Monitoring Contaminant Strategies: Tools, Techniques Methodologies and Modeling Approaches

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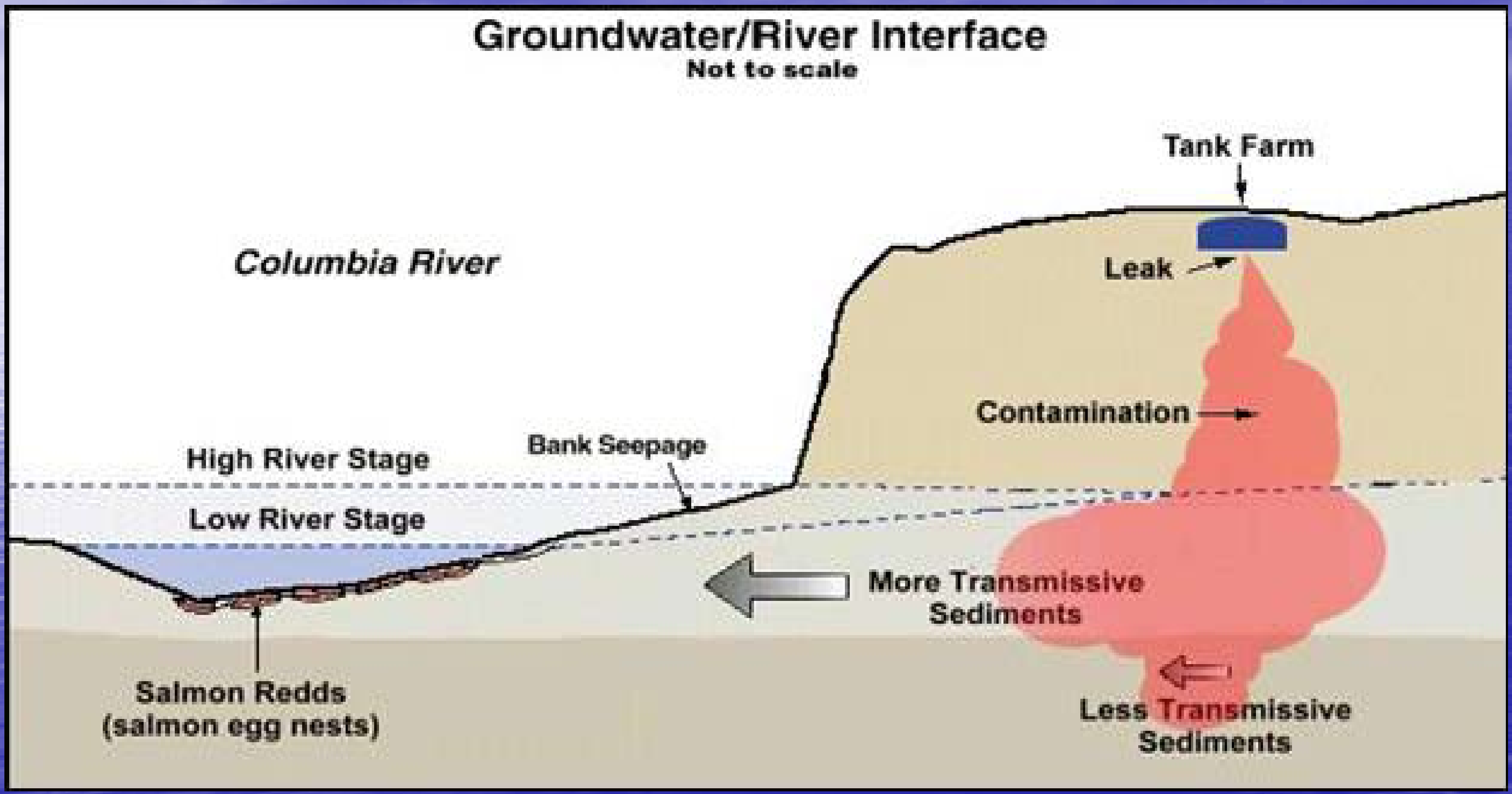
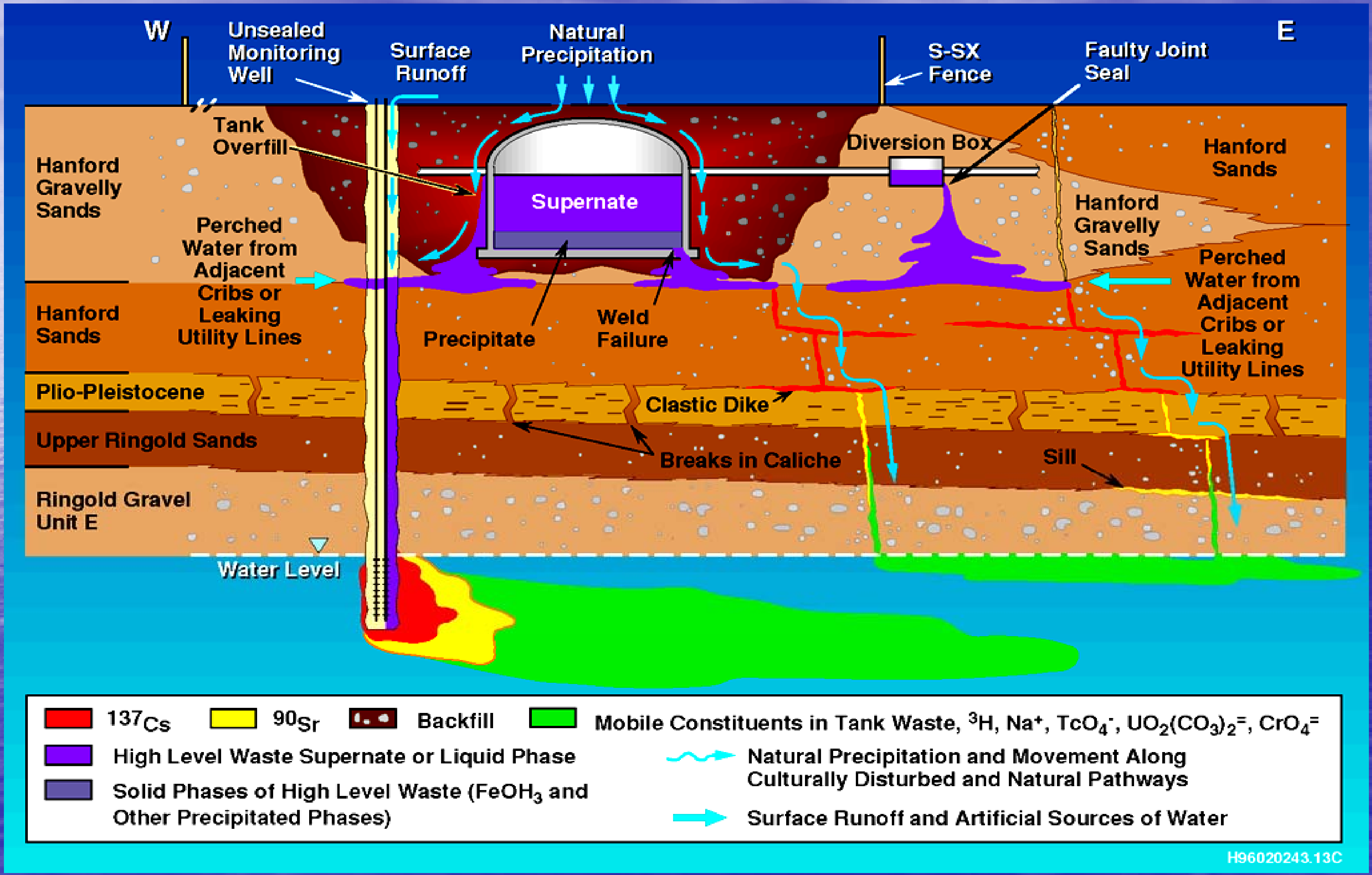
Subsurface Contaminant Transport: Textbook Representation



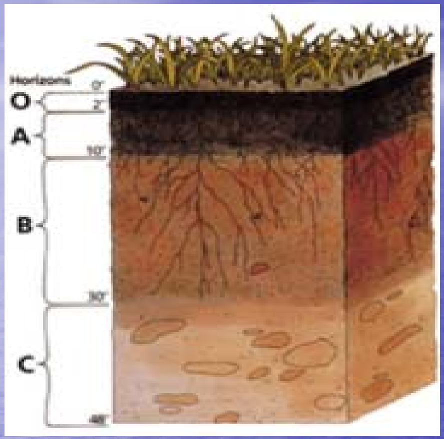
Conceptual Model of Contaminant Transport at the Hanford site



Ward et al. (1997) after Caggiano et al. (1996)

Different Definitions of Soils

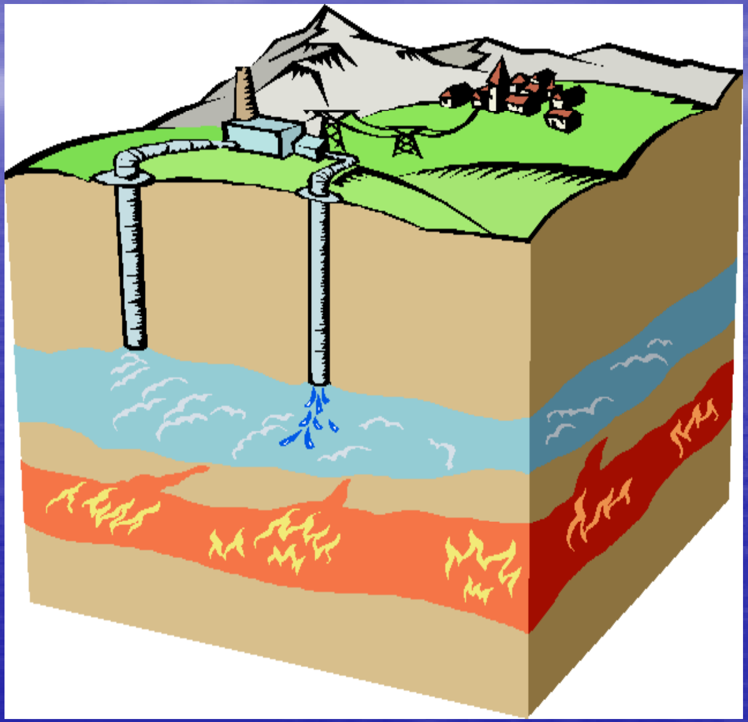
Agriculture



Talbott silty clay loam, TN, NRCS

3-5 m

Geotechnical Engineering



20-50 m

The variably saturated region between the soil surface and shallow ground water (the vadose zone) is complex, but often governs when and where compounds will arrive at the water table.

Working with Complex Systems

I. Understand the System

II. Concept and Parameterization

III. Test and Observe

IV. Model Evaluation

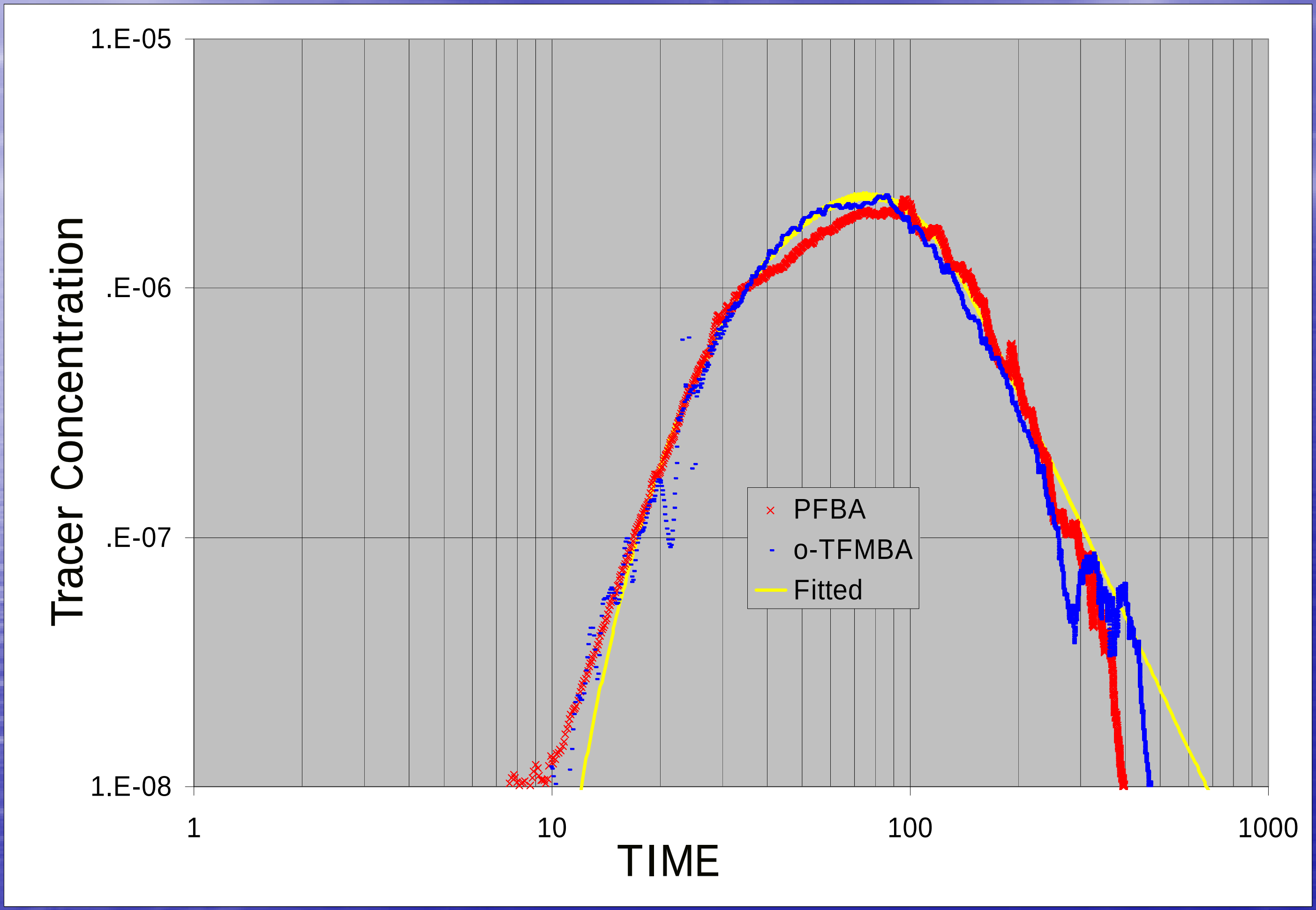
Introduction into Basic Chemical Transport Monitoring Approaches

I. Outflow breakthrough curves

II. Destructive sampling

III. Monitoring of the pore solution

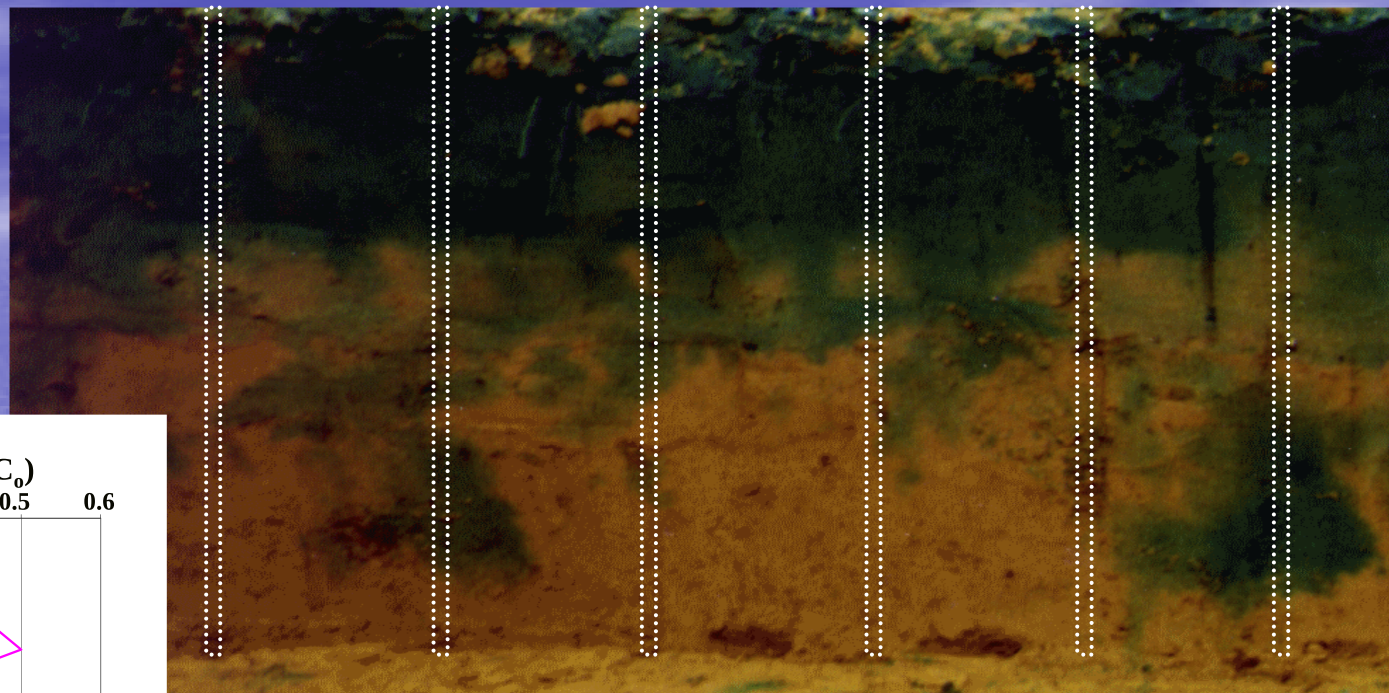
I. Outflow Breakthrough Curves

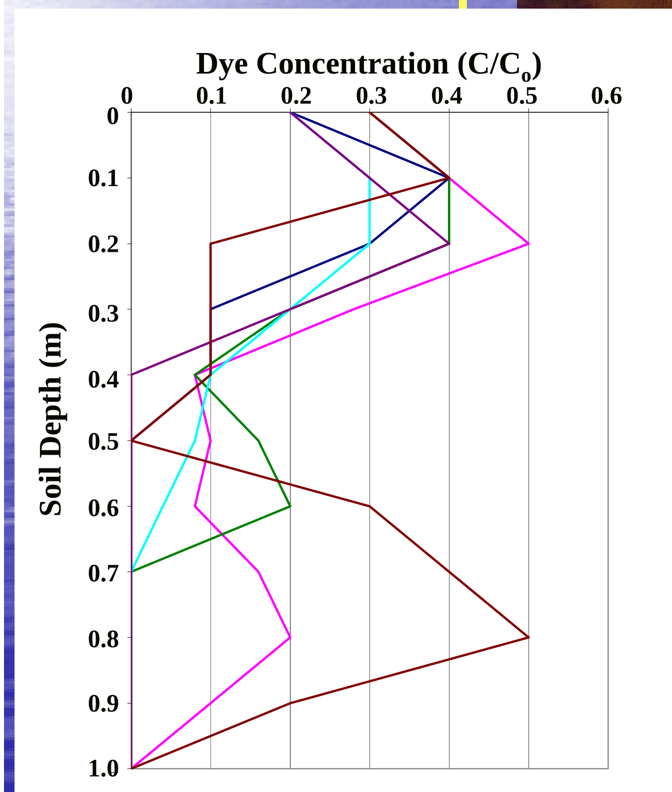


1) Initially developed using columns, this approach has been extended to field soils.
2) Probably the most reliable for obtaining tracer concentrations or fluxes.
3) Difficulty in interpreting several processes from a single curve.

II. Destructive Sampling

About
1m

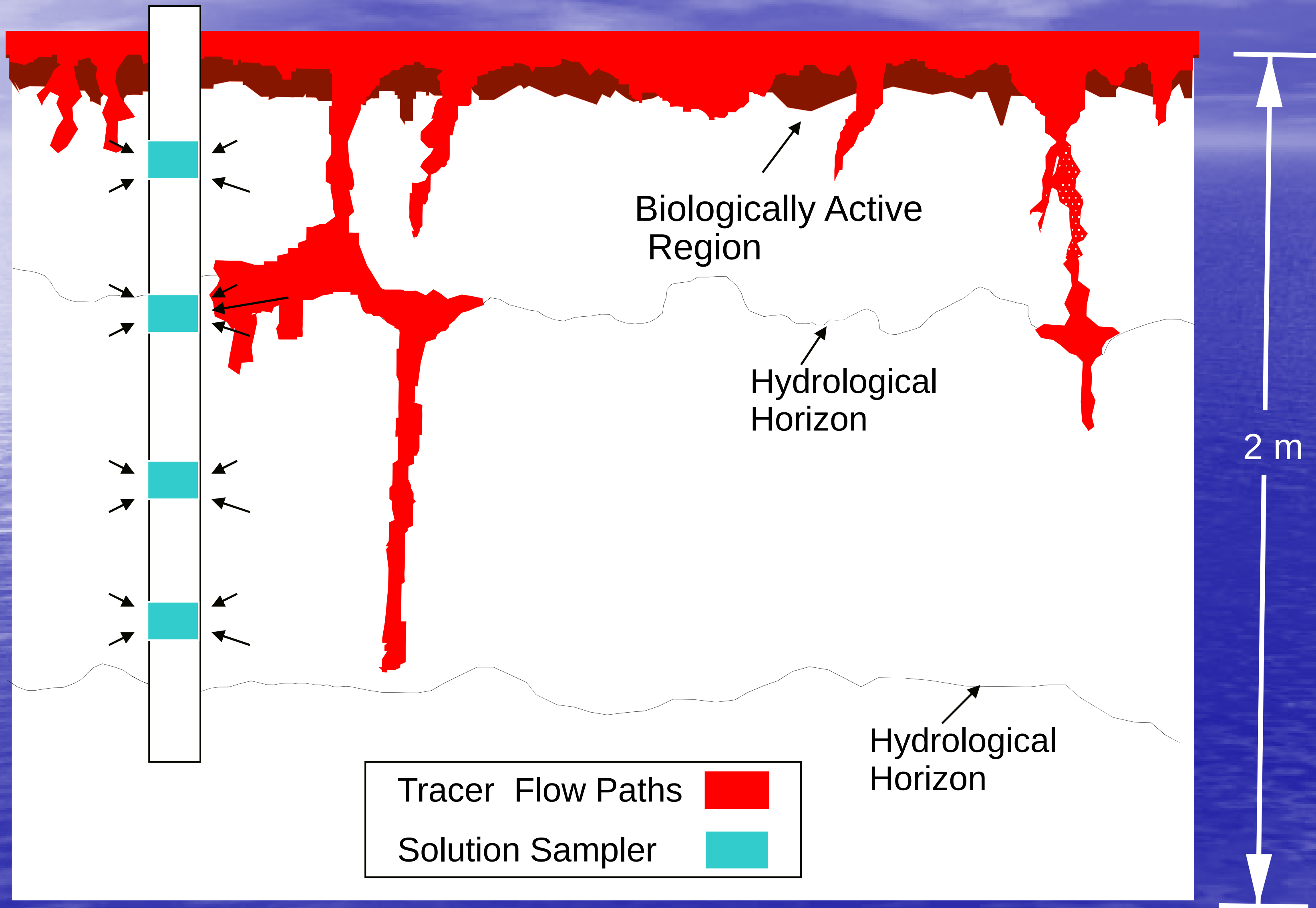




1) Generally, not effective for concentrations profiles.

1) However, very helpful for evaluating soil properties that influence transport.

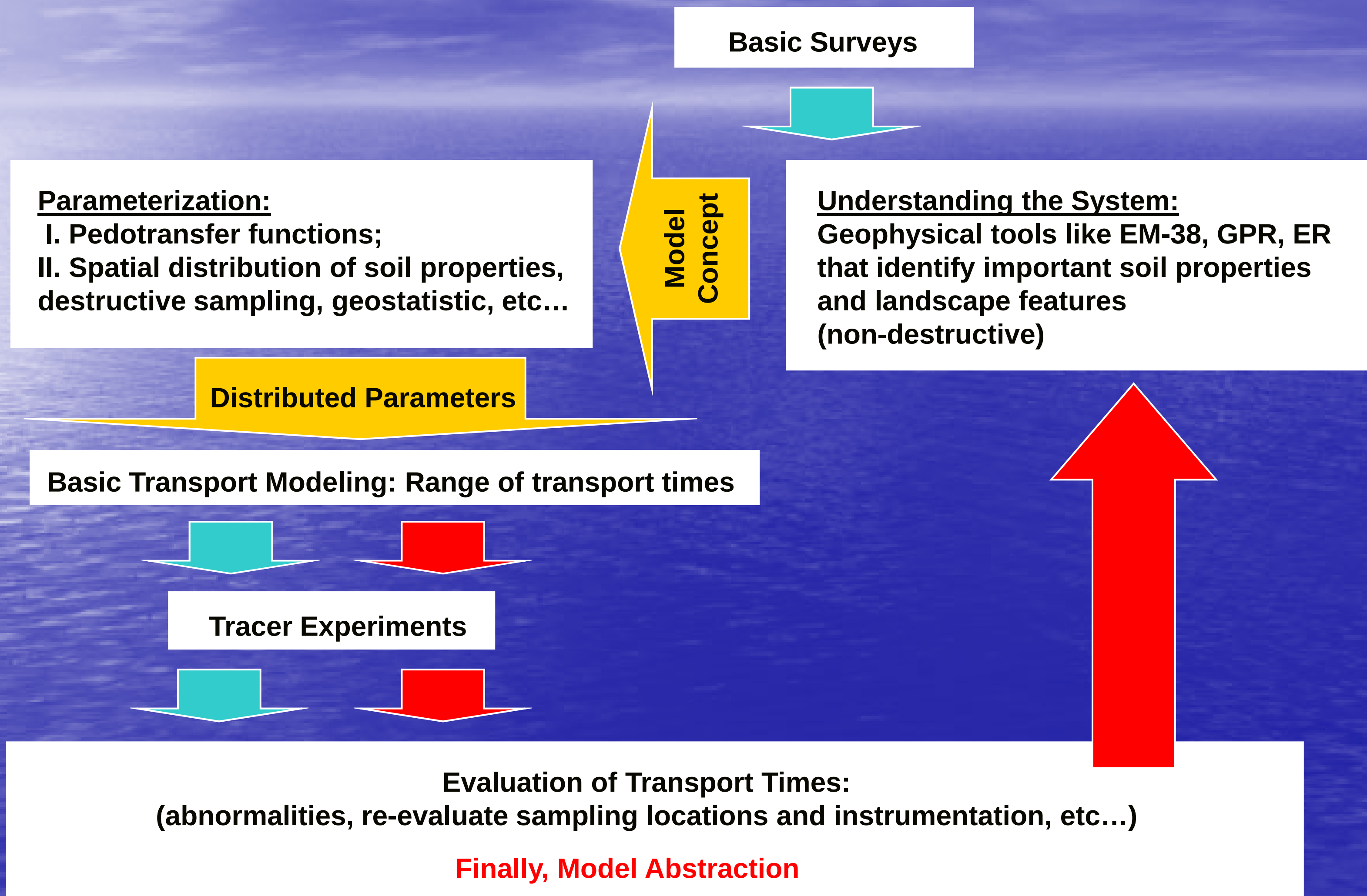
III. Pore Solution Monitoring



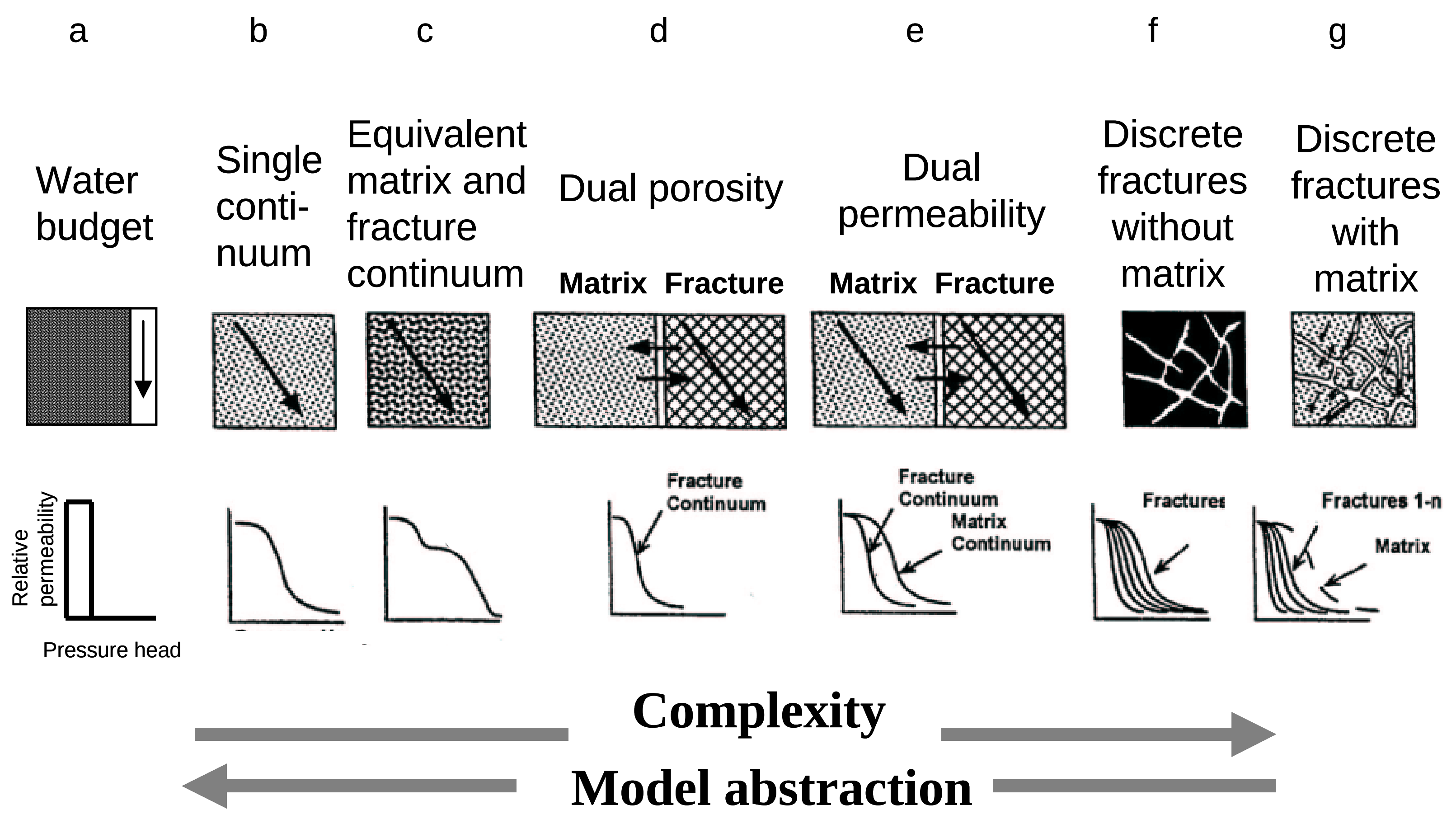
Each Monitoring Approach has Benefits and Limitations

Monitoring Approach	Benefits	Problems
Outflow Breakthrough	1) Integrates over an area or volume 2) Flux measurements possible	1) Interpretation of process from a single curve 2) Sorbed and degraded compounds
Post-Destructive Sampling	Diminishes transport ambiguity	1) Interpreting scale 2) Resource limitations 3) No preferential flow
Monitoring of Pore Solution	Easy and common	1) Scale issues 2) Interpretation difficult 3) Concentrations

Hybrid Monitoring and Modeling Approach



Model Conceptualizations



Hierarchy of models to simulate water flow and solute transport in structured soils or in unsaturated fractured rock (after Altman et al., 1996) .
Model abstraction techniques for evaluating soil-water and chemical transport (Pachepsky et al., 2006)

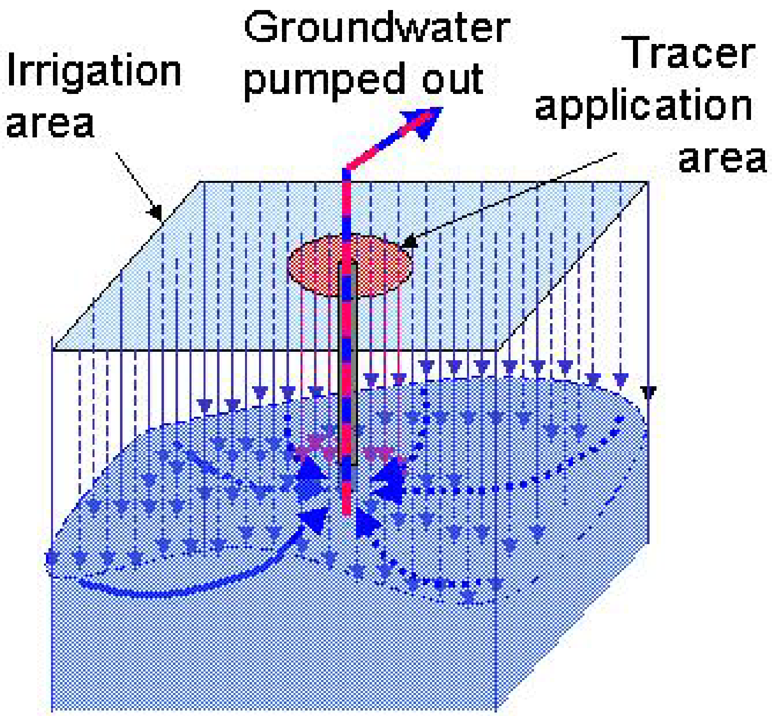
Optimizing Production Inputs for Economic and Environmental Enhancement

Important Data Collected

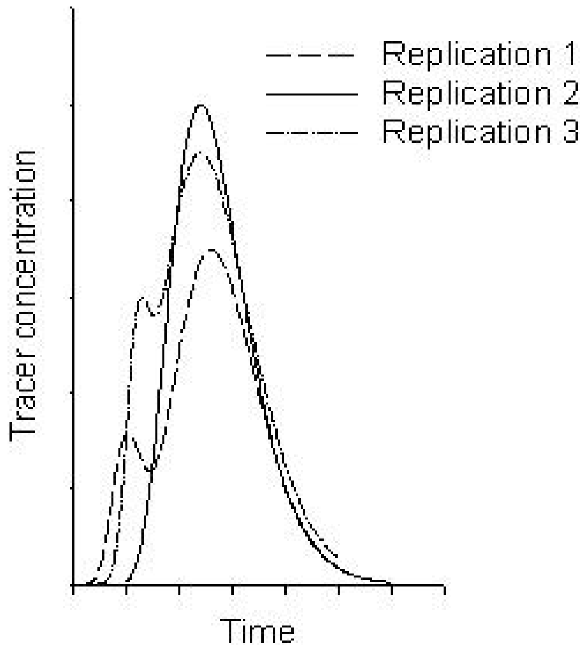
- Soil Survey
- Surface topography
- Ground-Penetrating Radar
- EM-38 and ER analysis
- Texture analysis
- Runoff flumes
- Eddy covariance meteorological station
- Dense network of soil moisture probes
- Tracer observation wells
- Groundwater levels
- Soil water pressure heads

Outflow Breakthrough Sampling

(Gish and Kung, 2004; Yakirevich et al., 2010)



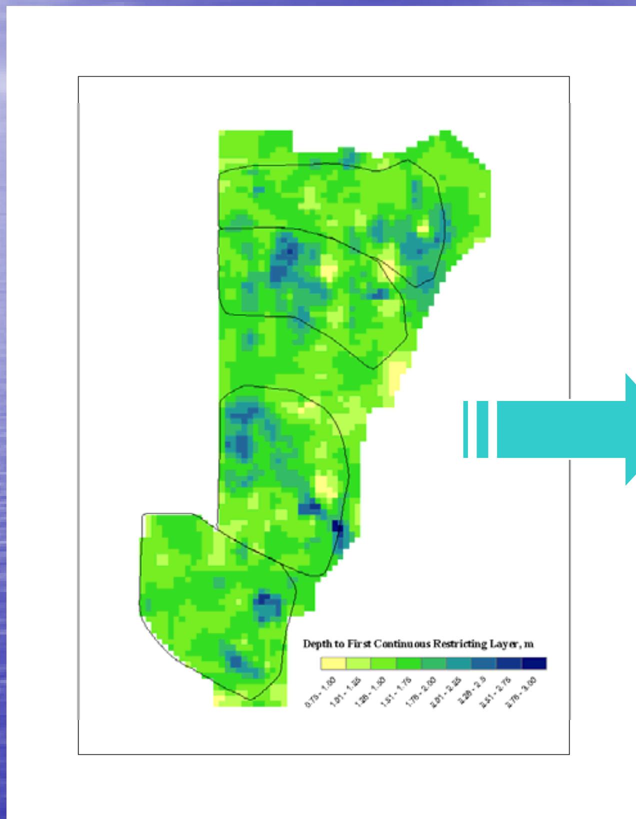
Design

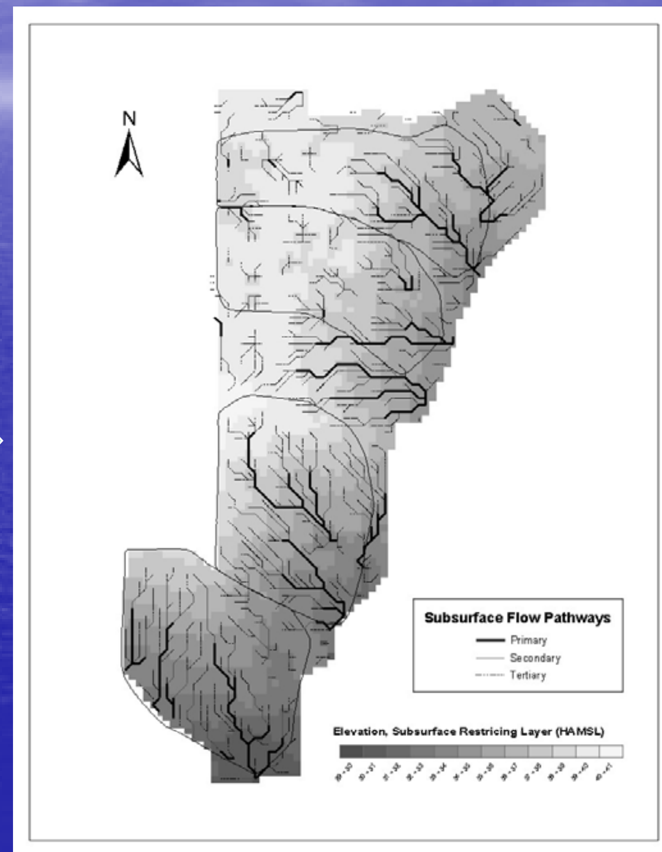


Resultant bromide breakthrough curves

Using Ground Penetrating Radar to Quantify Subsurface Soil Structures

Remote sensing helps us to understand subsurface drainage systems.

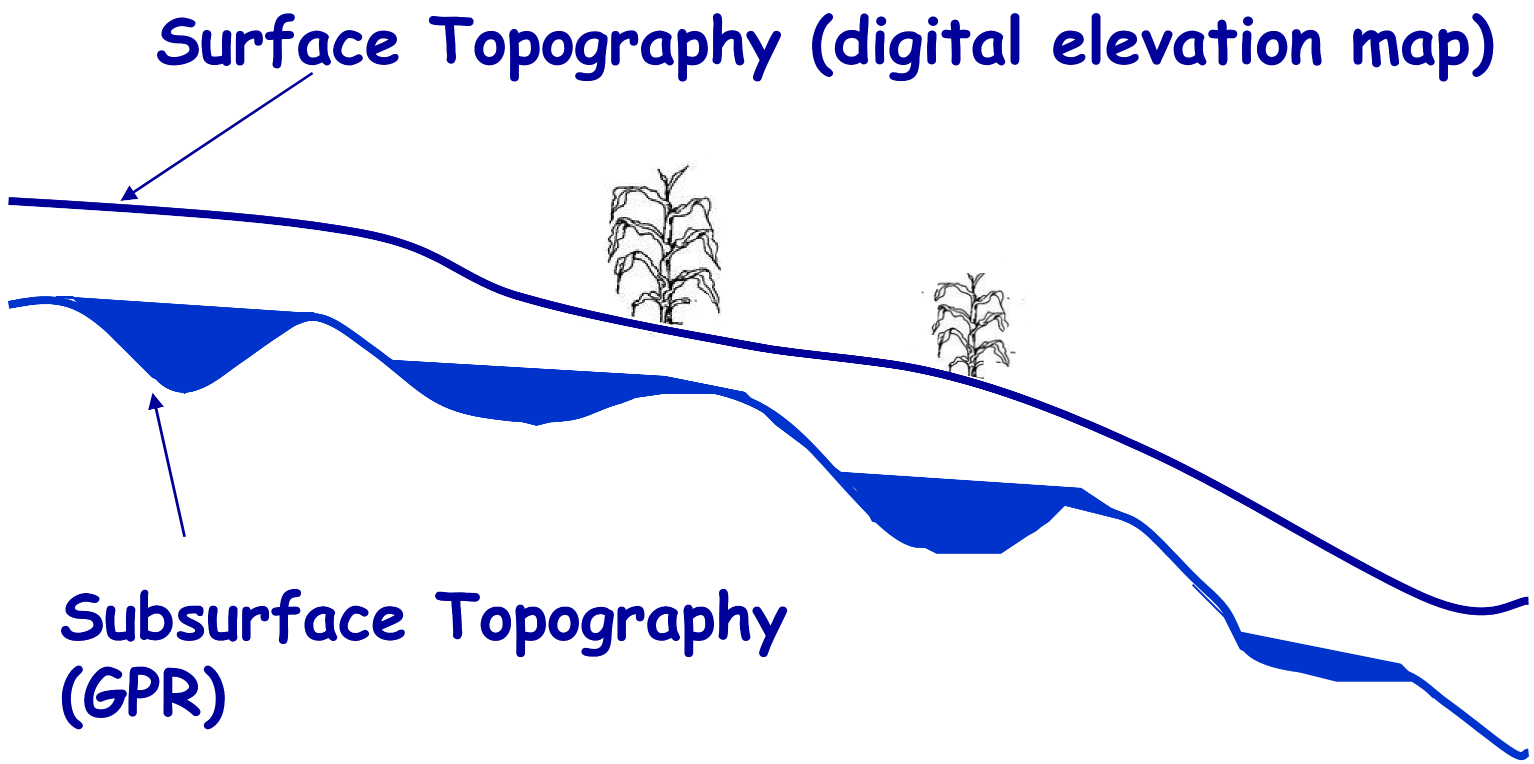




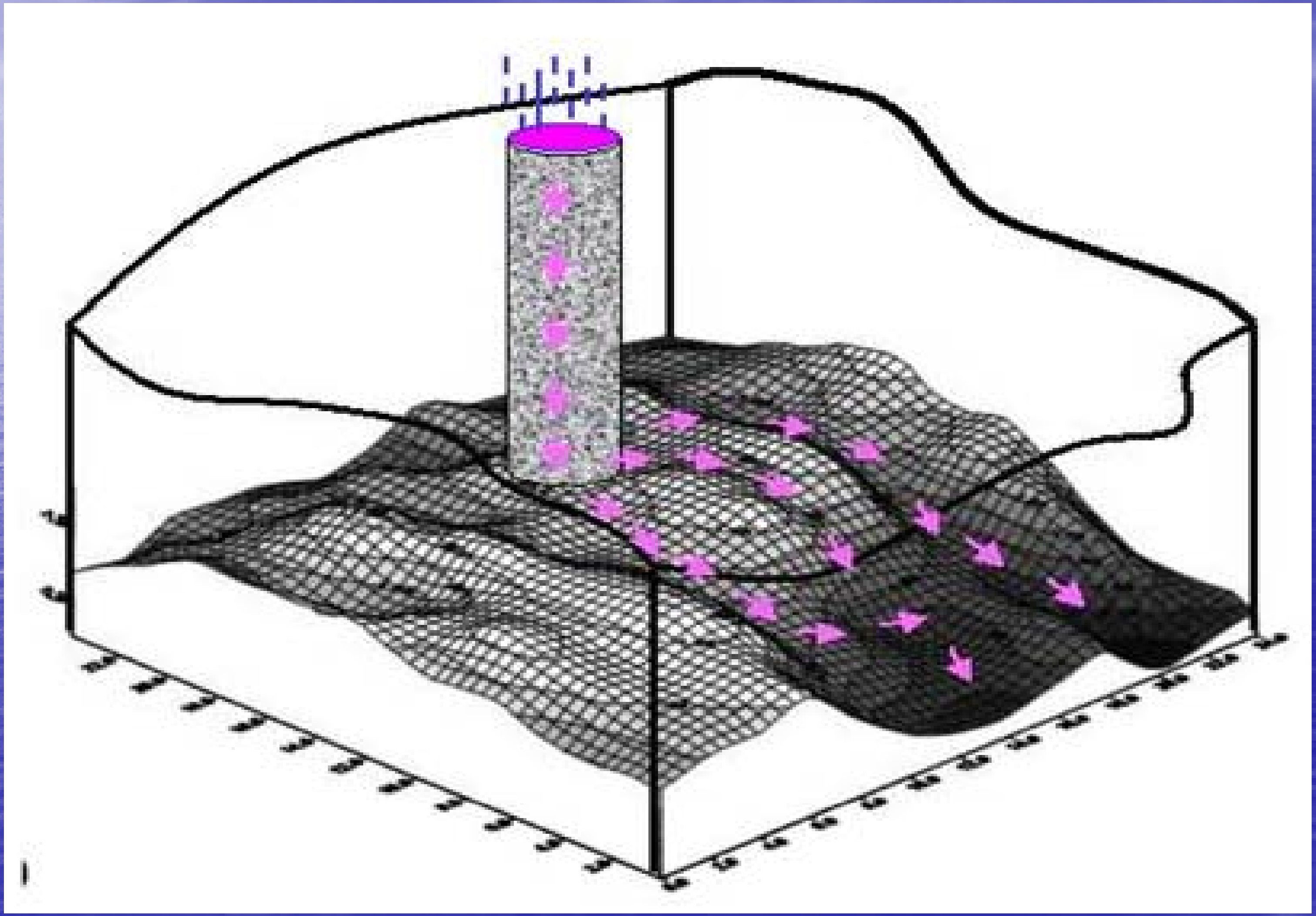
Depth To Subsurface Restricting Layer

Subsurface Flow Pathways

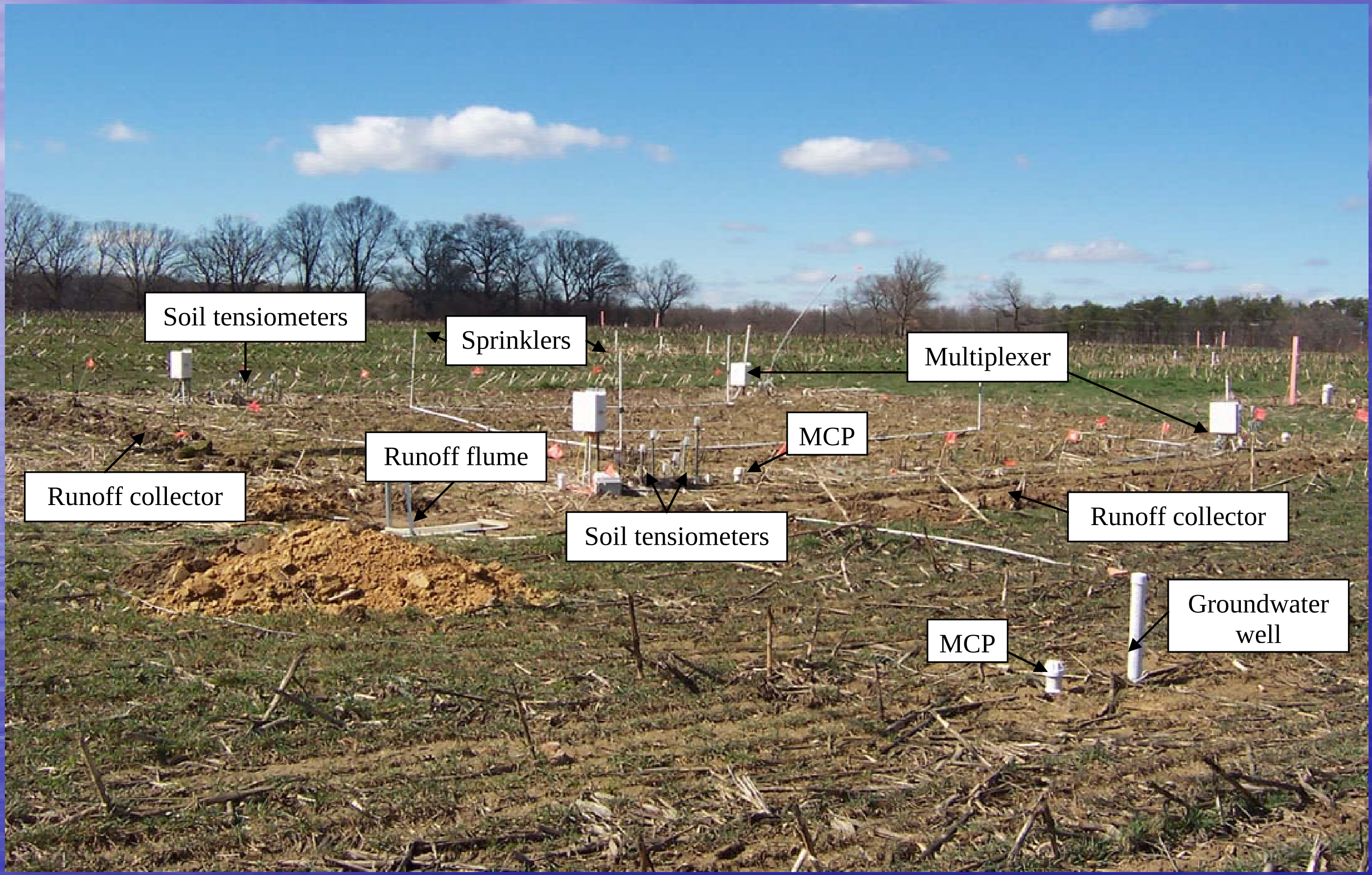
Spatial Dynamics of Cascading Pockets of Subsurface Water



Outline of Proposed Field Tracer Transport Experiment at the OPE3 Watershed



Multipurpose Tracer Experiment Site



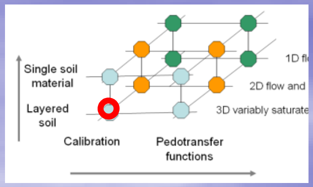
Chloride and Fluorobenzoic acid pulses

Transport Modeling

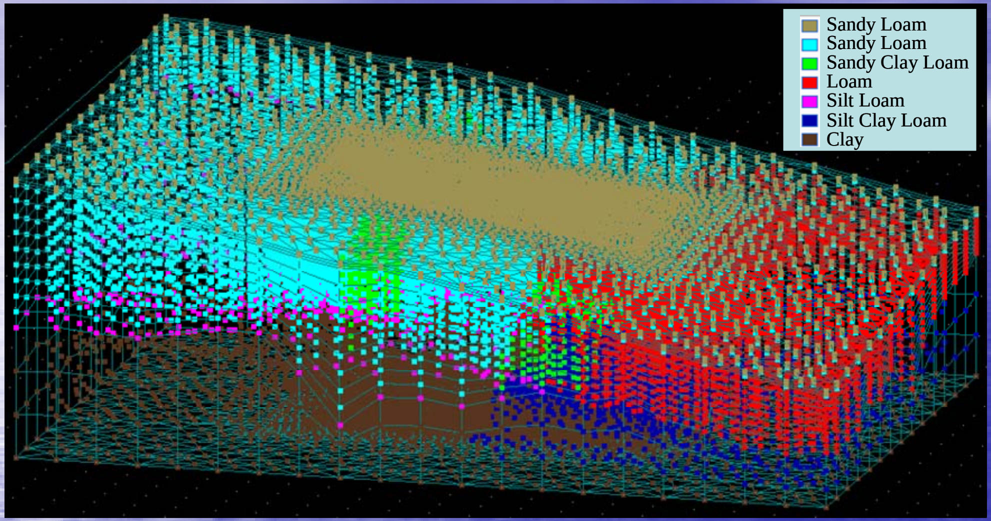
Role of Modeling in Environmental Contaminant Transport Projects

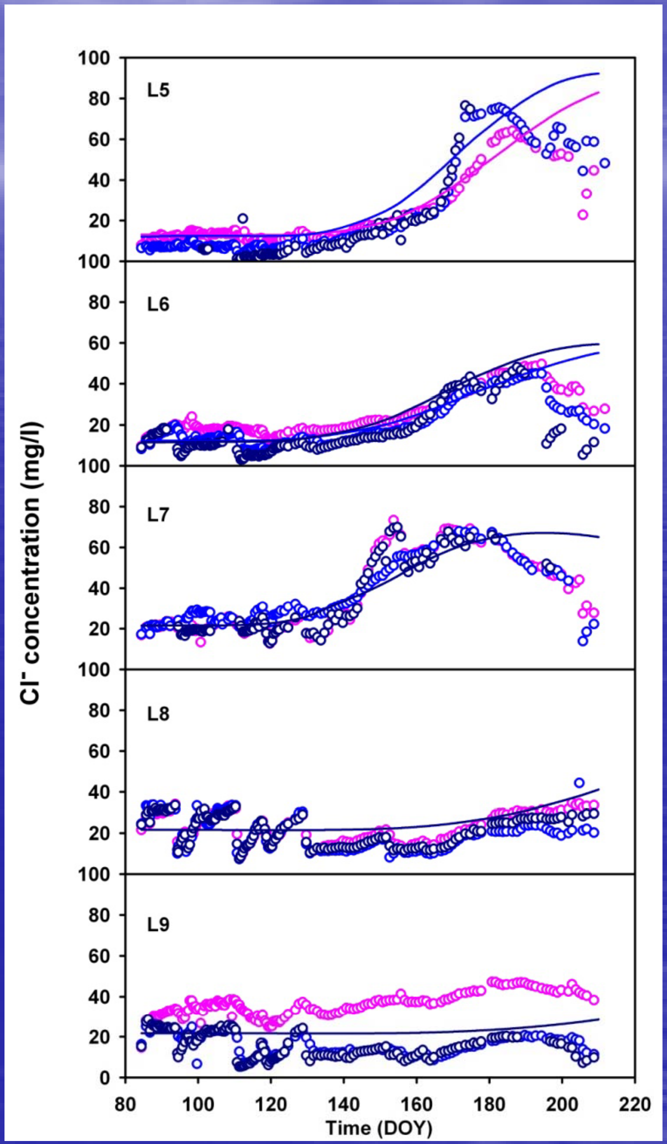
Problem type	*Reason for undertaking the project*
Understanding of subsurface hydrologic system	Investigation of hydrologic processes Determination of effective monitoring strategy Preliminary model to determine the current level of understanding
Parameterization	Analysis of tests, monitoring data and tracer experiments
Understanding the past	Understanding historical development of contaminant transport Estimation of predevelopment conditions
Understanding the present	Understanding the effect of groundwater pumping, irrigation and other water uses Determination of sources of water and contaminants in particular locations Determination of responsible parties
Forecasting	Management of the water quantity and quality

Modified after Reilly and Harbaugh, 2004



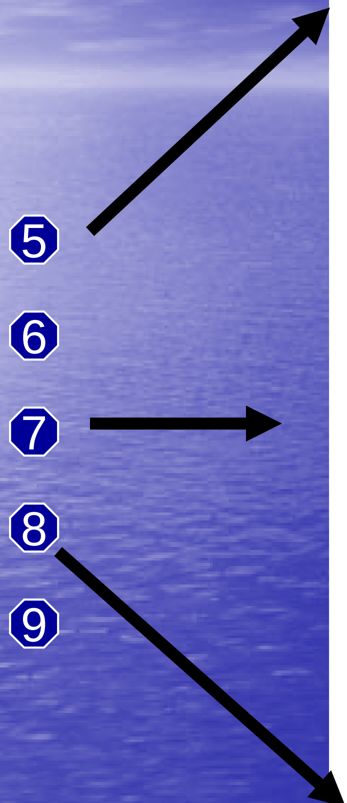
3D No-Preferential Transport Model

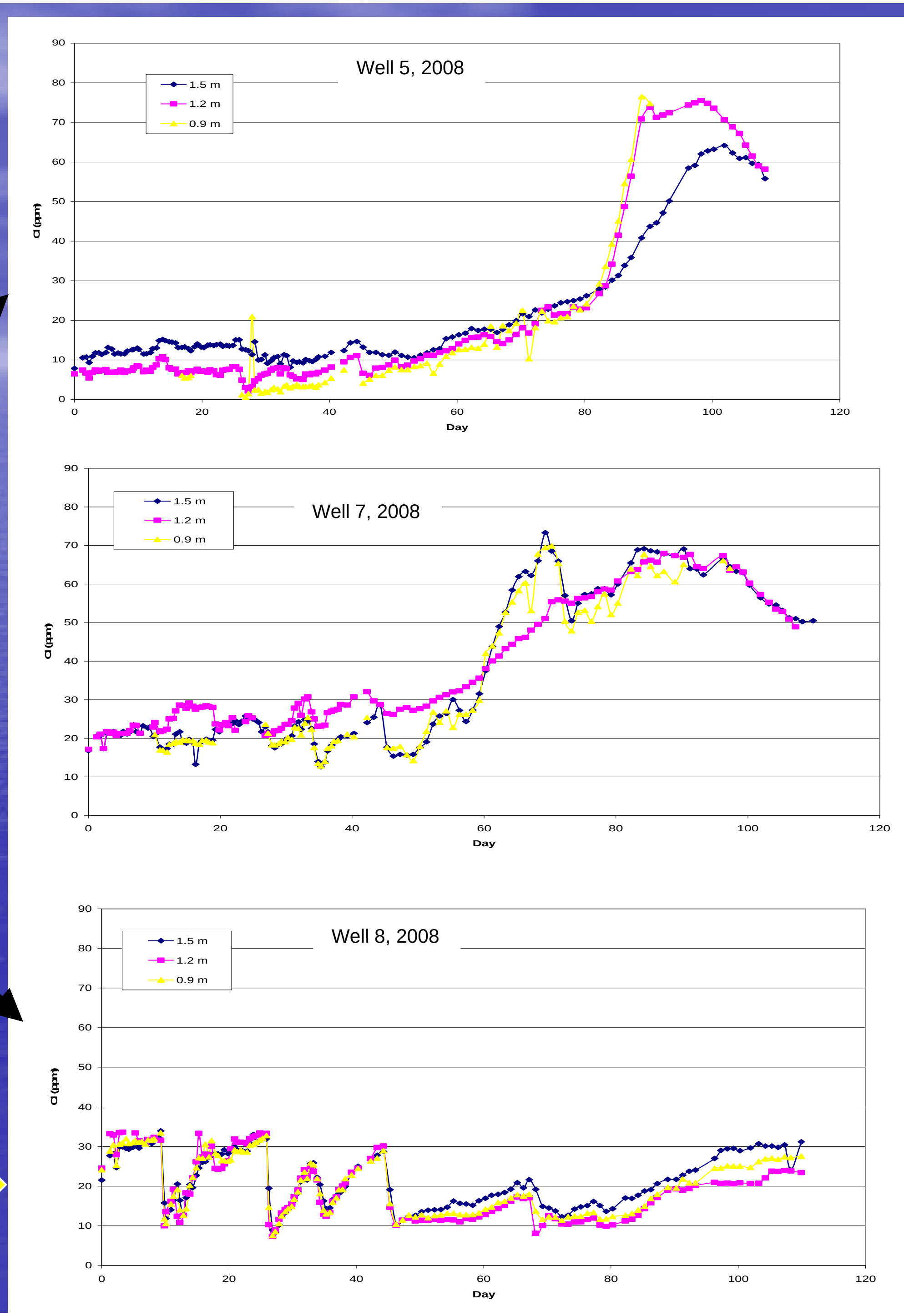




- Only manual calibration is possible; extremely time consuming.
- Textural differences generally reflect transport tracer transport velocities.
- Calibrated model can reproduce arrival times but not the breakthrough shape and not the maximum concentration arrival time

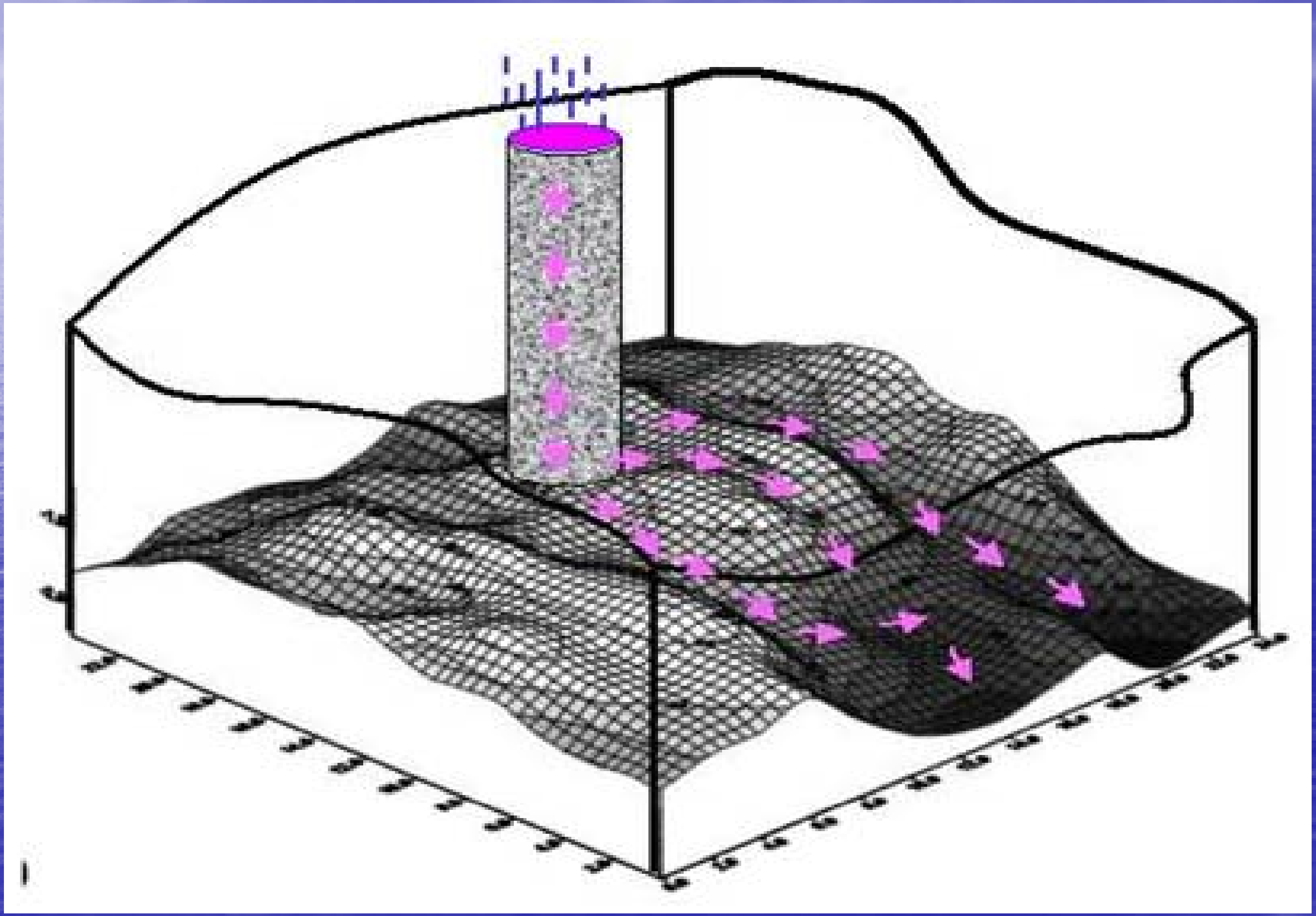
BTC indicate transit times on the order of months.





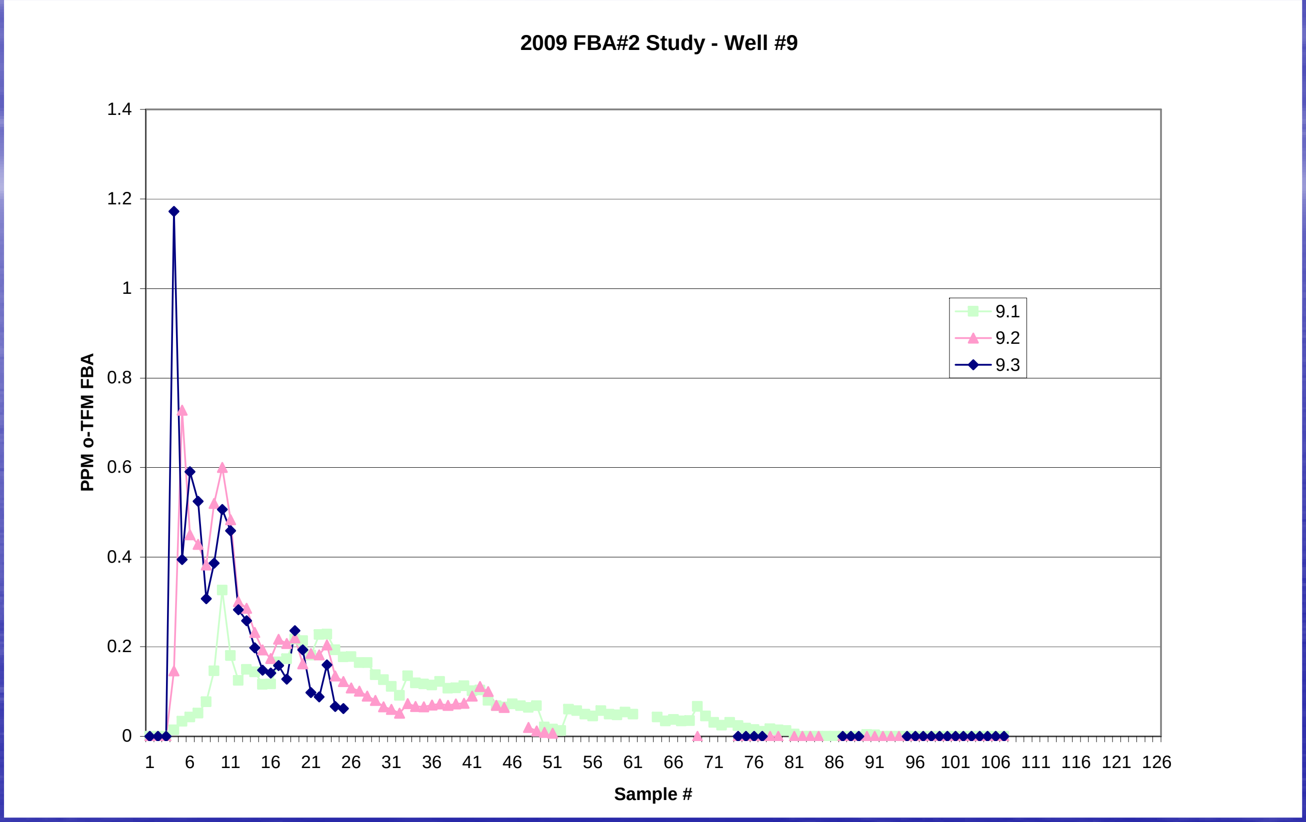
What is going on here, months or days?

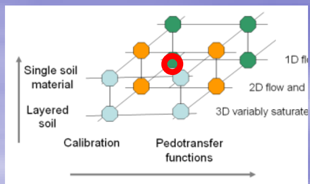
Outline of Proposed Field Tracer Transport Experiment at the OPE3 Watershed



2009, FBA tracer

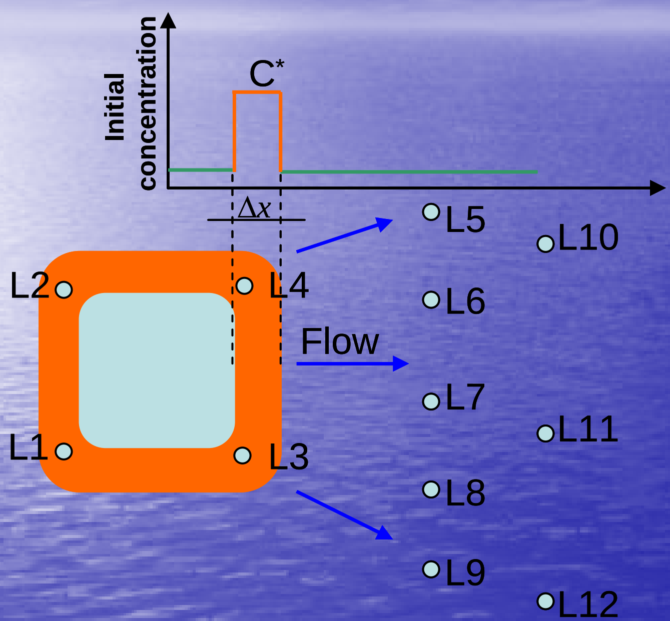
FBA Tracer Concentrations are zero in 2nd row with the exception of well 12.



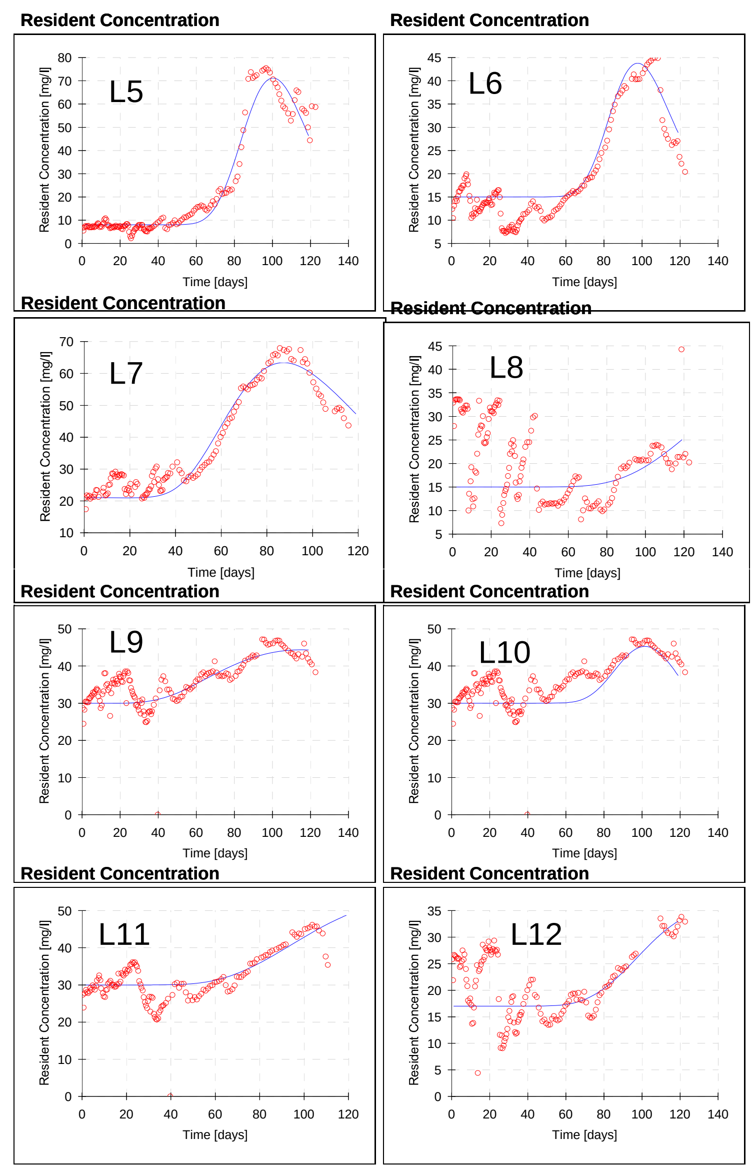


1D Transport in Groundwater Model

Conceptual model



1. **Transport velocities differ dramatically between well locations.**
2. **Some tracer transit times indicate that matrix flow processes dominate transport while others are dominated by preferential flow.**
3. **Model abstraction techniques were critical to interpreting tracer data.**



Vadose Zone Checklist

- ✓ Does a specific site have subsurface structural units and features that can significantly affect fate and transport of contaminants in the vadose zone along the projected trajectory of the contaminant plume?

- ✓ If a restrictive fine-material layer is expected, does it exhibit features such as dikes or faults; is the restrictive layer continuous; do perched water systems form?

- ✓ If a restrictive layer is expected, does it have appreciable variable thickness or undulating hydrogeologic unit contacts such that low spots (pockets) occur creating preferential pathways ?

- ✓ Are natural capillary barriers present, i.e. boundaries between the finer material overlaying much coarser material layers? If yes, are gaps in these barriers expected?

Vadose Zone Checklist (cont.)

- ✓ **Can unstable wetting fronts or funnel flow occur in coarse-textural soil units due to its location between much finer material units?**

- ✓ **Can geochemical conditions and microbial processes in (1) saturated fine material units; (2) capillary fringe; or (3) perched water systems facilitate contaminant transformations or retention?**

- ✓ **Does the media in a well-conducting drainage layer have fine-scale, high-conductivity portions of the pore space that will facilitate transport in large pores during infiltration events?**

- ✓ **Is the lateral conductivity in the capillary fringe high enough to create substantial lateral flow and transport in the capillary fringe above groundwater?**

Thank you!