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Monitoring & Modeling to Improve Understanding of Tritium Transport in an Arid Environment

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OUTLINE

- Introduction
- Tritium monitoring
  - Methods
  - Results
    - Plants, shallow & deep unsaturated zone, ground water
- Modeling transport
  - Deep unsaturated zone
- Conclusions

INTRODUCTION

Tritium (^3H)

- **Formed naturally (cosmic rays) & from human activities**
- **Radioactive form of hydrogen ... half-life ~12.3 yr**
  - Tritiated water (^3HHO) ... chemically like "ordinary" water (H_2O)
    - Migrates in both the liquid & vapor phases
- **EPA drinking water standard = 740 Bq/L**

  (20,000 pCi/L or 6,250 TU)
- **Large component of LLRW**
  - e.g., ~60% of total radioactivity disposed at Beatty, Nevada site
- **Despite prevalence in waste stream ... relatively little is known about its subsurface transport at LLRW sites**

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Tritium at the Amargosa Desert Research Site (ADRS)

- **1995 – elevated tritium & carbon-14 “discovered” beneath ADRS during study to determine natural distribution of gases in deep UZ**

(Prudic & Striegl, 1995; Striegl et al., 1996)

- **Scope of research was broadened to include study of processes affecting contaminant transport through the UZ**

- **1997 – ADRS incorporated into USGS Toxics Program**

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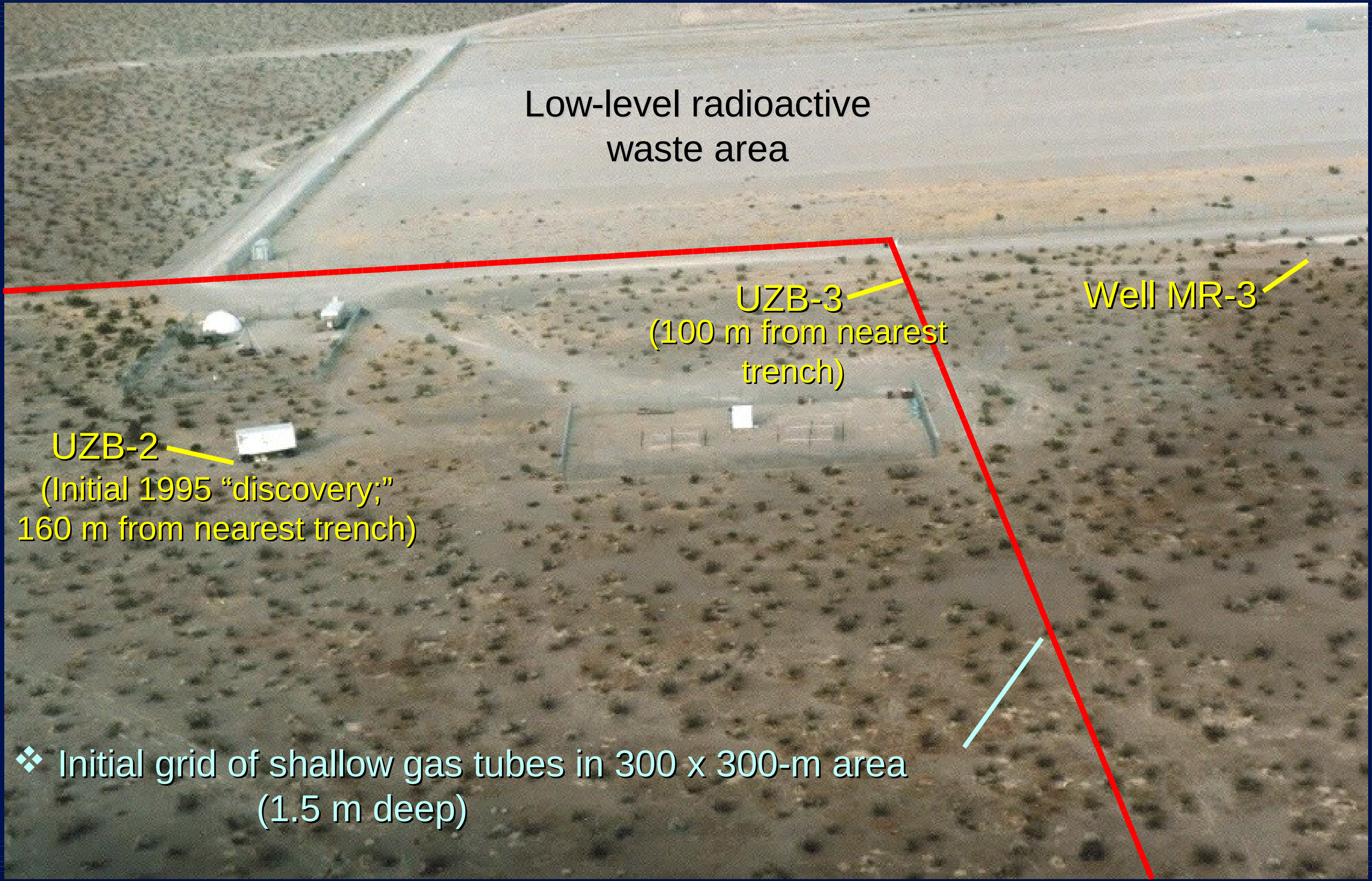
TRITIUM MONITORING – Deep & Shallow UZ, Ground Water



❖ Distant study area (3 km away) – deep & shallow UZ

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(Prudic & Striegl, 1995; Healy et al. 1999; Mayers et al. 2005)

Method for Sampling Soil-Water Vapor

- Soil air pulled through freeze trap
- Water vapor captured as ice, thawed & bottled for analysis

Deep UZ –
- Two primary boreholes
- Multiple depths (to 109 m)

Shallow soil –
- Multiple locations
- Two depths (0.5 &/or 1.5 m)

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Shallow Vapor Sampling ... all over the desert

- Installation – labor intensive
- Equipment & tools – lots to move from site to site
- Sampling time – 12 to 24 hours per sample

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Plant Method for Detecting & Mapping Tritium Contamination

Sample

Solar distill

Lab prep

No preparation

Filter + SPE

0.5 g   2 g

- Noninvasive, no “installation” required
- Simple
- Rapid ... 100 locations = 4 days = sample (1 d) + distill (1 d) + lab prep (2 d)
  - Shallow vapor = 4+ weeks ... assuming no breakdown in equipment/people

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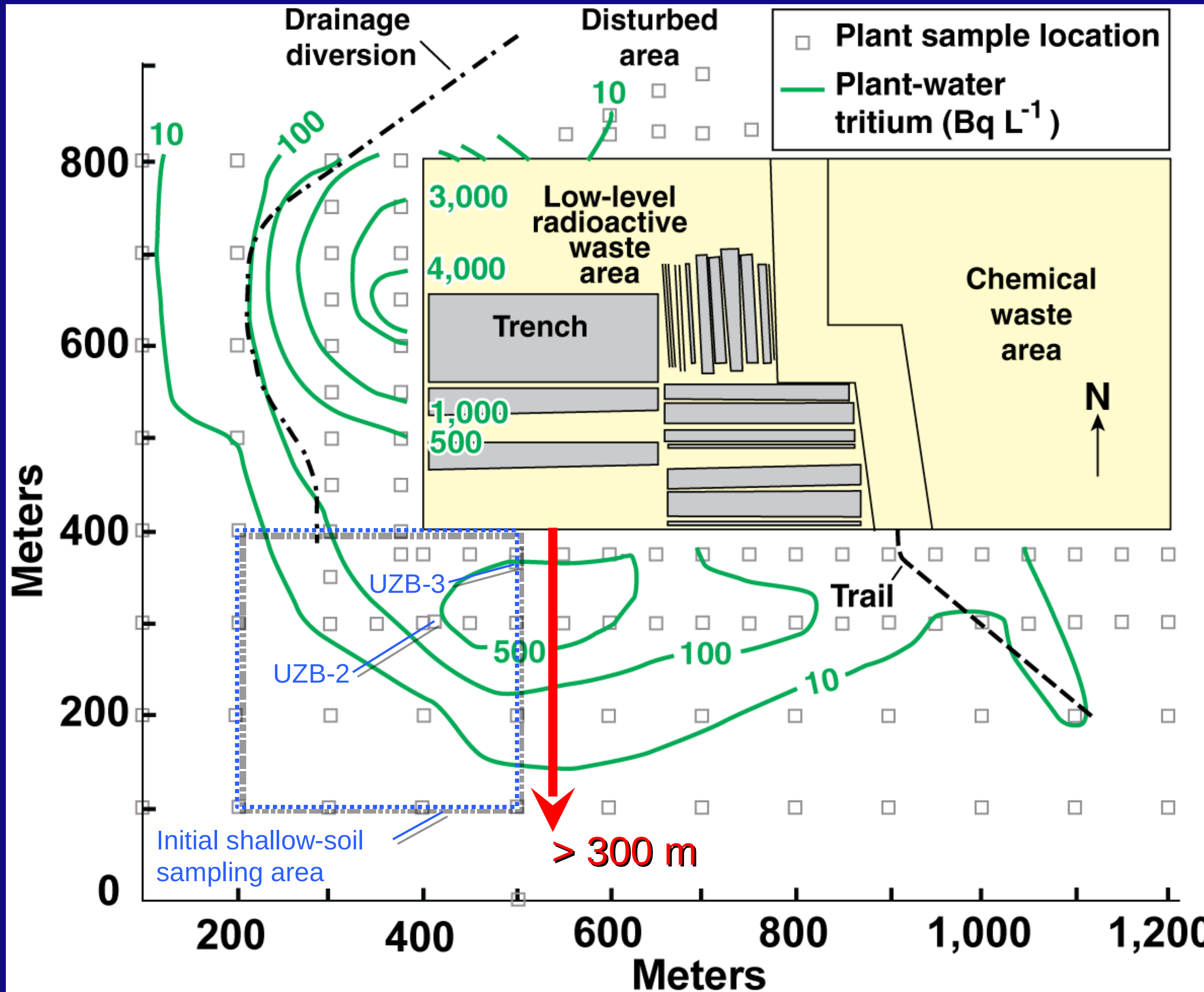
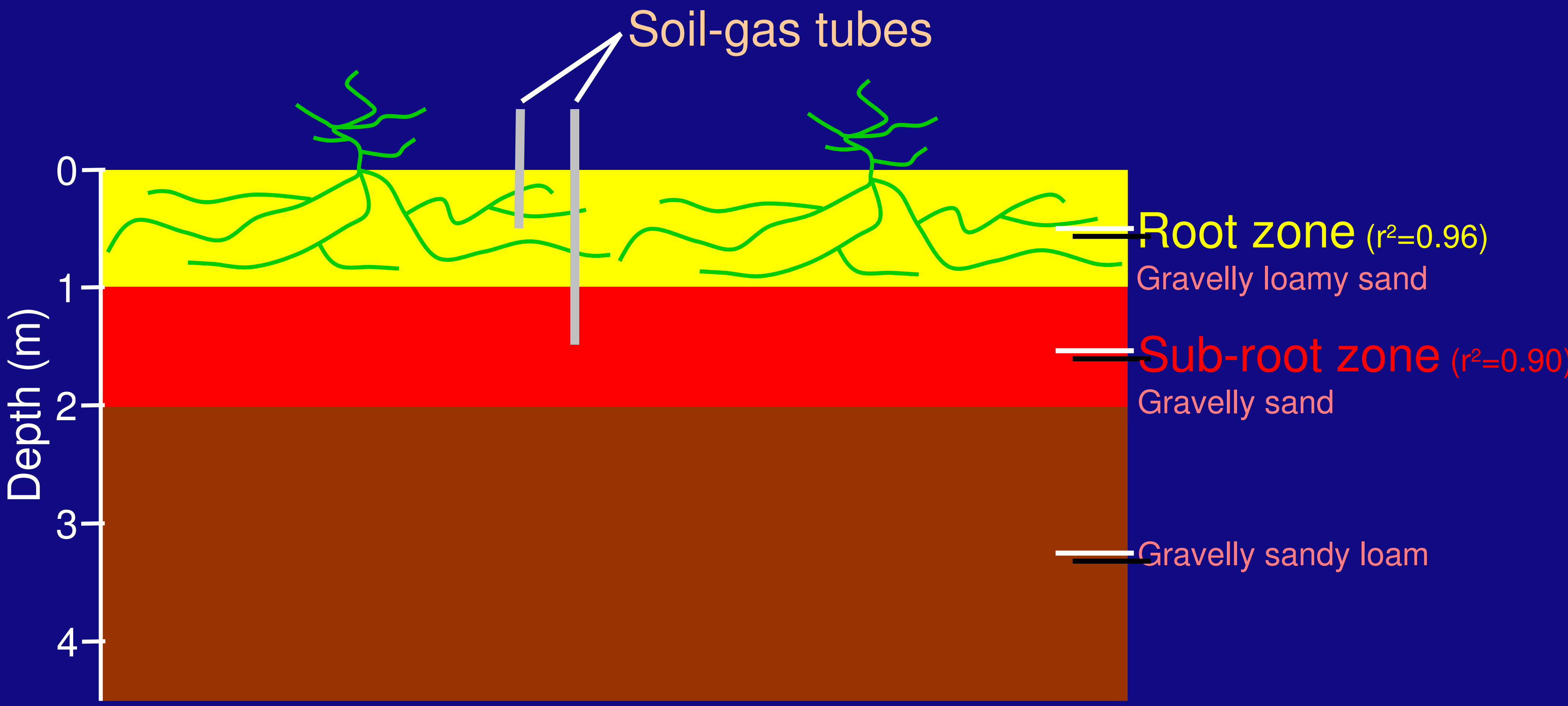
(Andraski et al., 2003)

Plant Sample Locations & Plume-Scale Delineation of Tritium



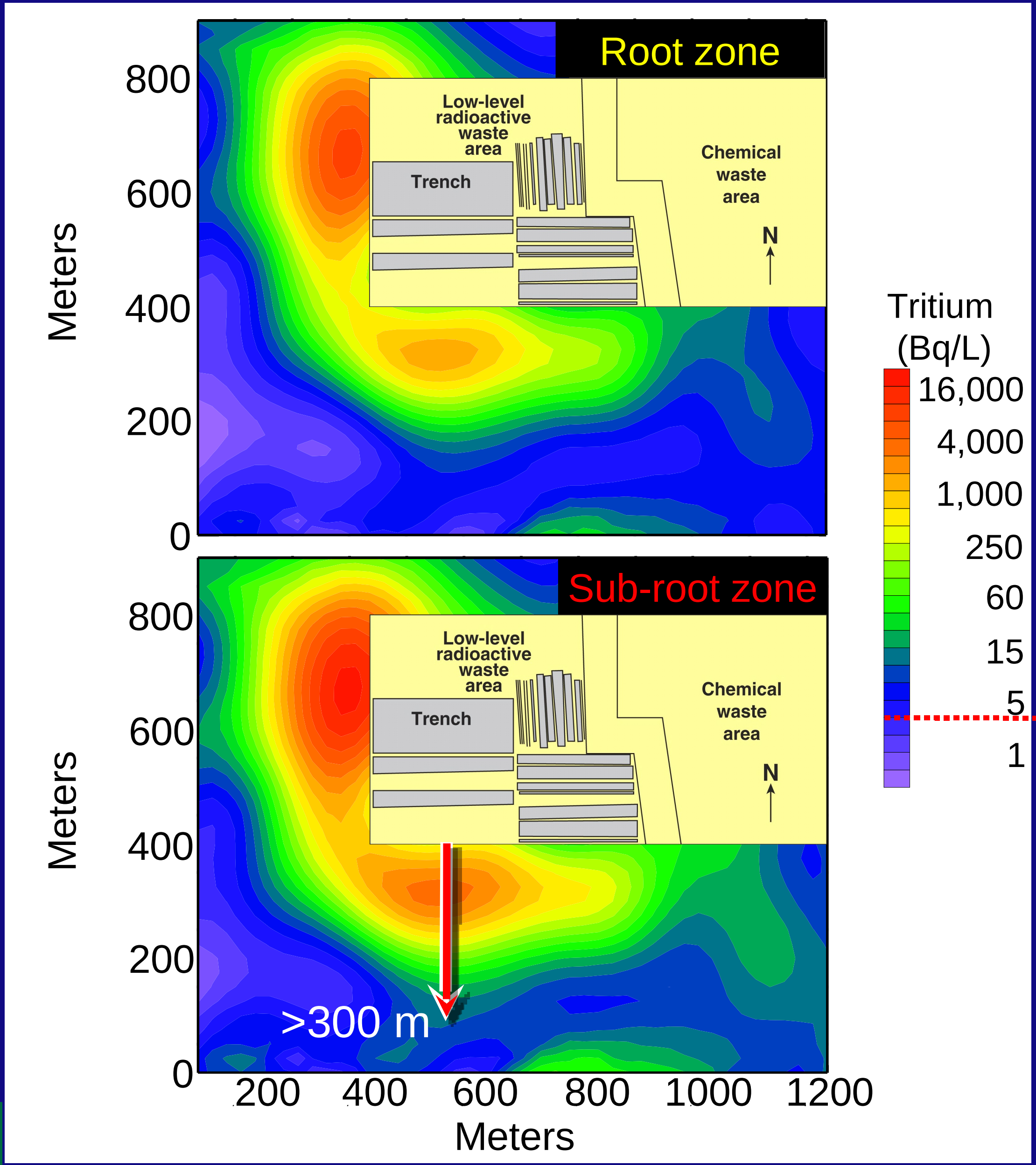
(Andraski et al., 2005)

Field measurements to develop predictive equations for mapping subsurface contamination from plant data



(Andraski et al., 2005)

Maps of Predicted Root-Zone & Sub-Root Contamination



Concentrations < 3 Bq/L

- “Background” for plants; root- & sub-root zones
- Precipitation

(Andraski et al., 2005)

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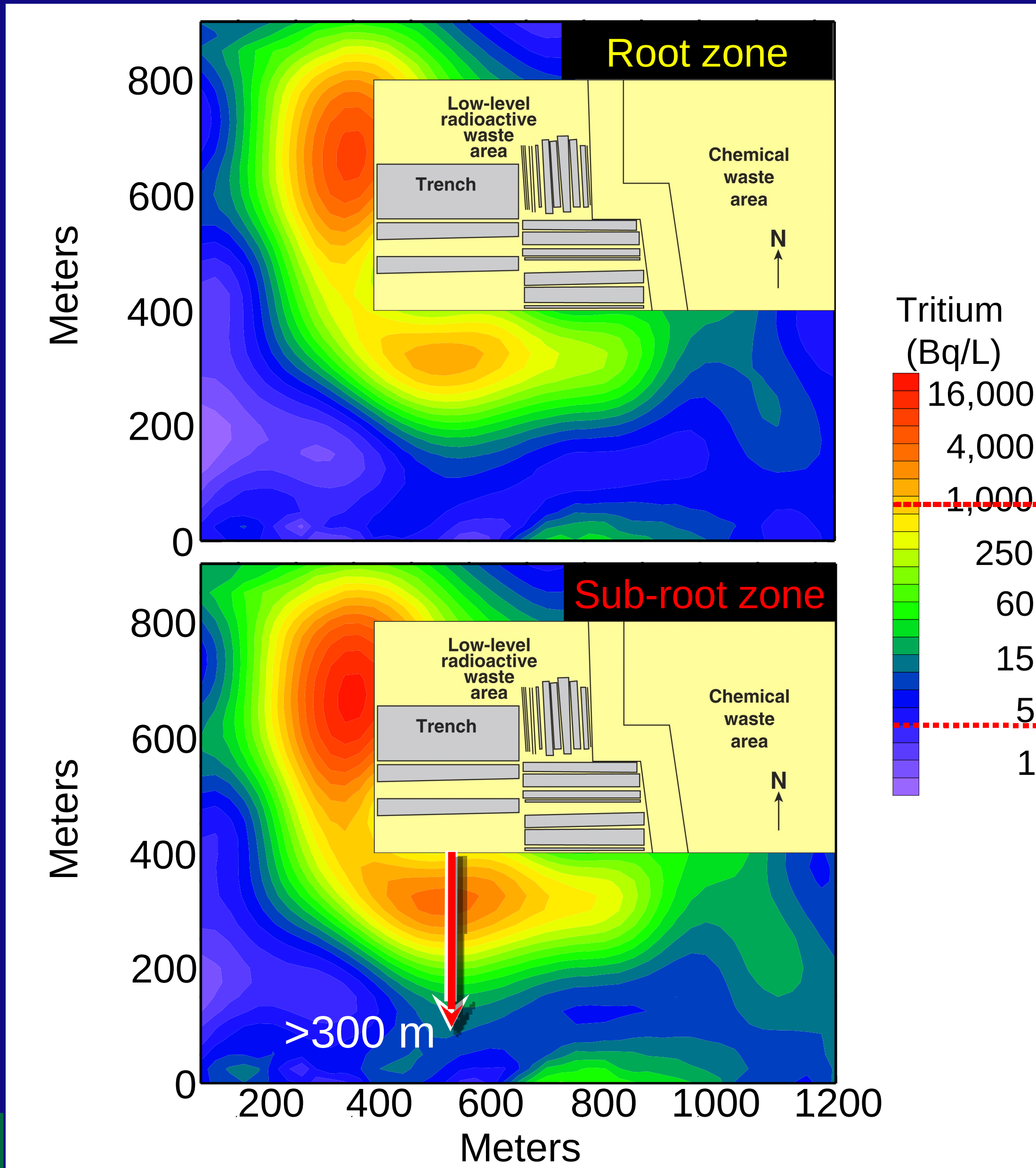
Maps of Predicted Root-Zone & Sub-Root Contamination



Solar Distillation of Water from Soil and Plant Materials: A Simple Desert Survival Technique
RAY D JACKSON
C. H. M. VAN BAVEL
Science, September 17, 1965, Vol. 149, No. 3690, pages 1377-1379

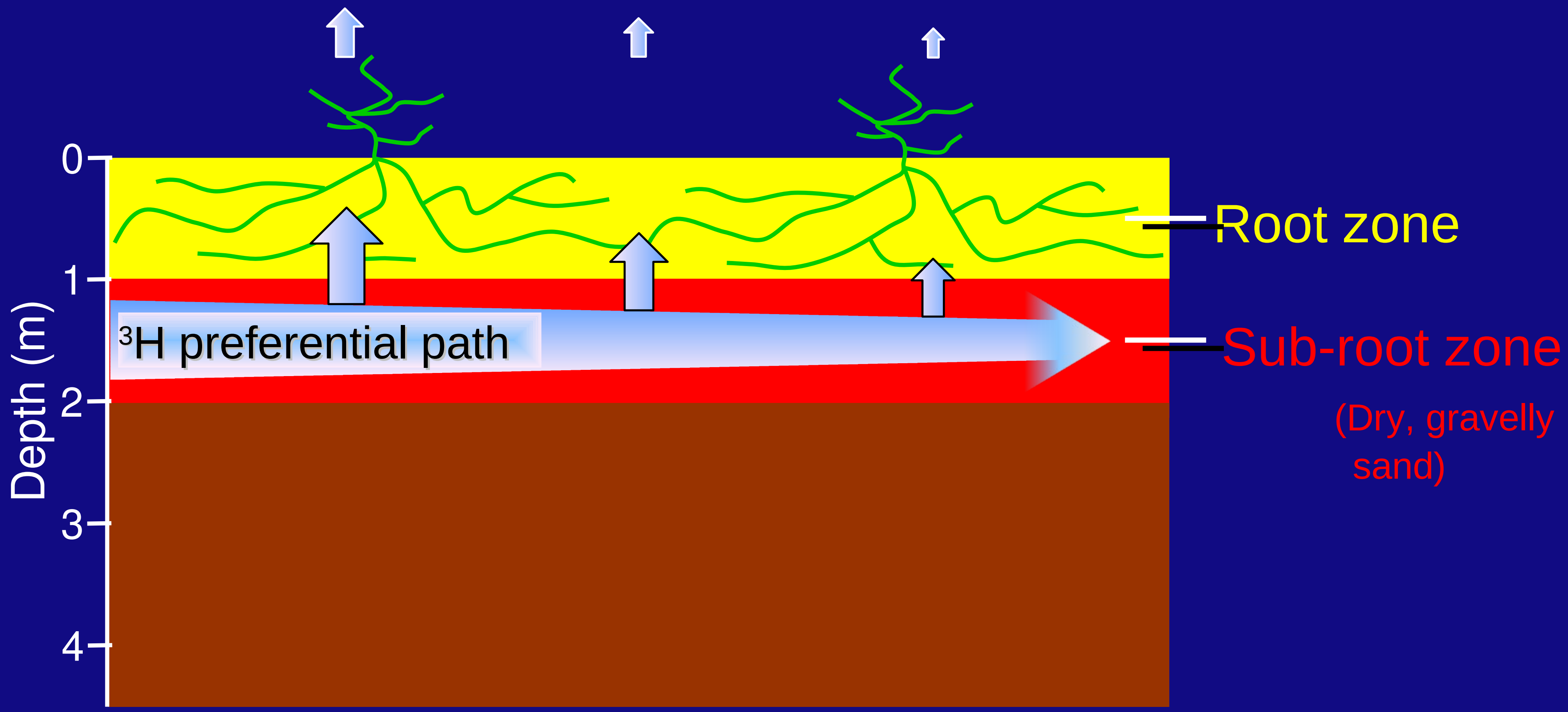
Drinking water std = 740 Bq/L

Concentrations < 3 Bq/L
- “Background” for plants; root- & sub-root zones
- Precipitation

(Andraski et al., 2005)

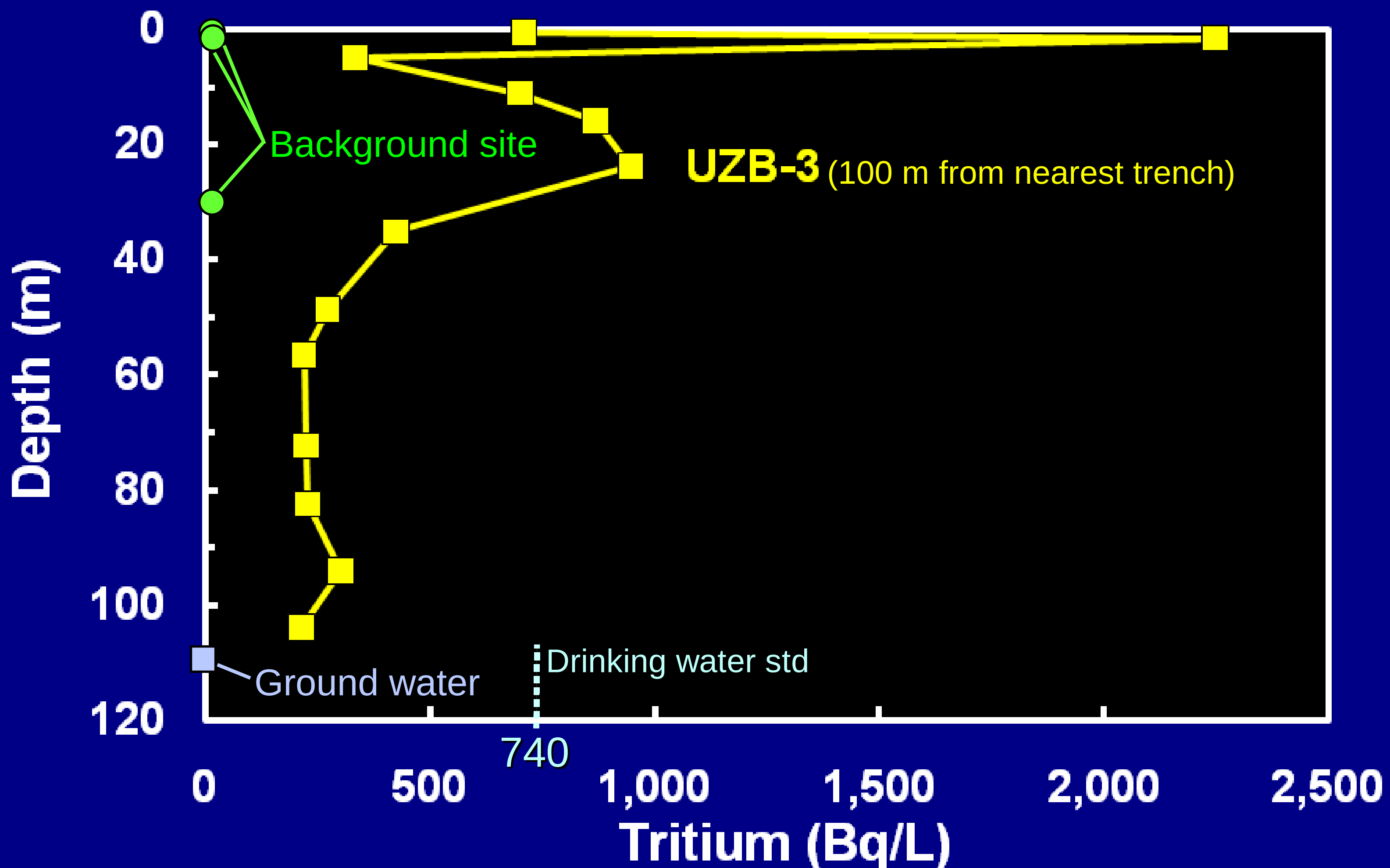
Plant-based mapping aided identification of transport pathways

- Long-distance, preferential lateral movement away from waste source
- Subsequent upward movement into root zone & release to atmosphere



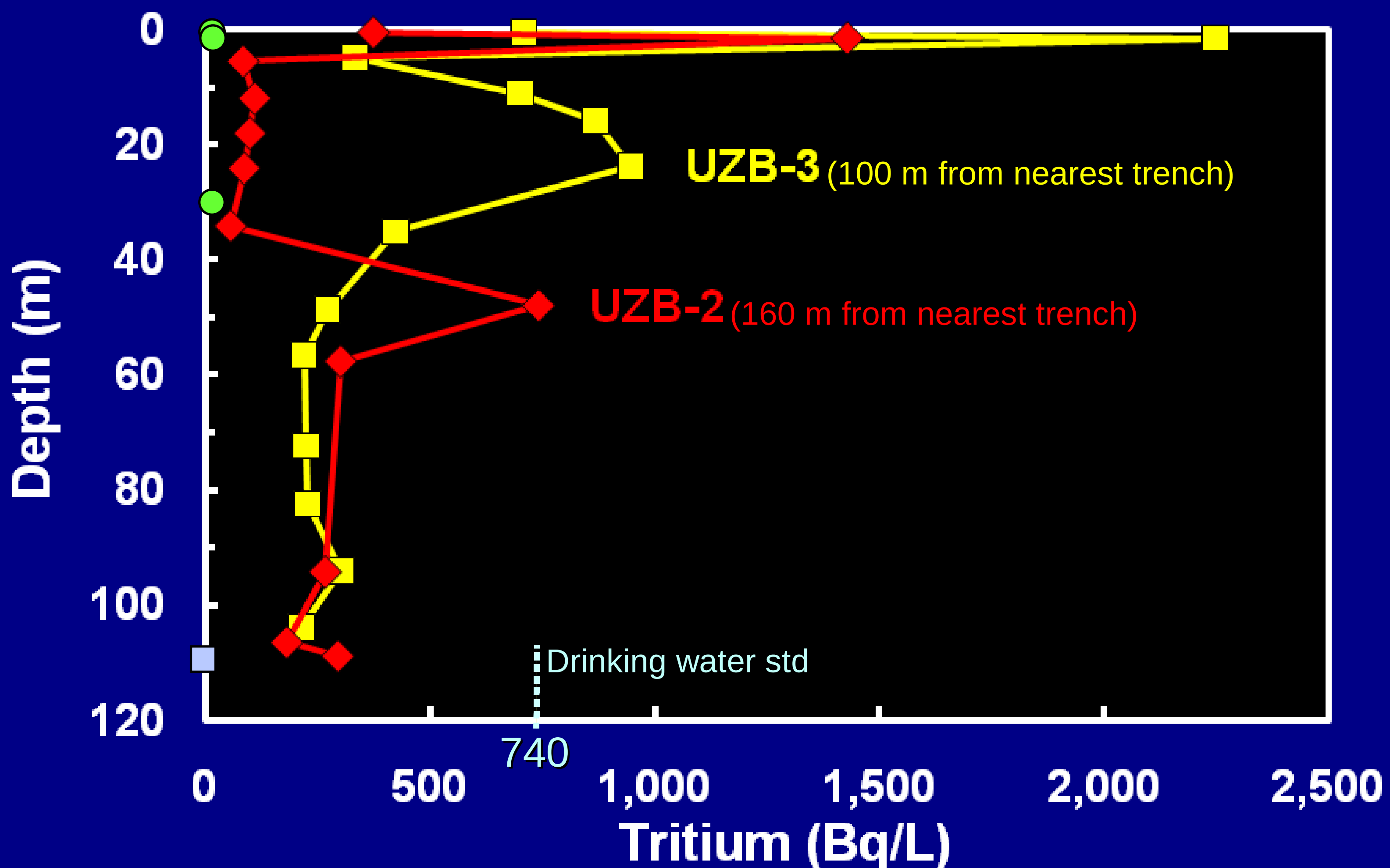
(Andraski et al., 2005)

Deep Unsaturated Zone – Tritium Monitoring



(Mayers et al. 2005)

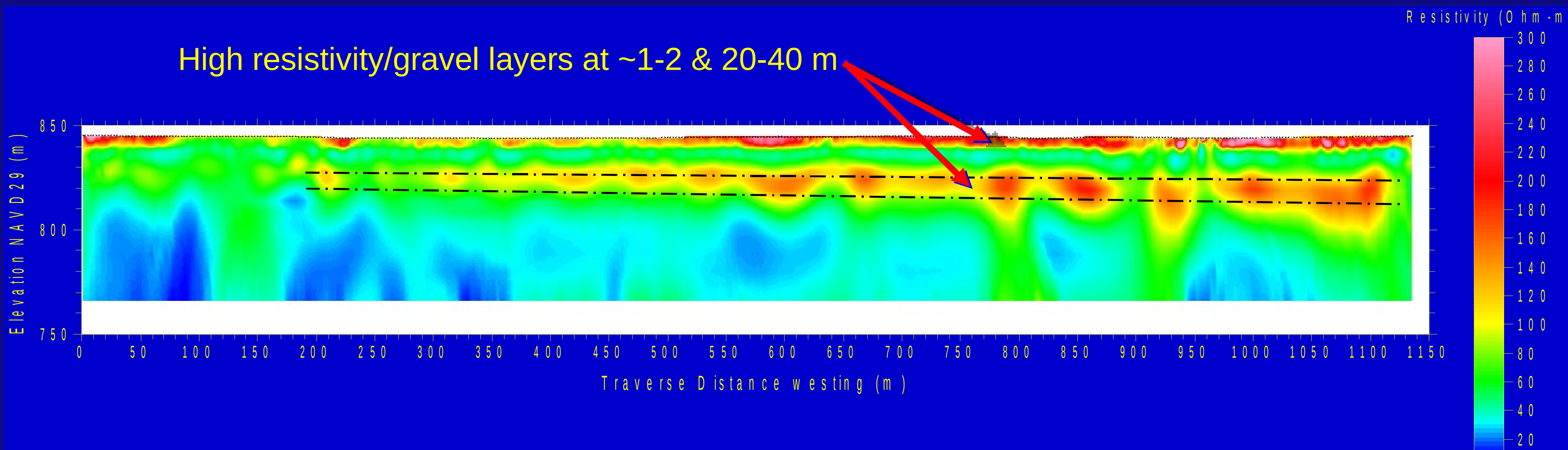
Deep Unsaturated Zone – Tritium Monitoring



(Mayers et al. 2005)

Depths of peak concentrations

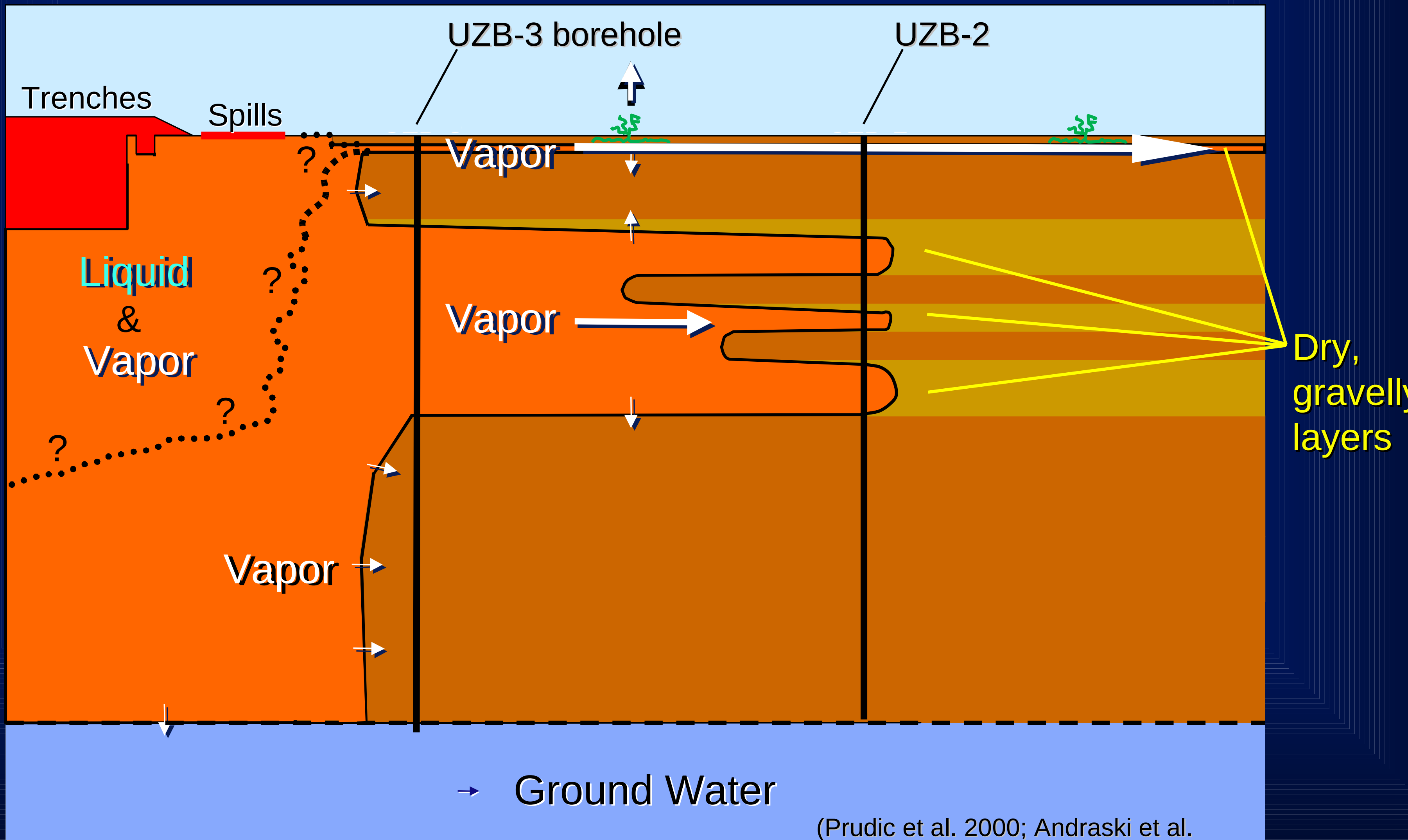
- Correspond with dry, gravelly layers mapped using non-invasive, DC resistivity



(Abraham & Lucius, 2004)

MODELING – Conceptual Tritium Transport

Predominantly lateral, vapor-phase transport controlled by stratigraphy



(Prudic et al. 2000; Andraski et al. 2005)

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Numerical Model

- Coupled liquid-gas-heat flow
- Non-isothermal, heterogeneous domain
- 40-yr simulations (1962-2002)
- Assumptions
  - Instantaneous emplacement of all waste
  - Instantaneous isotopic equilibrium between gas & liquid phases

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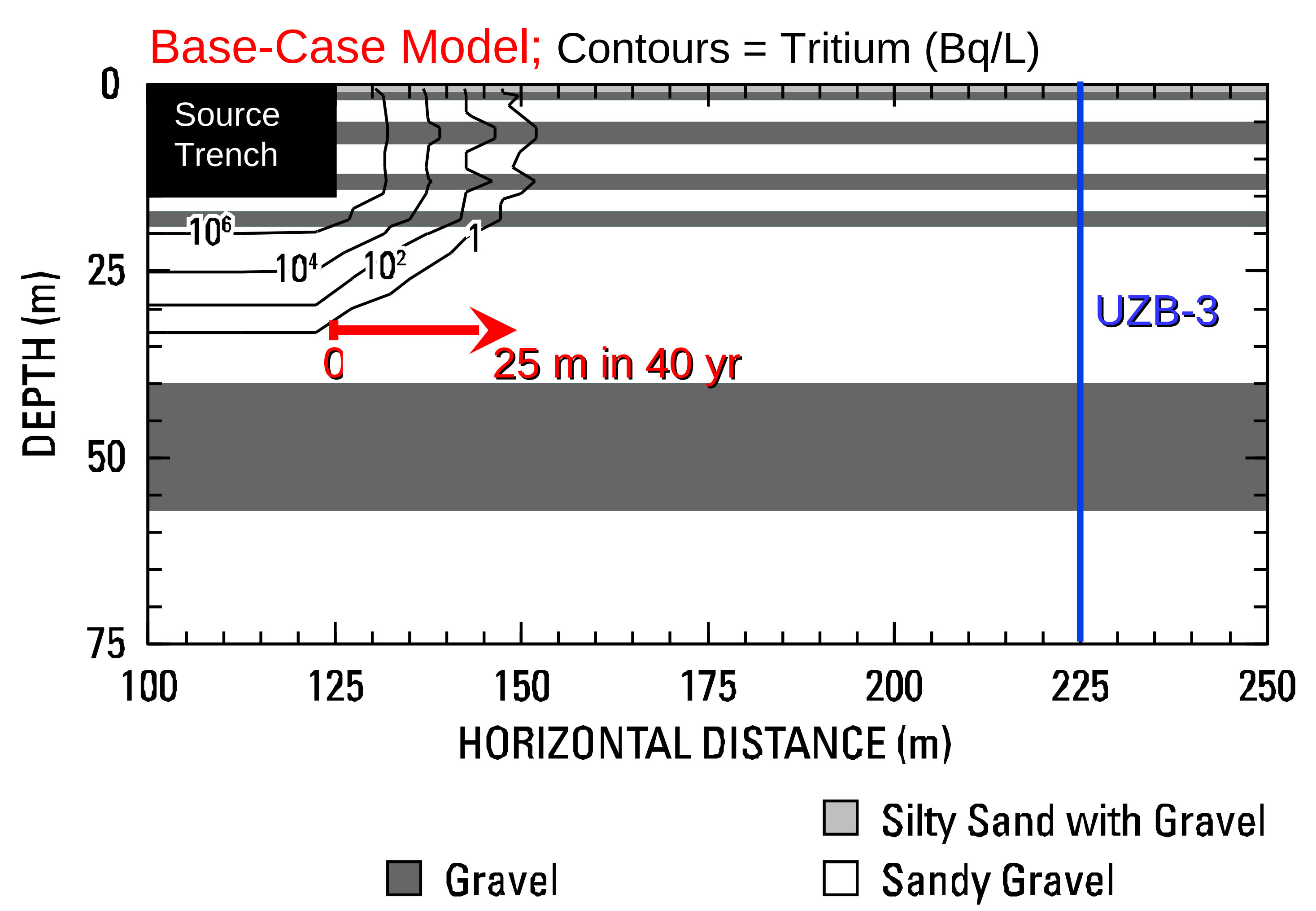
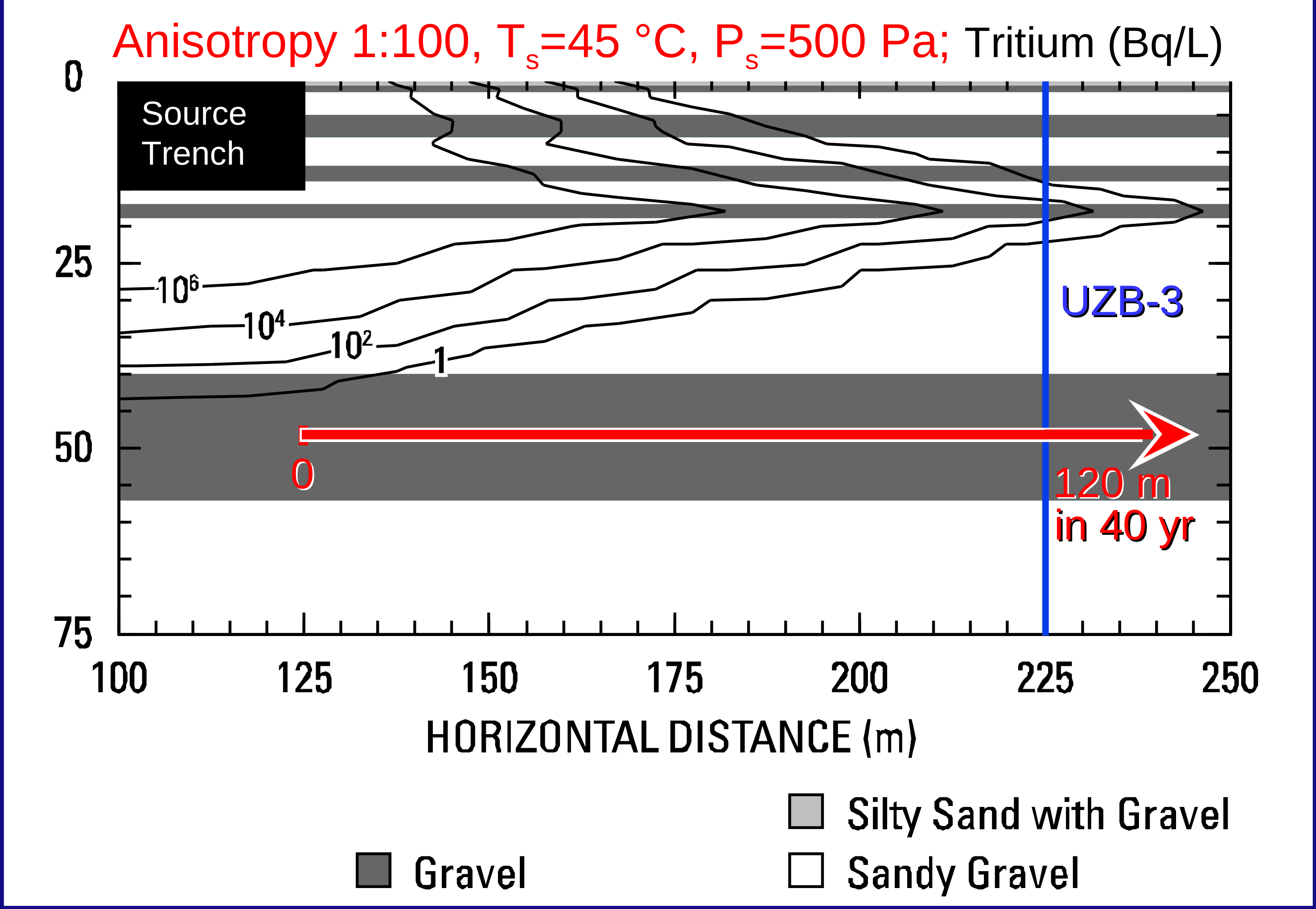
(Mayers et al. 2005)

- Base Case



(Mayers et al. 2005)

- Expanded model
  - Effects of anisotropy, source temperature & pressure forcing



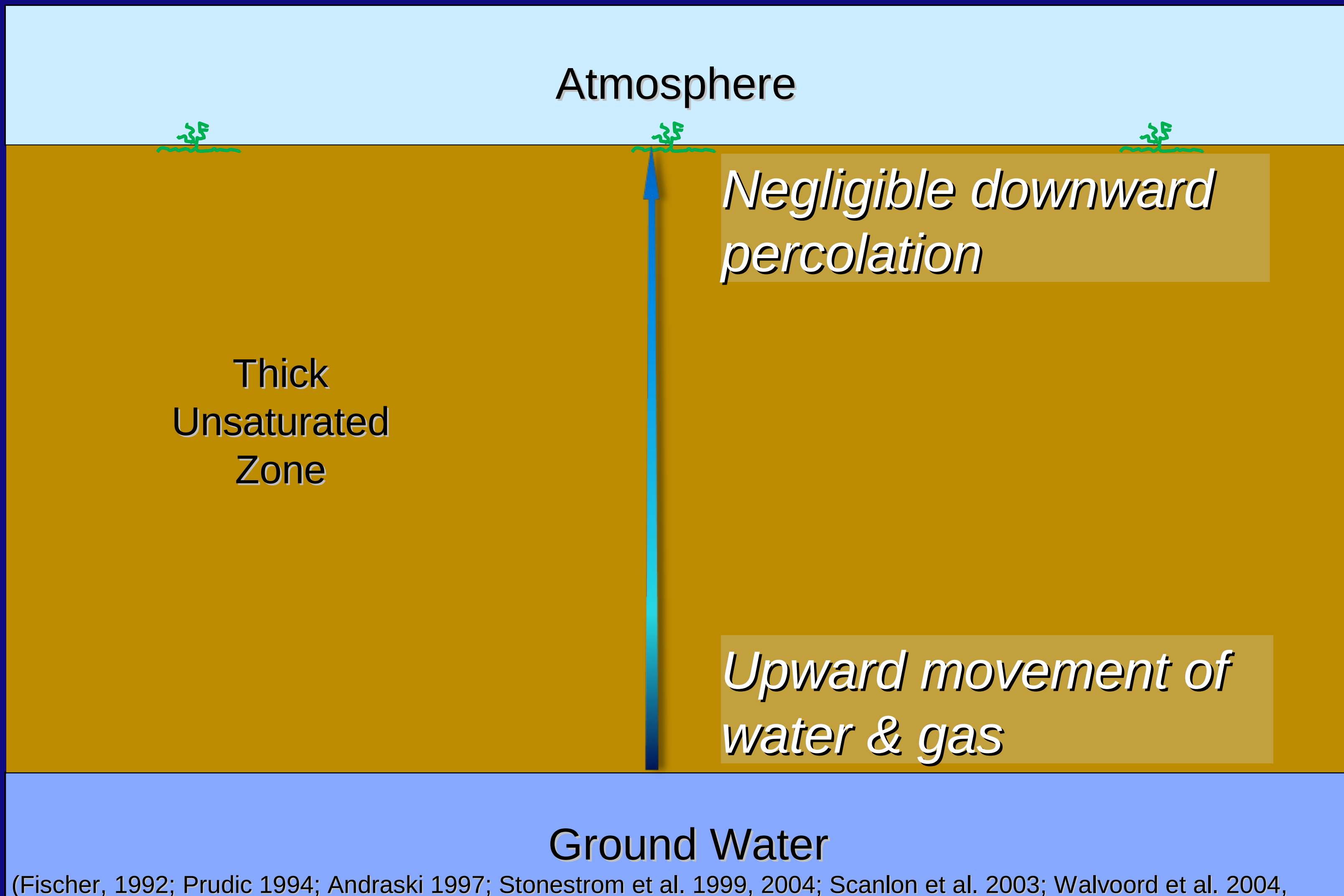
(Mayers et al. 2005)

- Expanded model
  - Anisotropy & heat/pressure generated by decaying waste
  - Greatly reduced discrepancies between basic theory & measurements

- Further work is needed to evaluate other processes that may be enhancing vapor-phase tritium transport ...
  - Barometric pumping?
  - Interactions with volatile-organic compounds?

... step back/recap ... Two conceptual models developed from ADRS studies

(1) Natural system – negligible percolation + upward water/gas flow

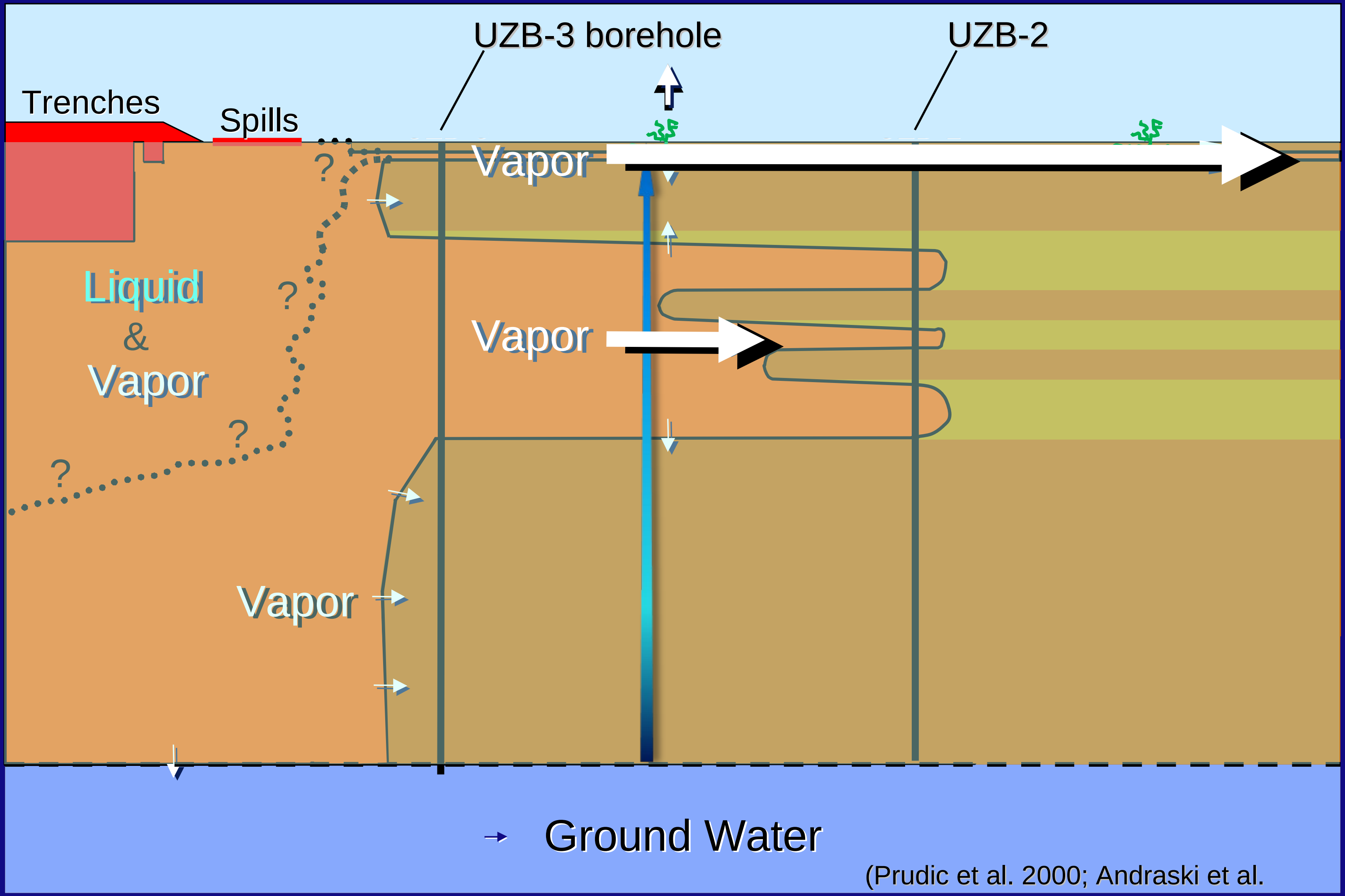


(Fischer, 1992; Prudic 1994; Andraski 1997; Stonestrom et al. 1999, 2004; Scanlon et al. 2003; Walvoord et al. 2004, 2005)

... step back/recap ... Two conceptual models developed from ADRS studies

(1) Natural system – negligible percolation + upward water/gas flow

(2) Contaminated – lateral tritium migration superimposed on natural, upward flow field



(Prudic et al. 2000; Andraski et al. 2005)

CONCLUSIONS – Tritium Monitoring & Modeling

- We CAN measure the tritium

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CONCLUSIONS – Tritium Monitoring & Modeling

- **We CAN measure the tritium**
- **We CAN map the tritium**

CONCLUSIONS – Tritium Monitoring & Modeling

- **We CAN measure the tritium**
- **We CAN map the tritium**
- **But … our present models CANNOT accurately reproduce the observed extent or distribution of transport**

CONCLUSIONS – Tritium Monitoring & Modeling

- **We are continuing to look for the answer ...**

- Ultimately … better process understanding is needed to develop & build confidence in UZ transport models