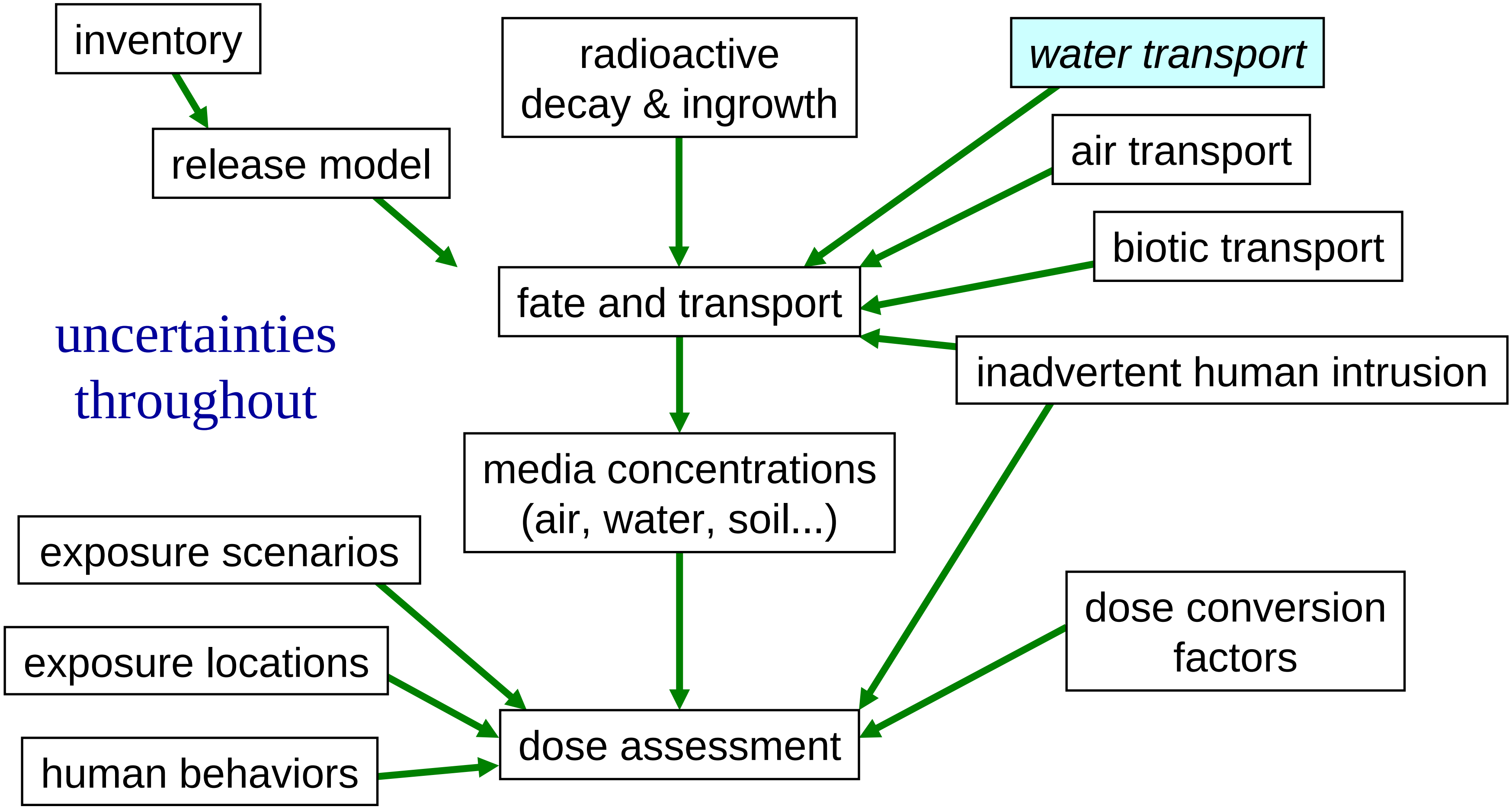
A comprehensive list of FEPs is compiled:

- Evaluate previous FEP work for PAs.
- Consider FEPs unique to the site.
- Combine redundant FEPs into categories.
- Screen out those that are irrelevant.
- Address those that are relevant by including them in the conceptual model.

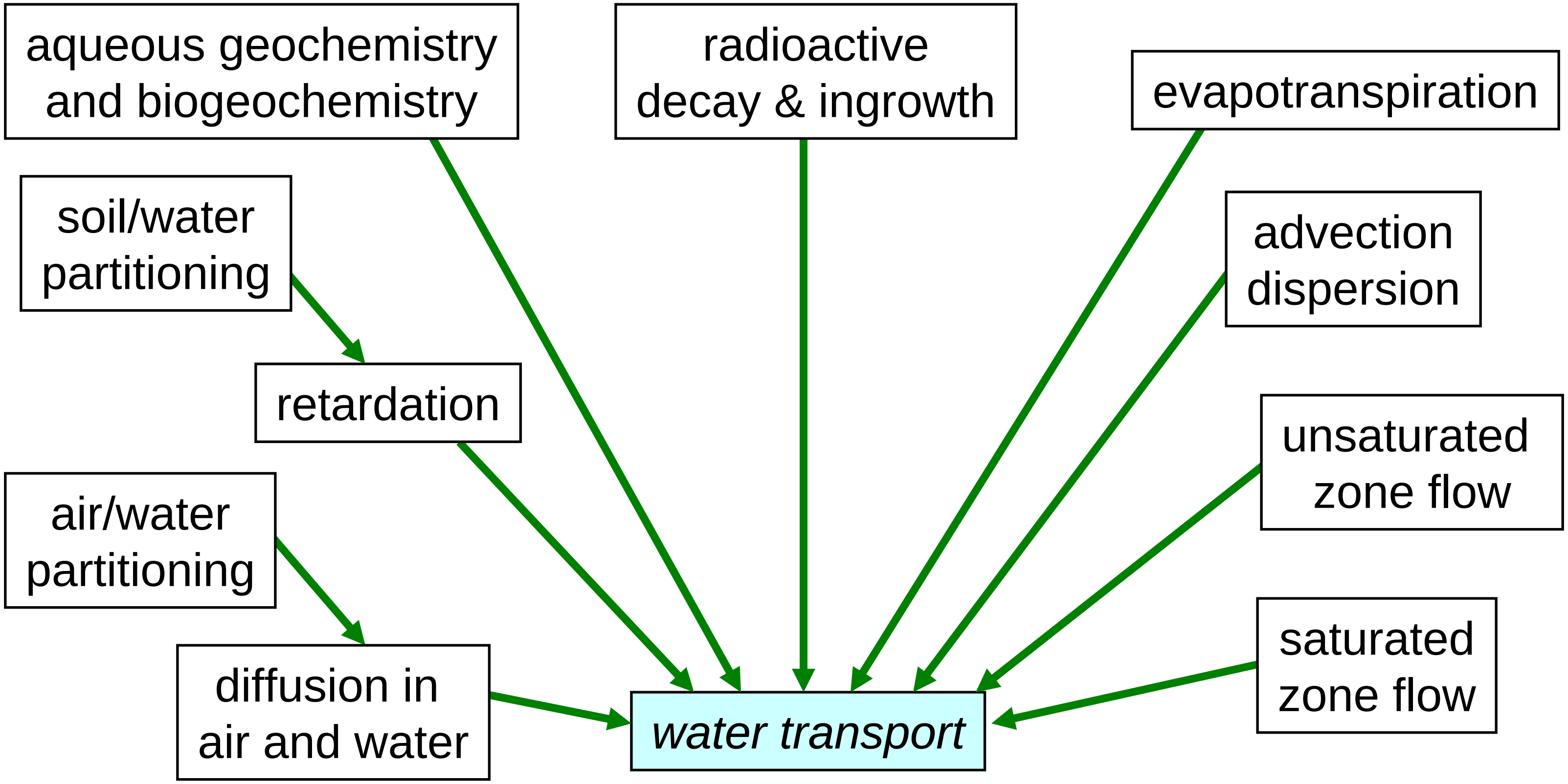
Conceptual Site Model (CSM)

- Inventory
- Engineered barriers
  - Release and transport into environment
- Environment
  - Transport
- Exposure scenarios
  - Dose
- Deep time
  - Consideration of future climate

A PA Influence Diagram



Influences in Water Transport



uncertainties throughout

CSM – Transport Examples

- "Water flows through porous media."
- "Radon diffuses through interstitial air in porous media."
- "Animals deposit burrow spoils on the ground surface, and burrows collapse."
- "Wind carries contaminants in dust to other locations."

These are developed into mathematical expressions and are implemented in the computer model.

Mathematical Models

Physical processes are modeled as coupled partial differential equations and transfer functions:

$$N_i = \lambda_1 \lambda_2 \cdots \lambda_{i-1} N_{1(0)} \sum_{j=1}^{i} \frac{e^{-\lambda_j t}}{\prod_{k \neq j} (\lambda_k - \lambda_j)}$$

$$C_{air} = K_H \times C_{water}$$

$$\tilde{J} = -\theta_a D_s \nabla C$$

$$C_{water} = \left(1 + K_d \frac{\rho_b}{\theta_w}\right) \times C_{soil}$$

$$\tilde{J} = -\theta_w D_s \nabla C$$

$$v_x = \frac{K}{n} \nabla h$$

$$Q_{atm} = f_R \times C_{soil}$$

$$C_{water} \leq C_{solubility}$$

Computer Modeling

- Systems-level modeling
  - Fully-coupled
  - Probabilistic
  - Supports global sensitivity analysis
- Supported by process-level models
  - More detailed modeling
    - Deterministic
  - Abstracted into the systems model

Statistical Support

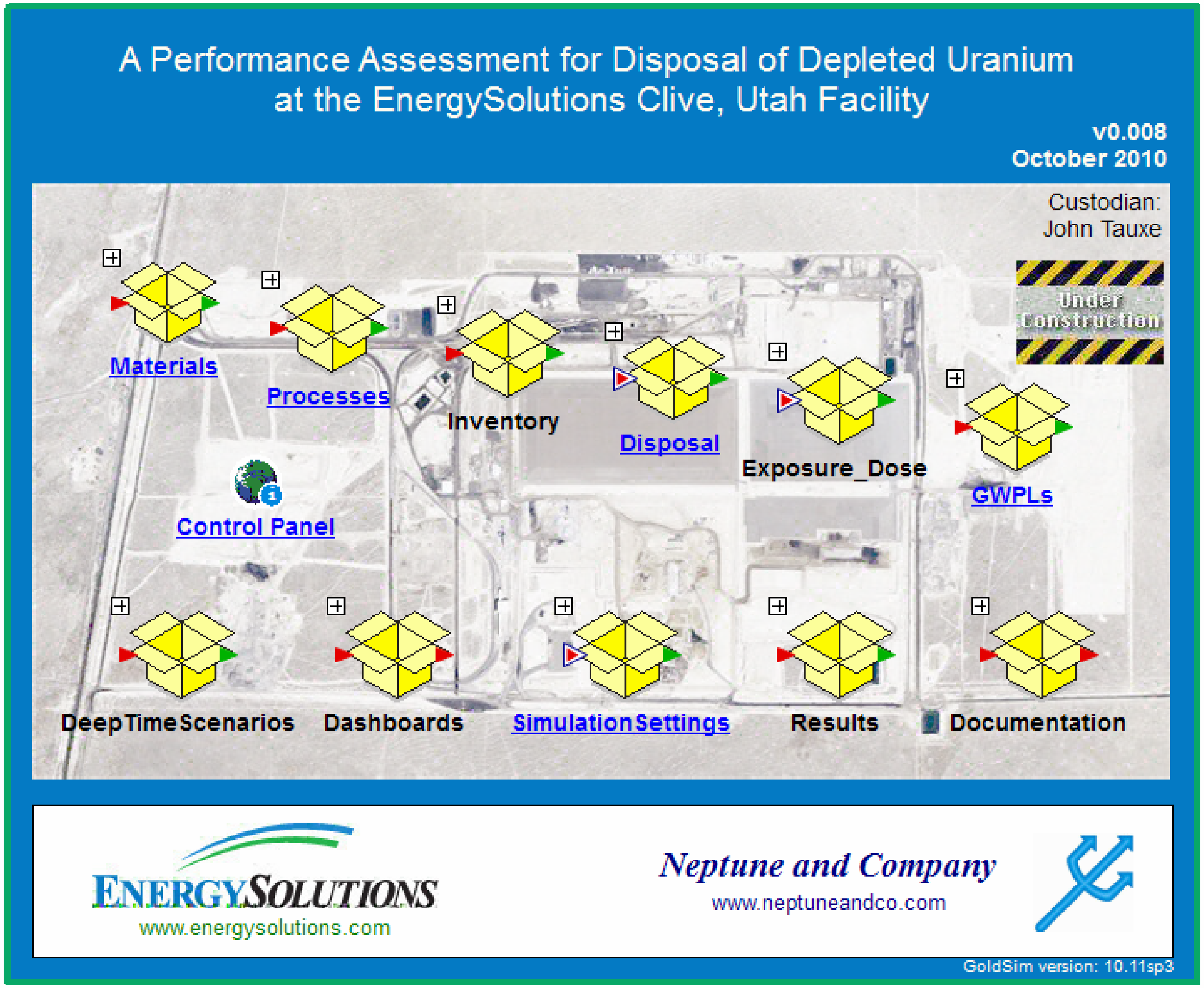
- Develop input probability distributions using
  - Field or laboratory data and observations
  - Model abstraction
  - Information from the literature
  - Expert elicitation
- Uncertainty *vs*. variability
- Spatio-temporal scaling
- Correlation between input parameters

Evaluating the PA Model

- Test the model during development
- Thorough QA – traceability
- Uncertainty analysis
    - Compare results to objectives
- Sensitivity analysis
    - Global for input parameters
        - Simultaneous
    - Identify important input parameters

The Clive
Depleted Uranium
Performance Assessment

The Clive DU PA Model



Scope of the Clive DU PA

- Clive, Utah facility
- Depleted uranium wastes that are candidates for future disposal
- Single embankment: Class A South
- Address performance objectives specified in UAC R313-25-8

Quantitative for 10,000 y; qualitative after

PA Conditions: Clive Facility

Spatial extent:

- Class A South embankment
- Exposures on and off site
- Groundwater, soil, and atmosphere

Waste inventory:

- Powdered depleted uranium (DU) as UO_3 and U_3O_8 (*not* UF_6)
- Associated contaminants in the DU

PA Conditions: Time

Near time (within 10,000 y):

- Project current conditions/knowledge (society, technology)
- Estimate radiation doses

Deep time (peak activity > 2 million y):

- Consider changes in climate, including recurrence of large lakes

Clive PA Exposure Scenarios

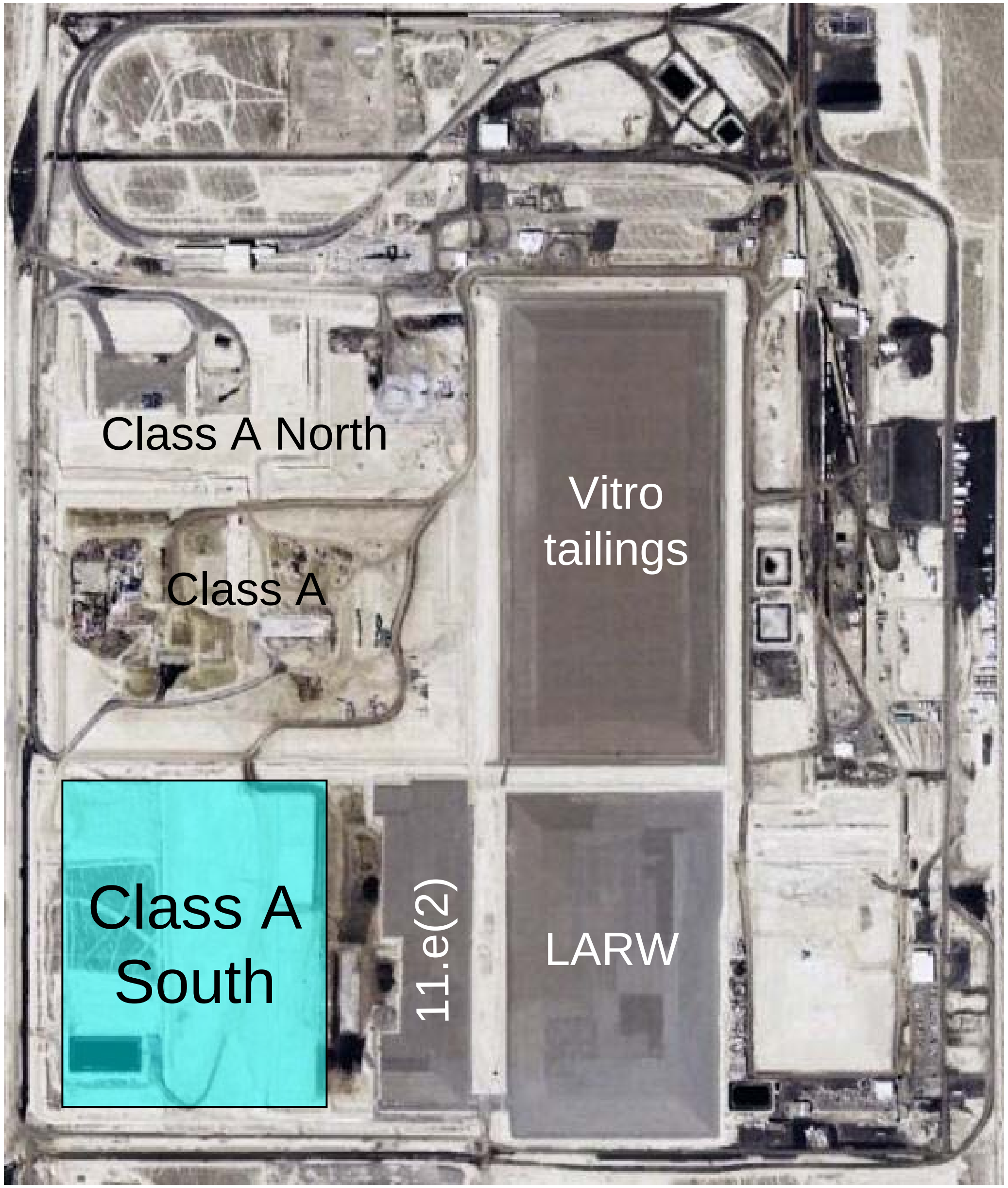
On-site and adjacent Off-site areas

- Ranch workers:
  herding, maintenance
- Recreationalists:
  OHV users; hunting, camping

Off-site locations

- Travelers (highway, rail, Test Range access)
- OHV users (Knolls OHV Recreation Area)
- Resident (Grassy Rest Area at Aragonite)

Class A South Embankment



Modeling assumptions:

- Class A South only
- future DU waste only

FEPs for this PA

18 groups of FEPs were identified:

- Celestial
- Climate change
- Containerization
- Contaminant Migration
- Engineered Features
- Exposure
- Hydrological
- Geochemical
- Geological
- Human Processes
- Hydrogeological
- Marine
- Meteorological
- Model Settings
- Other Natural Processes
- Source Release
- Tectonic/Seismic/Volcanic
- Waste

The FEPs were then subjected to screening.

CSM topics: 10,000-y Model

- Inventory
- Engineering design
- Natural environment
- Contaminant transport
- Radiological decay and ingrowth
- Human exposure scenarios
- Dose assessment

CSM topics: Deep Time

- Return of a large lake
- Fate of cover
- Fate of wastes
- Radiological decay and ingrowth

Contaminant Transport Mechanisms: Near-Field

Inventory: DU Waste

Depleted Uranium Waste consists of

- DU: mostly ^{238}U by far, with little ^{235}U and very little ^{234}U
- Very small amounts of decay products
- Trace contaminants from introducing reprocessed U into the cascade: ^{99}Tc, ^{129}I, ^{X}Pu, ^{237}Np

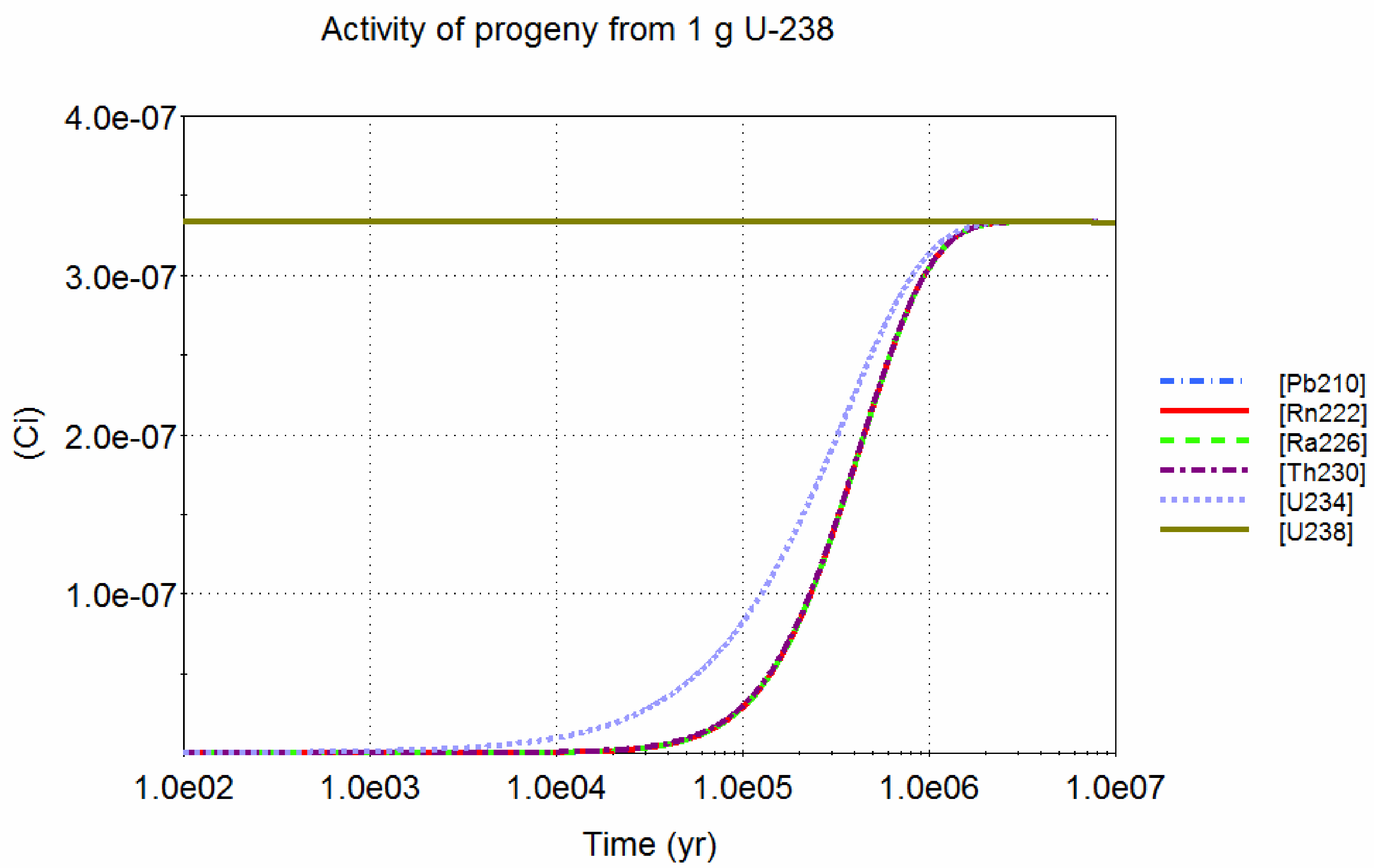
DU Waste Containment

Depleted UO_3 from the Savannah River Site is packaged in steel drums.

Depleted U_3O_8 from the gaseous diffusion plants (GDPs) is packaged in diffusion plant cylinders

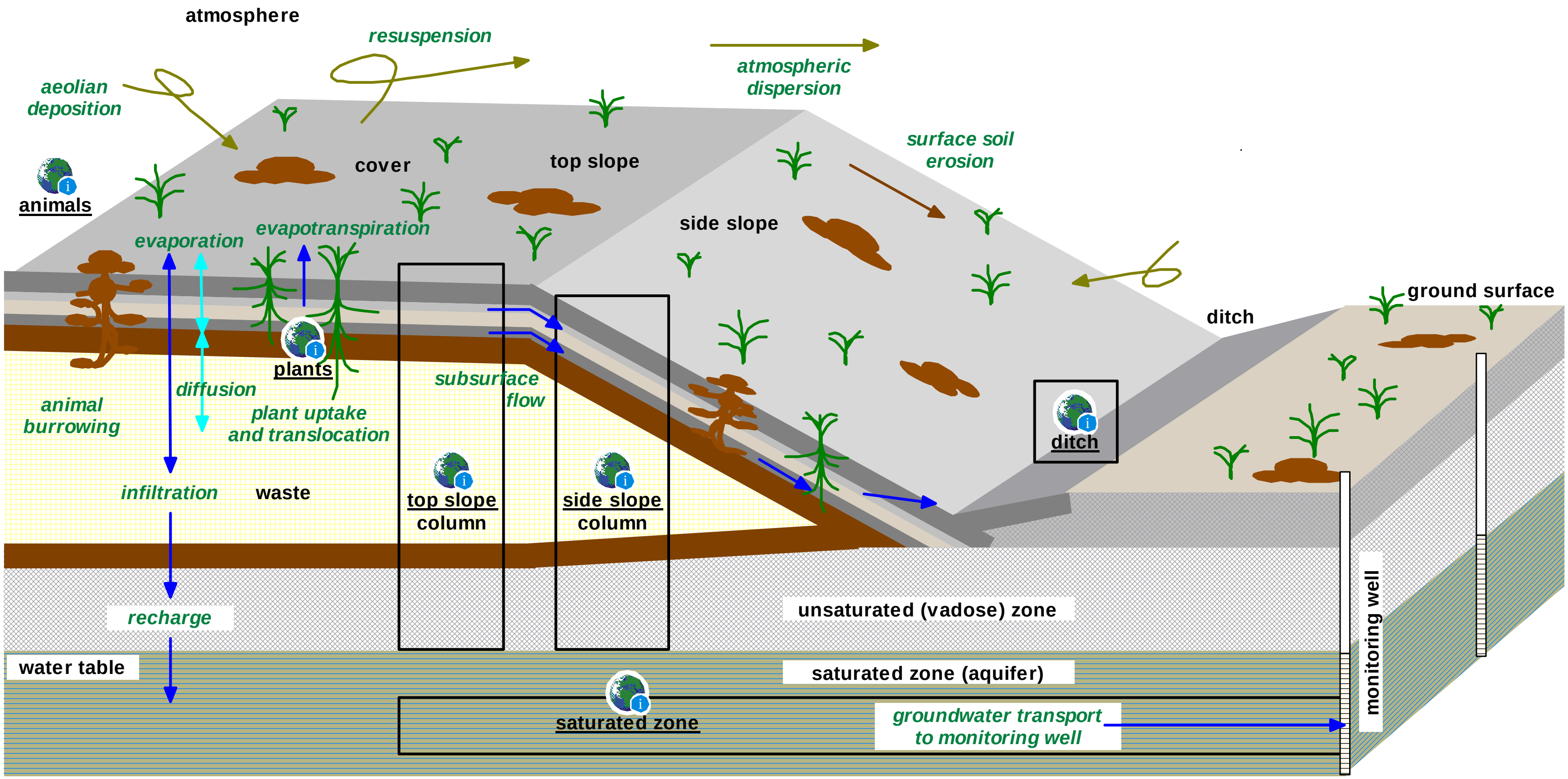
No credit is taken for any packaging or containerization.

Activity of ^{238}U Progeny

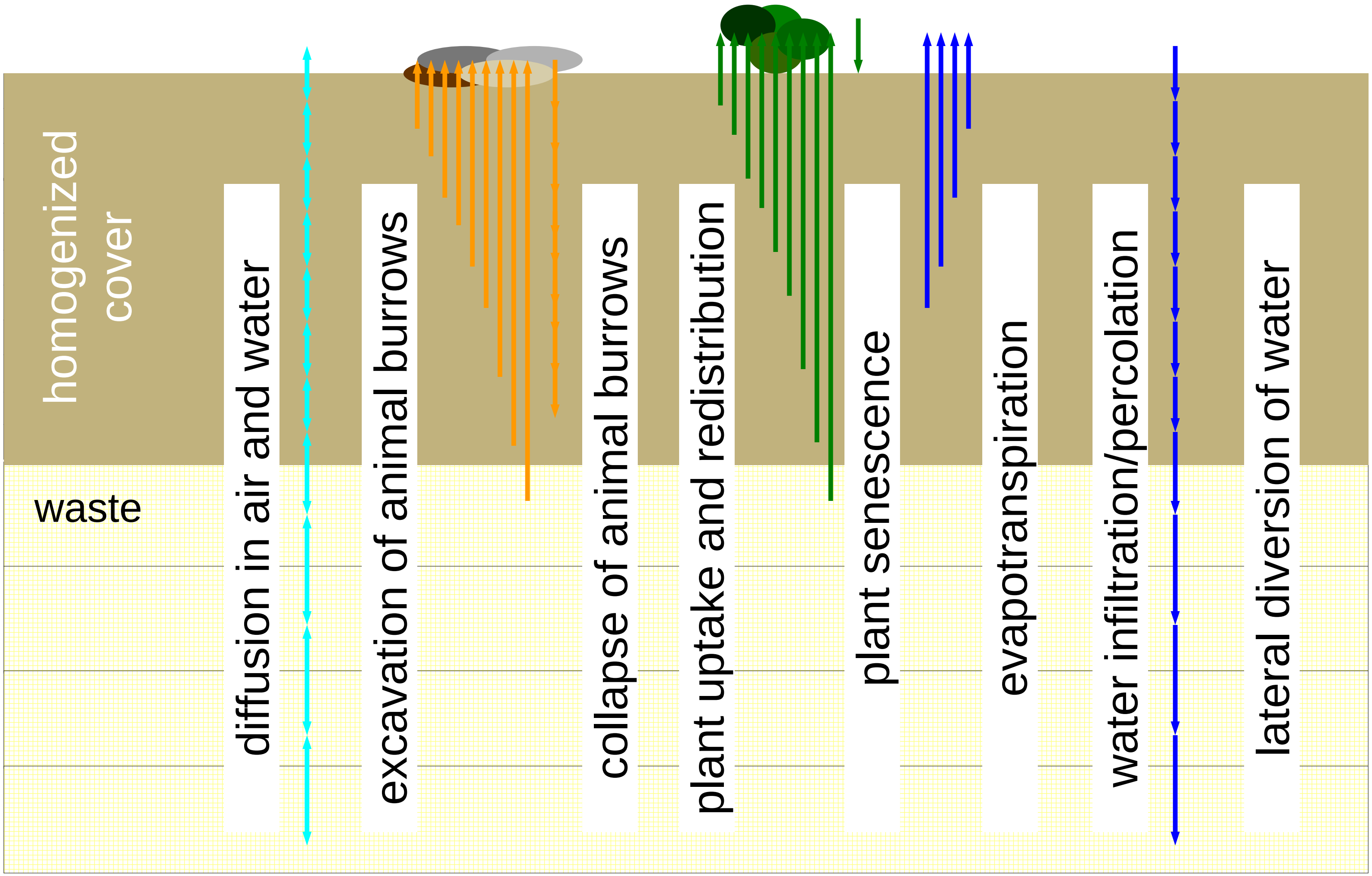


Near-Field CT Mechanisms

Conceptual diagram of physical processes for contaminant transport for an above-grade waste disposal embankment, responsive to UAC R313-25-8 (1).



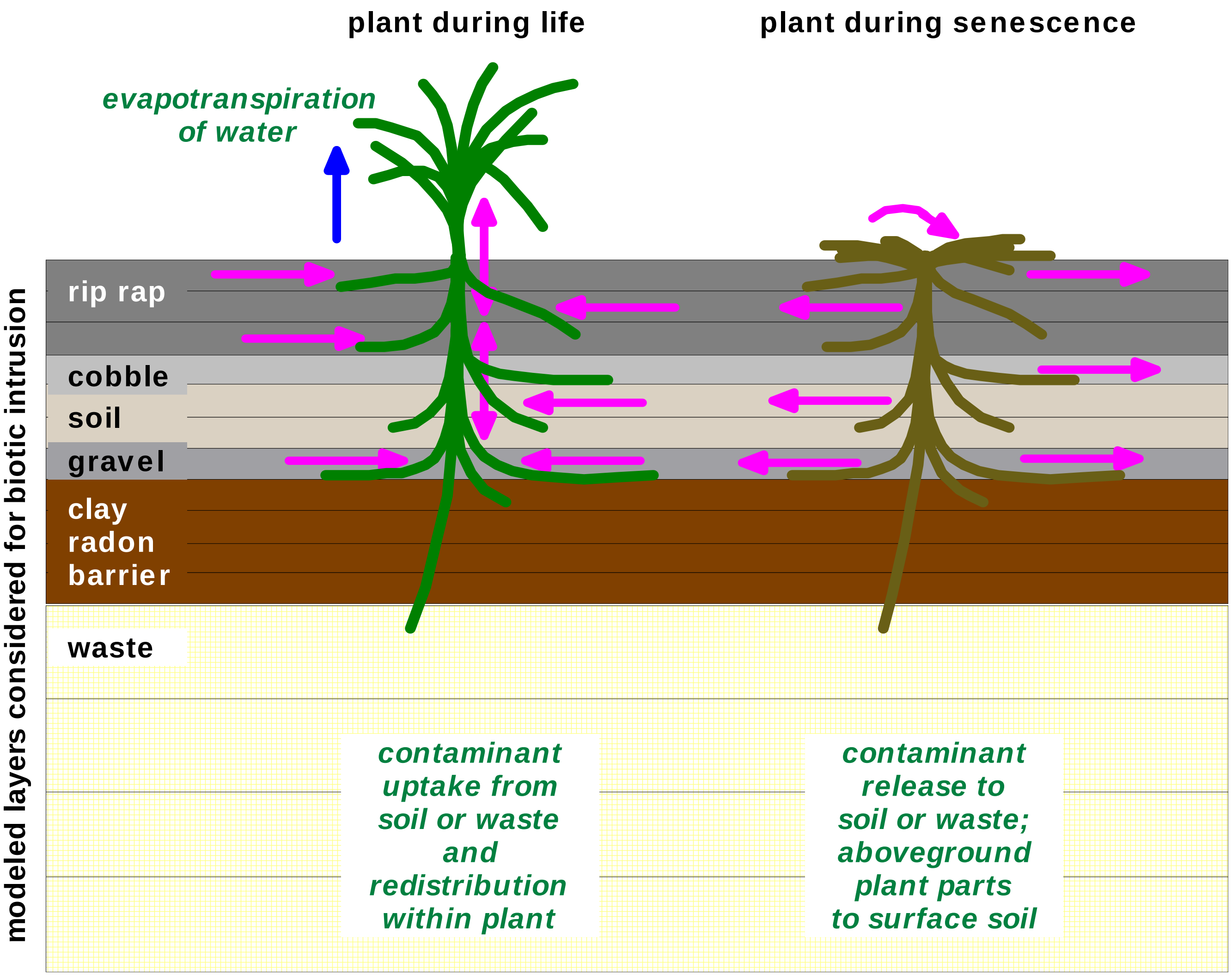
CT Processes in the Cover



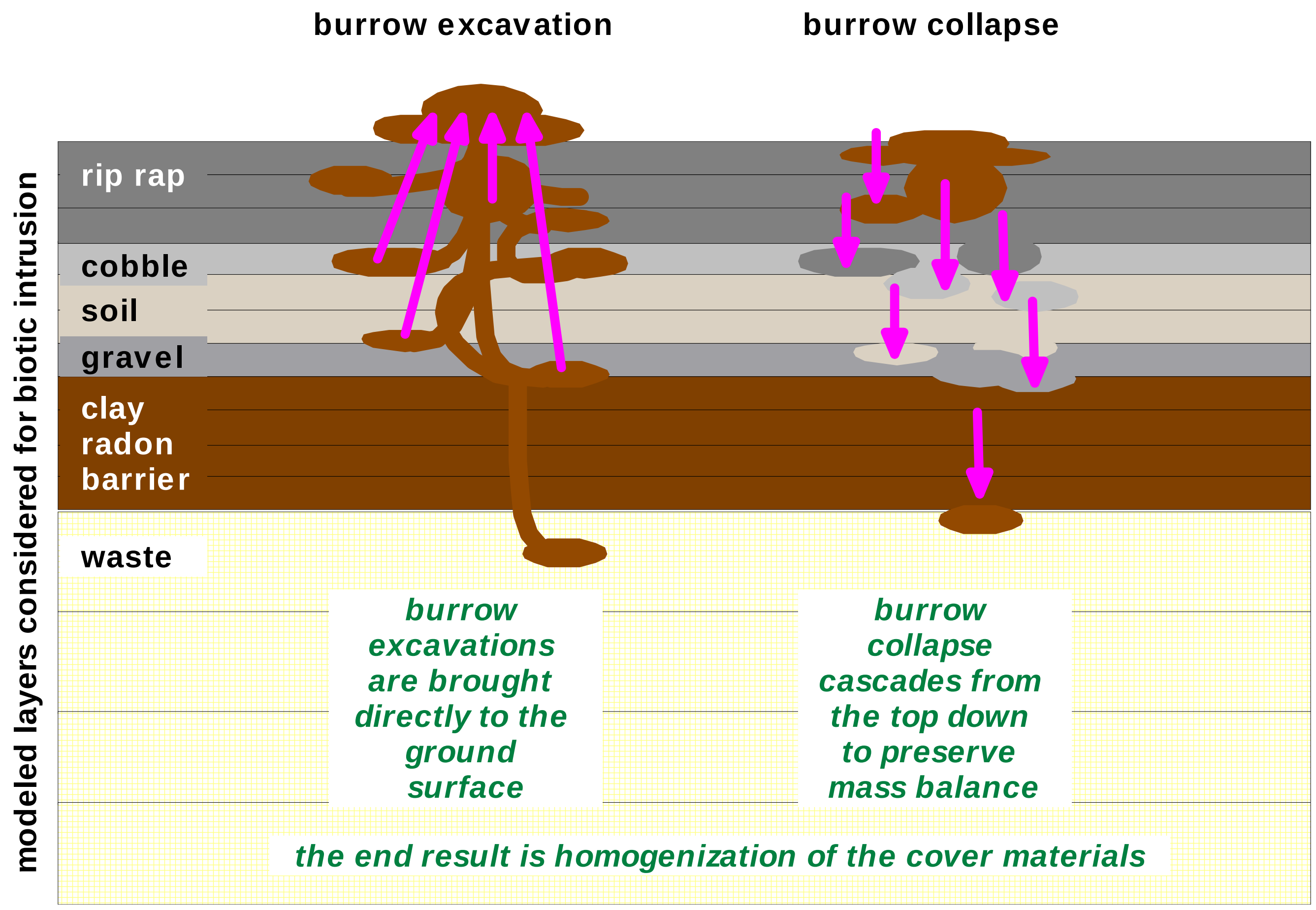
Geochemical Processes

- solubility
- K_d (soil:water)
- K_H (water:air)

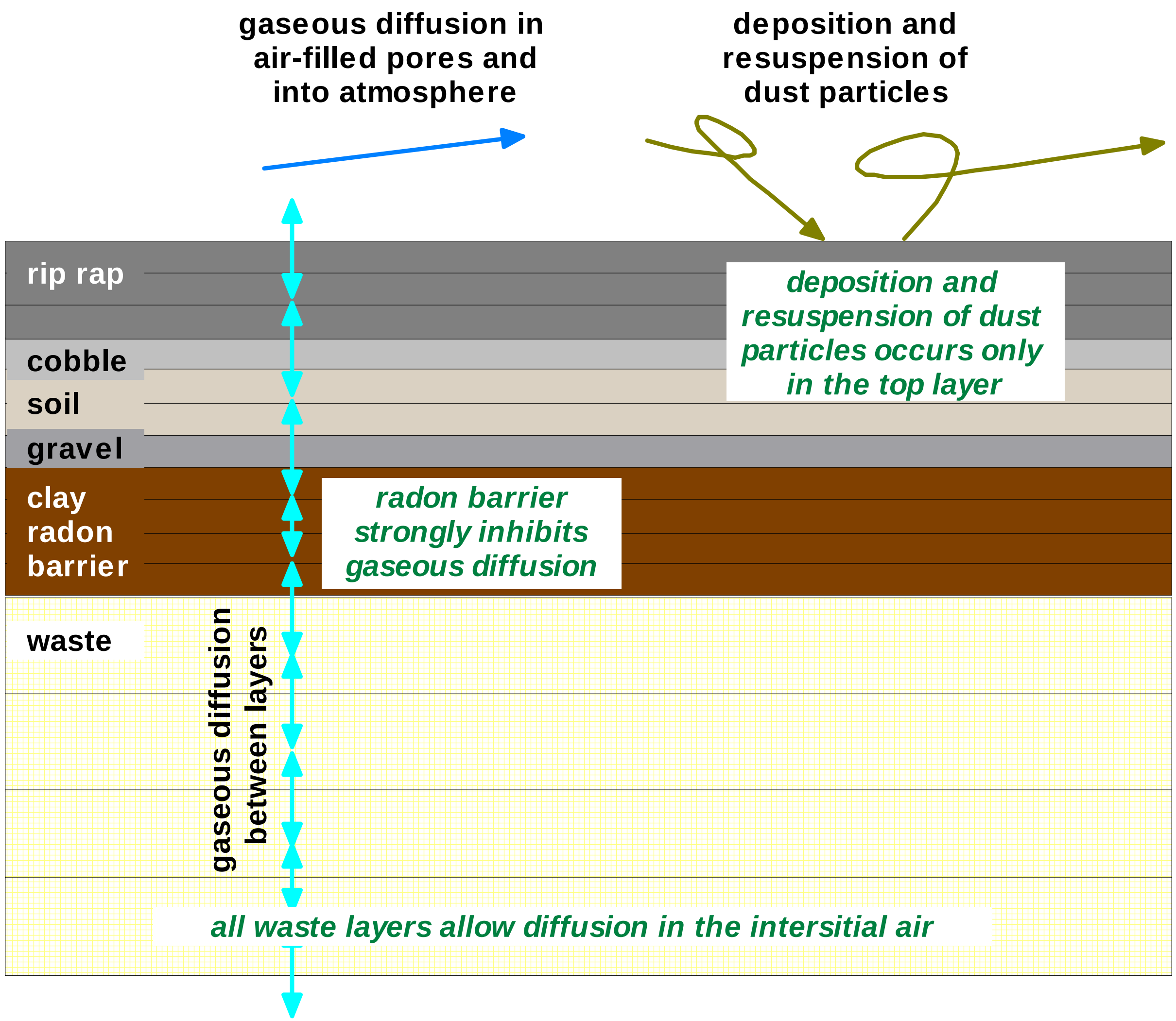
Plant Uptake and Redistribution



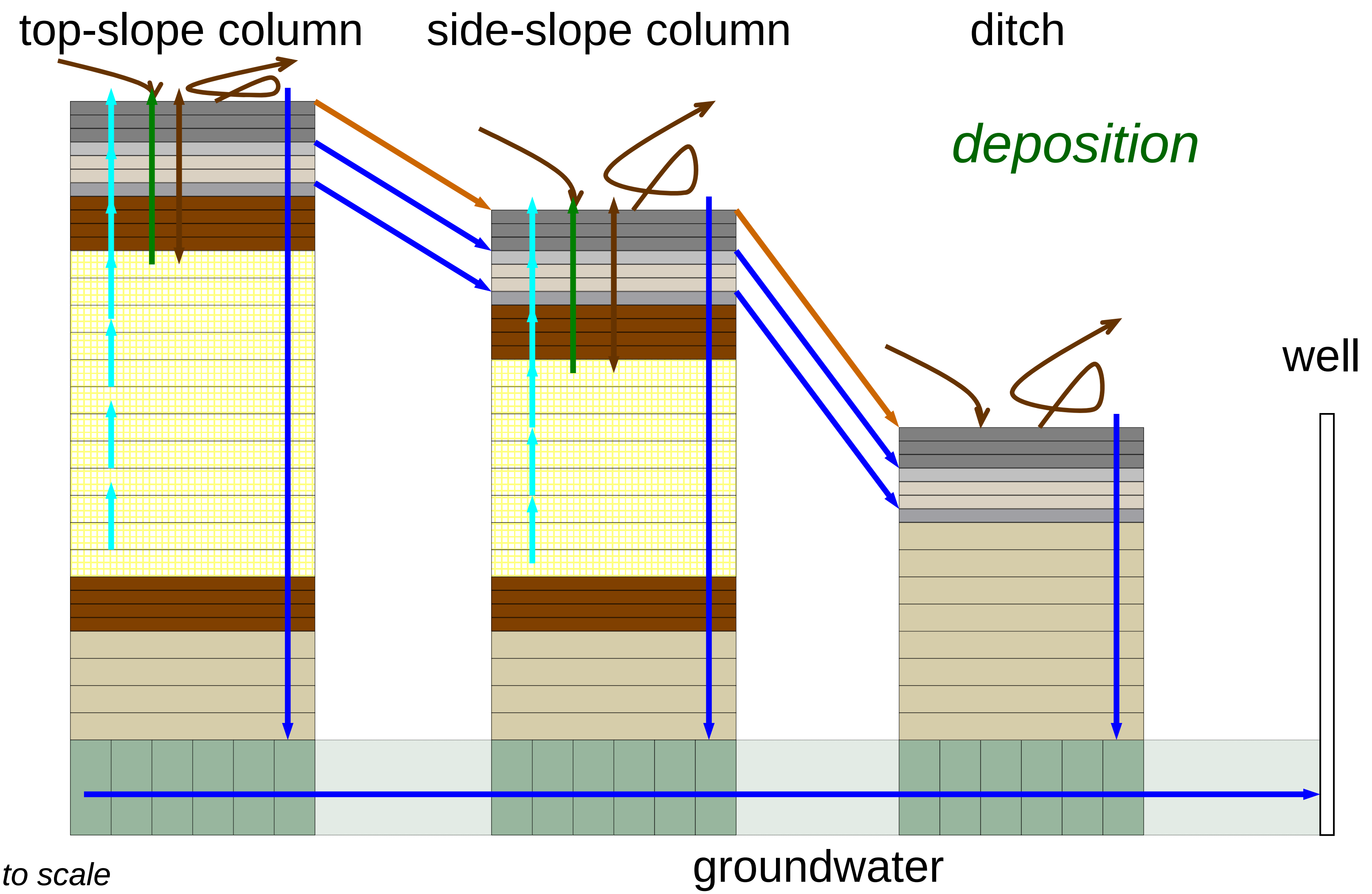
Animal Burrowing



Near-Field Airborne Transport



Abstracted Near-Field Model



not to scale

Groundwater Pathways

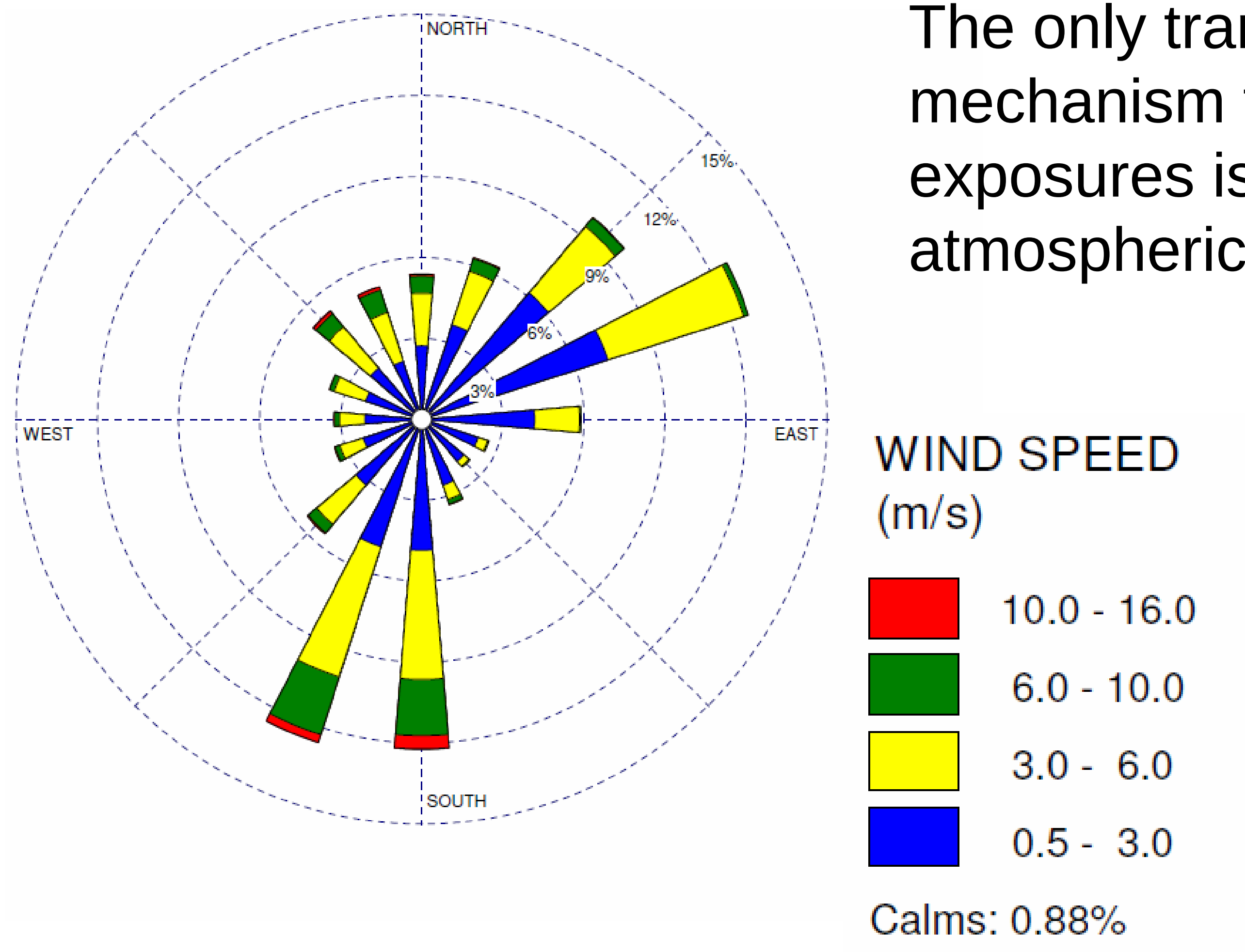
Near-Field:
groundwater transport to monitoring wells for comparison to groundwater protection limits (GWPLs)

Far-Field:
no endpoints

Groundwater is Class IV saline and nonpotable. Comparison to thresholds is not performed in the context of possible human exposures.

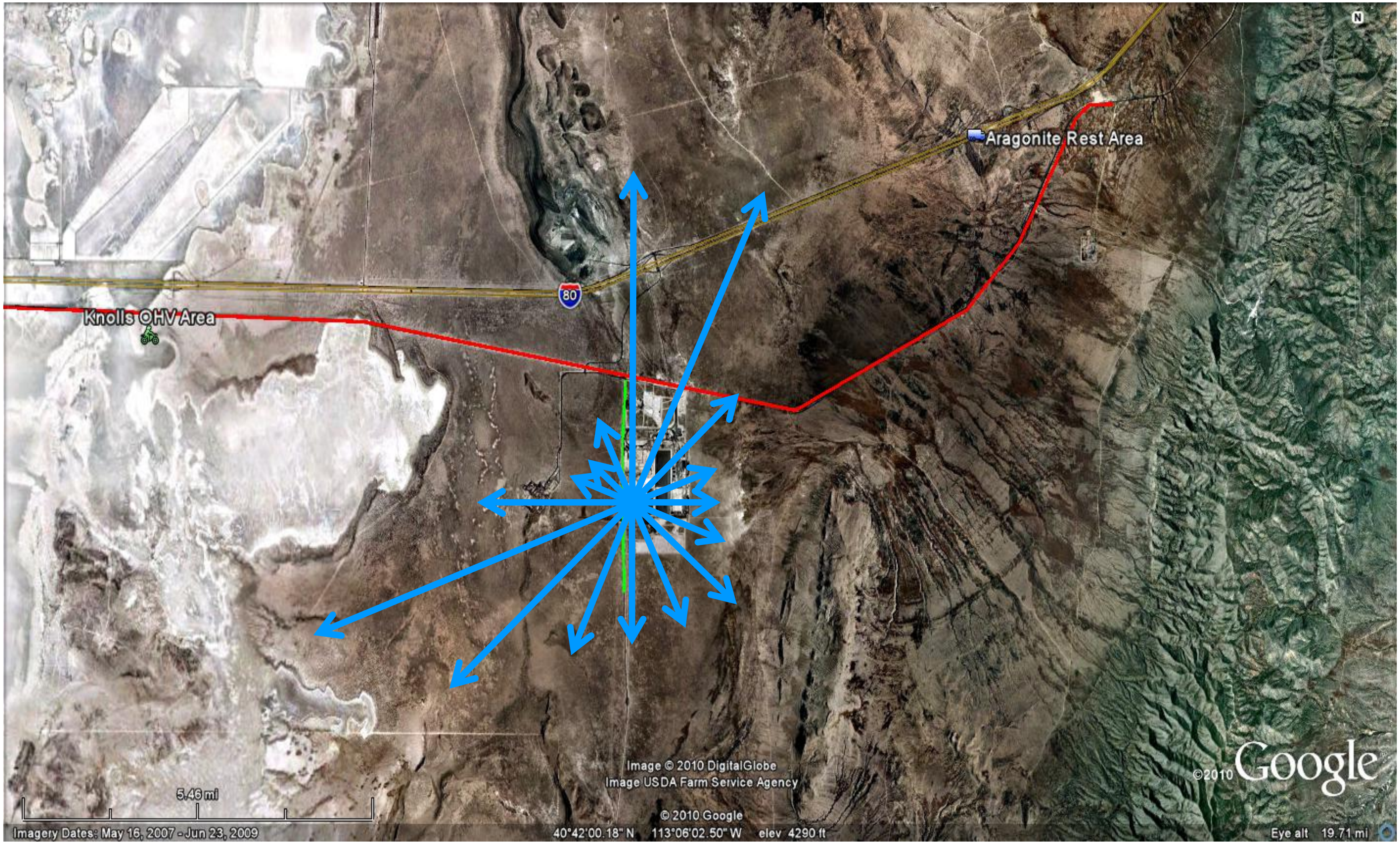
Contaminant Transport Mechanisms: Far-Field

Far-Field CT Mechanisms



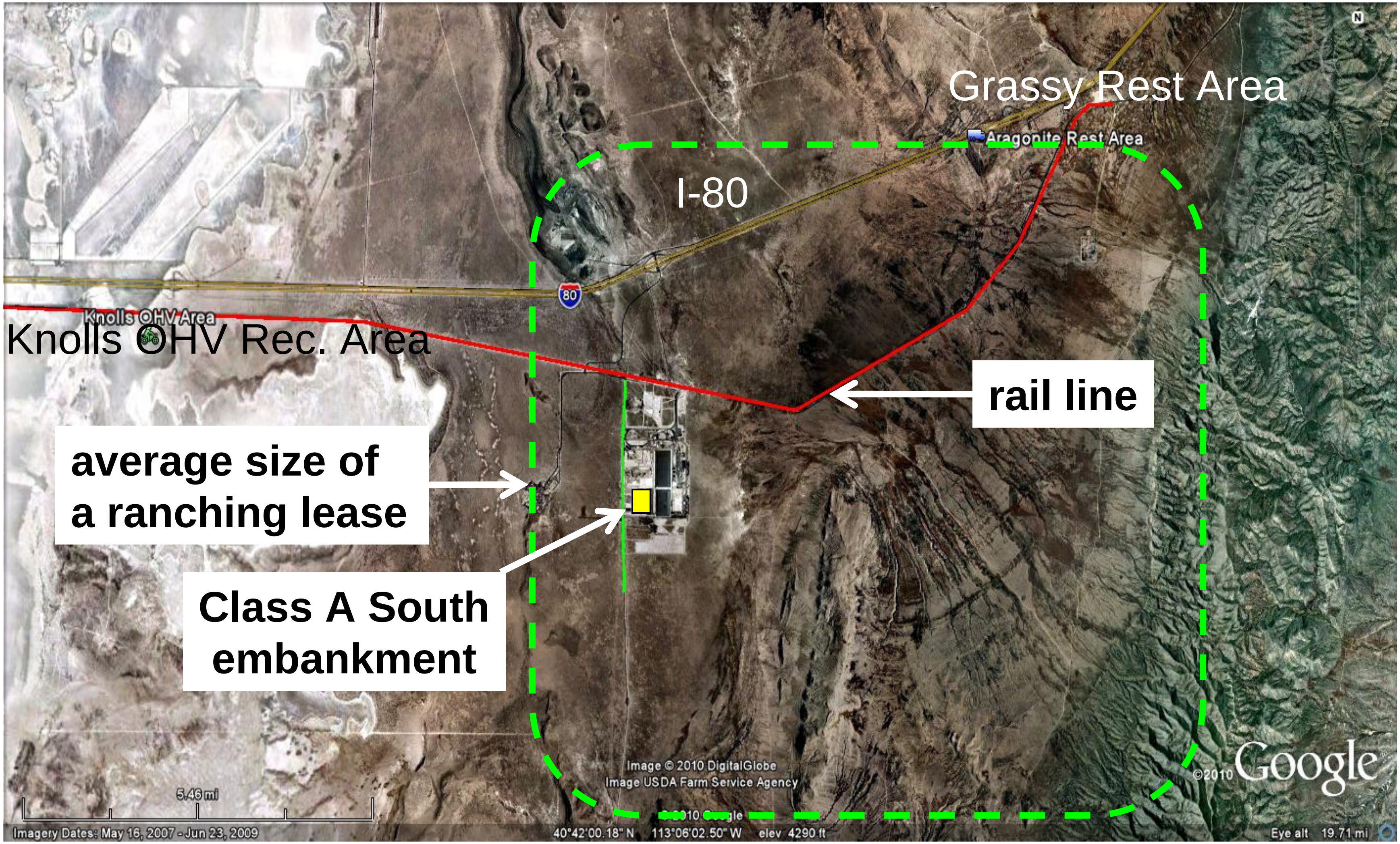
The only transport mechanism for far-field exposures is atmospheric dispersion.

Atmospheric Dispersion



Exposure Assessment

Dose Assessment Locations



Dose Assessment Scenarios

Ranching Scenario

Exposure Pathways

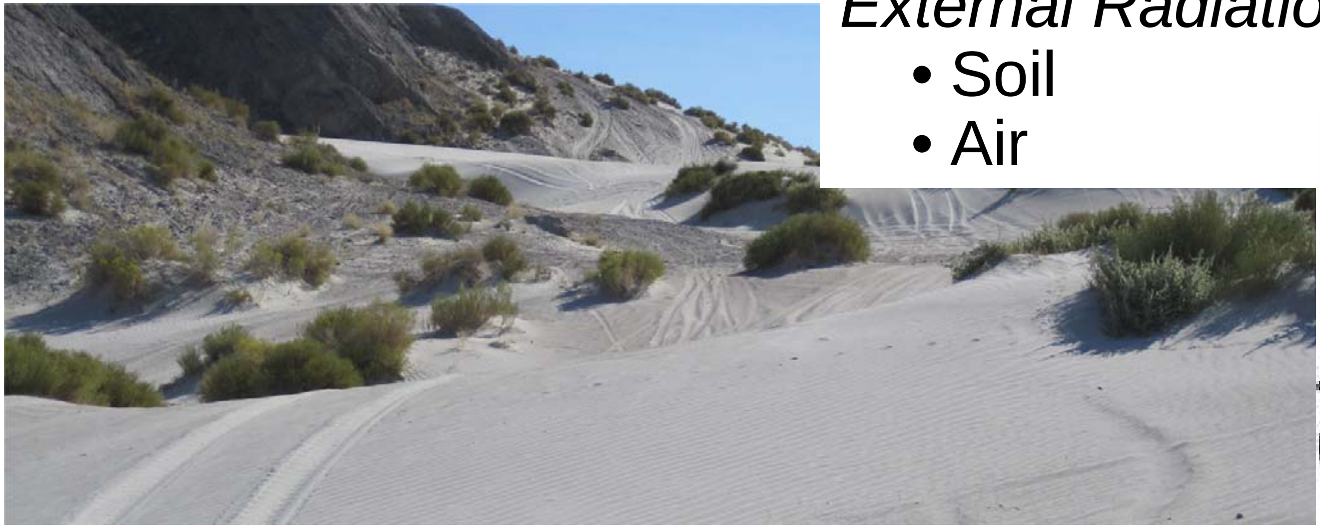
Inhalation:
- Wind-derived dust
- Mechanically-created dust
- Radon gas

Ingestion:
- Soil
- Livestock

External Radiation:
- Soil
- Air

Recreation Scenario

Exposure Pathways



Inhalation:

- Wind-derived dust
- Mechanically-created dust
- Radon gas

Ingestion:

- Soil
- Game meat

External Radiation:

- Soil
- Air

Dose Assessment Calculations

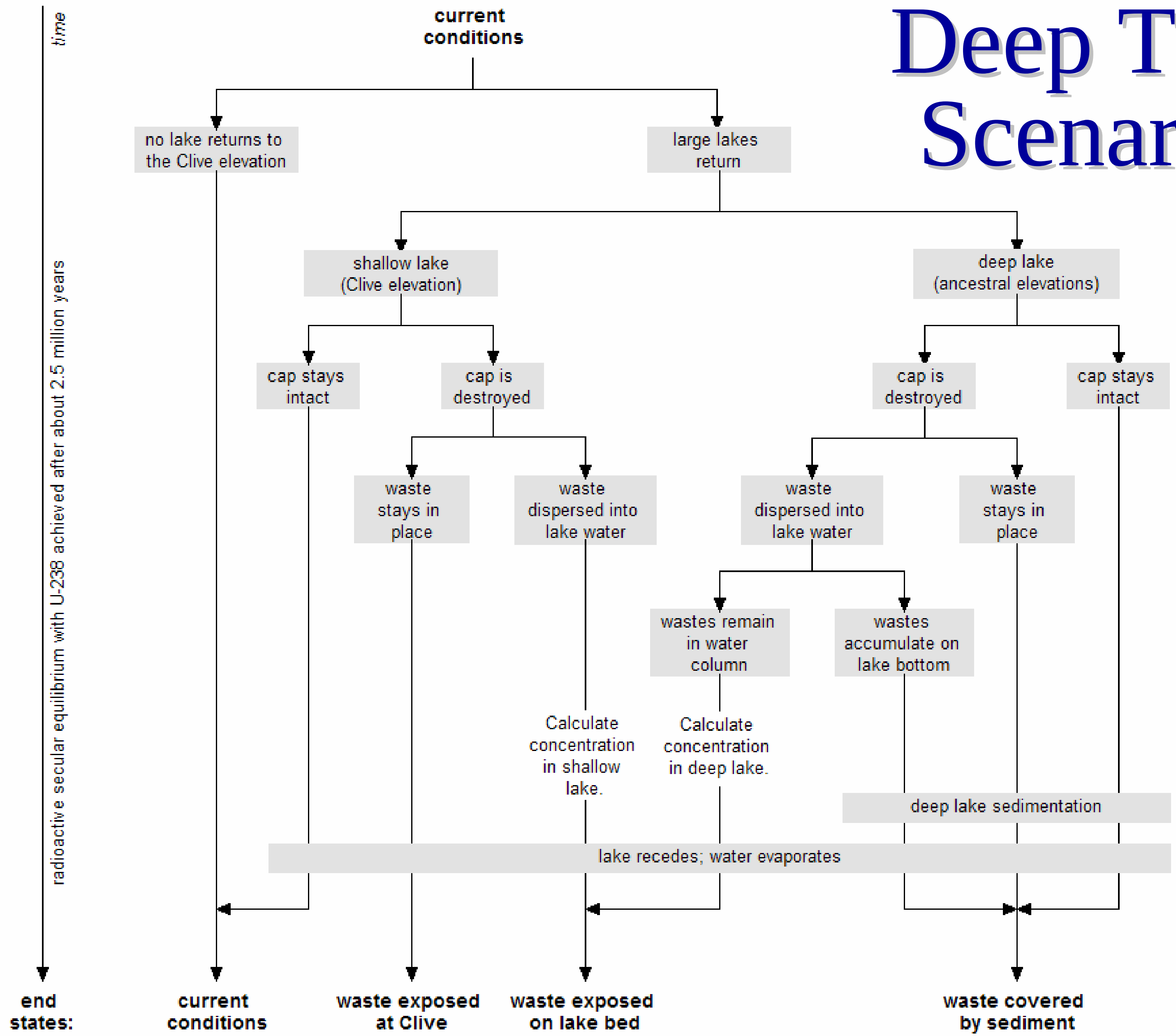
Example: external soil dose

Dose = soil concentration × daily time × frequency × dose factor

soil concentration	daily time × frequency	dose factor
transport model	exposure model	dosimetry model
activity / mass	year (fraction)	dose/year per activity/mass

Deep Time Scenarios

Deep Time Scenarios



Deep Time Scenarios

Possible future events:

- Large lake inundates Clive (and Salt Lake City)
- Large lake returns to the elevation of Clive
- No large lake reaches that elevation

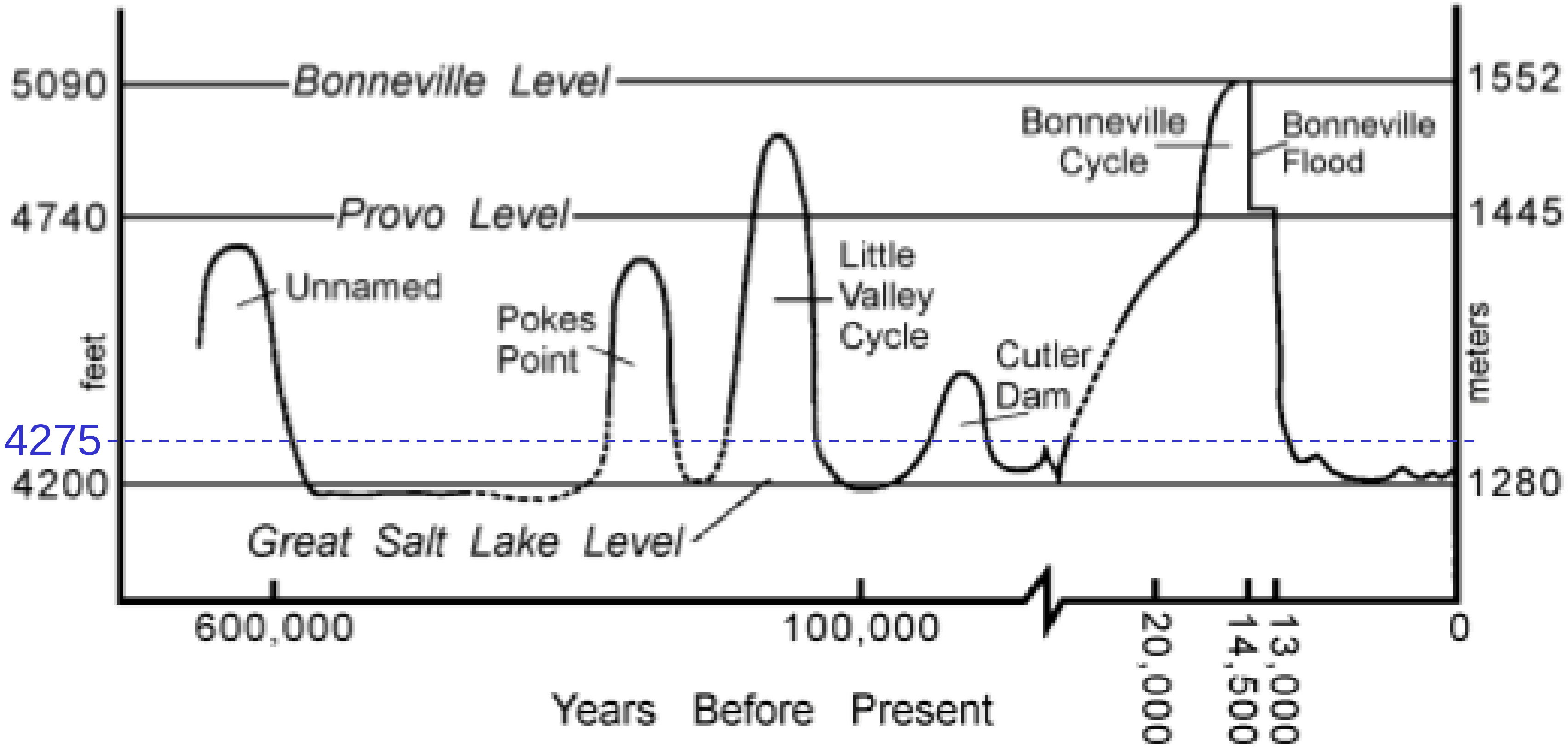
Pluvial Lakes in the Great Basin

Pluvial lake: a land locked basin that fills with water during times of glaciation (e.g., Lake Bonneville and its predecessors)

• They typically form when warm air from arid regions meets chilled air from glaciers. This creates cloudy, cool, rainy weather beyond the terminus of the glacier.

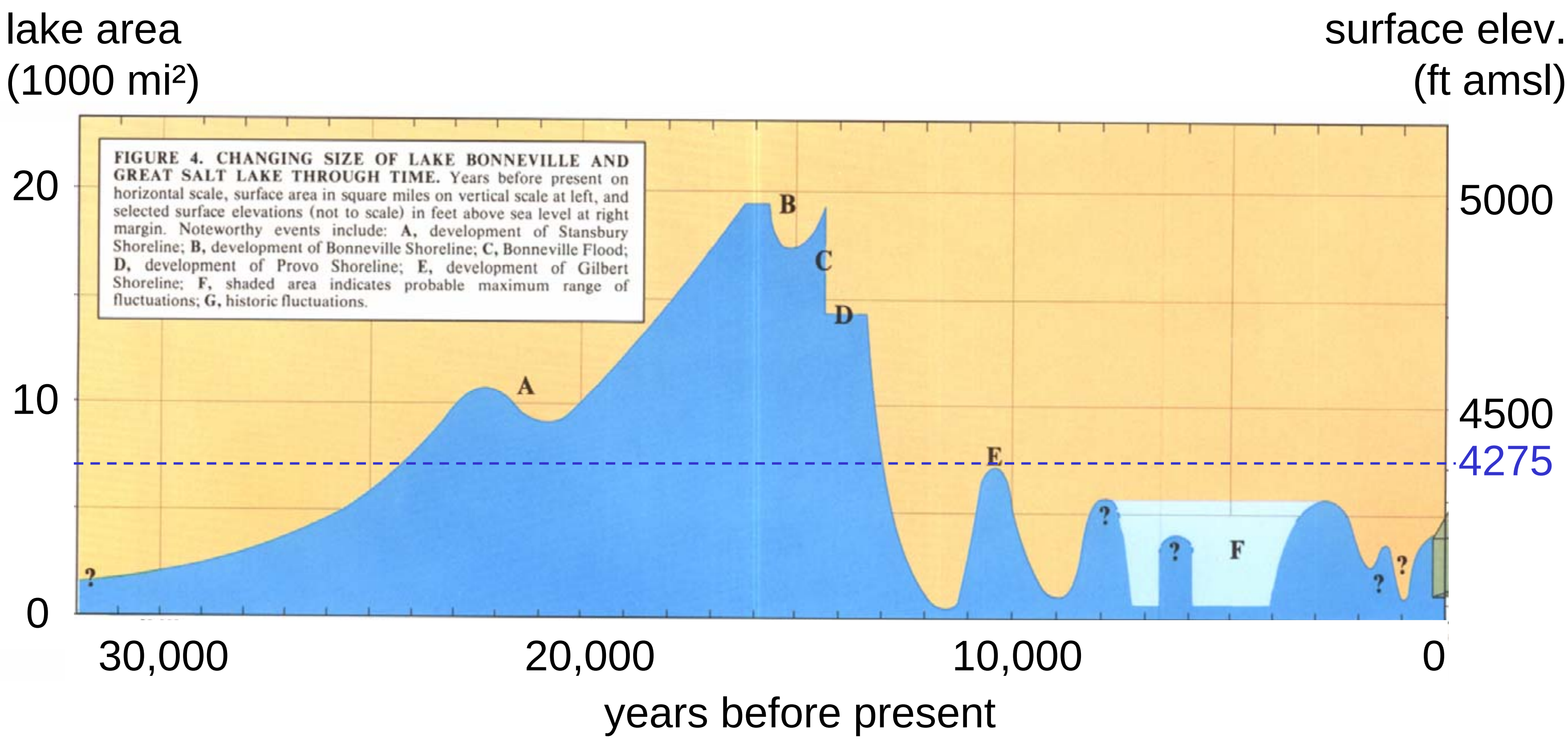
• Accumulated sediments show the variation in historical water levels and record the previous lake cycles (e.g. Oviatt *et al.*, 1999).

Ancient History of Lakes



from Link, P.K., D.S. Kaufman, and G.D. Thackray, (1999). *Field guide to Pleistocene Lakes Thatcher and Bonneville and the Bonneville Flood, southeastern Idaho,* in: Hughes, S.S. and G.D. Thackray (eds.), *Guidebook to the Geology of Eastern Idaho*, Idaho Museum of Natural History, pp. 251-266.

Recent History of Lakes



from Utah Geological and Mineral Survey (1984): ***Map73*** *Major Levels of Great Salt Lake and Lake Bonneville*

Future Lake Implications

In the event of a large lake returning:

- Cover (current design) might not survive.
- Waste might be dispersed.
- The lake will deposit sediment.

The issues of how deep the lake would be, and how often it may recur may not influence the outcome very much.

Thank You