U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

NUCLEAR WASTE TECHNICAL REVIEW BOARD
FULL BOARD MEETING

SUBJECT: AMBIENT AND THERMALLY PERTURBED FLOW MODELS AND ABSTRACTIONS FOR TSPA-1995

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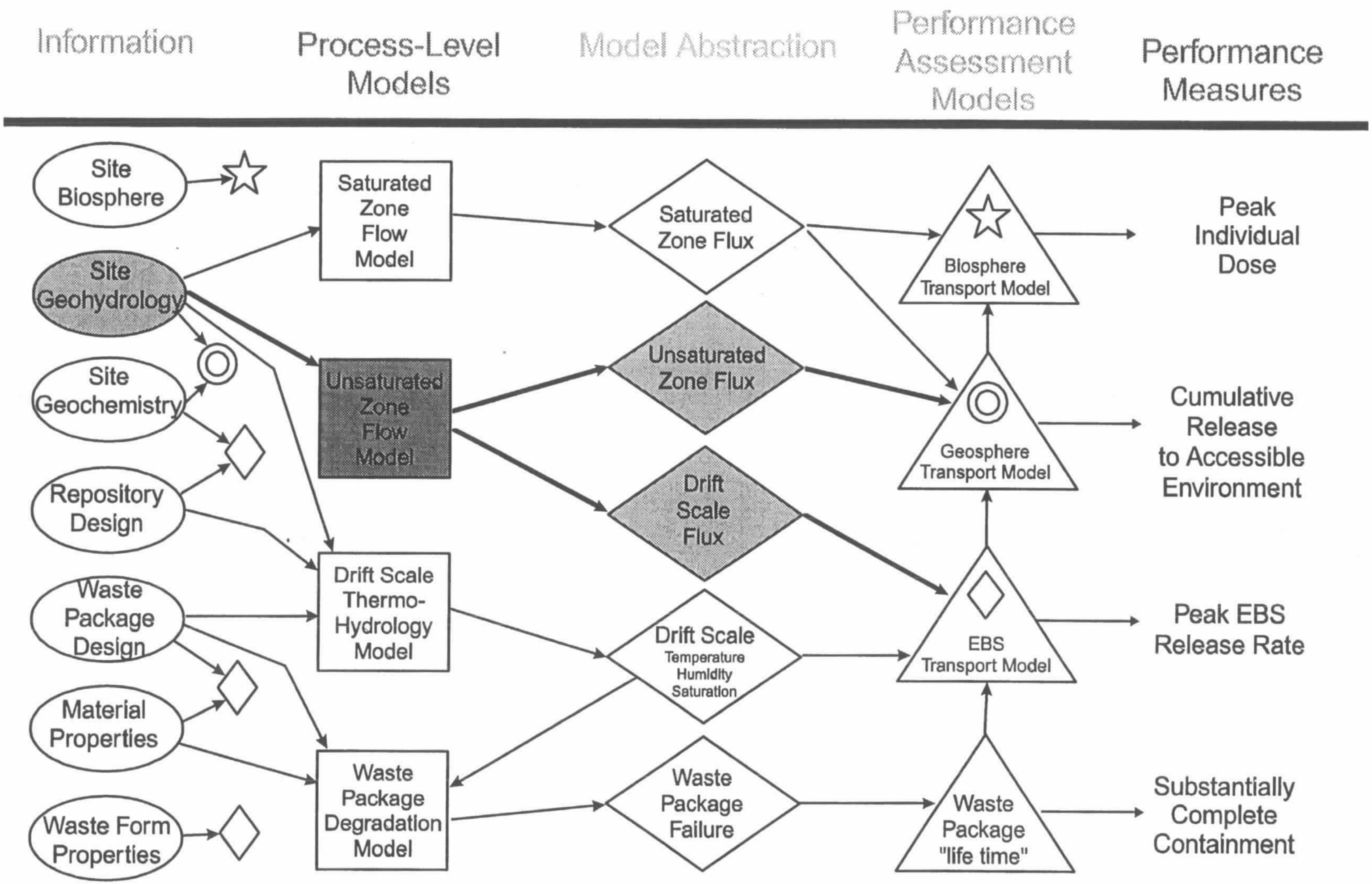
Introduction

- Total system simulator *RIP* does not explicitly include hydrologic and thermo-hydrologic process models

- Abstractions of velocity / flux from external models required as input to engineered barrier system (EBS) and geosphere transport calculations

- Abstractions of temperature / saturation / relative humidity from external models required as input to waste package degradation and EBS release calculations

TSPA-1995 Information Flow Diagram
Unsaturated Zone Hydrologic Modeling



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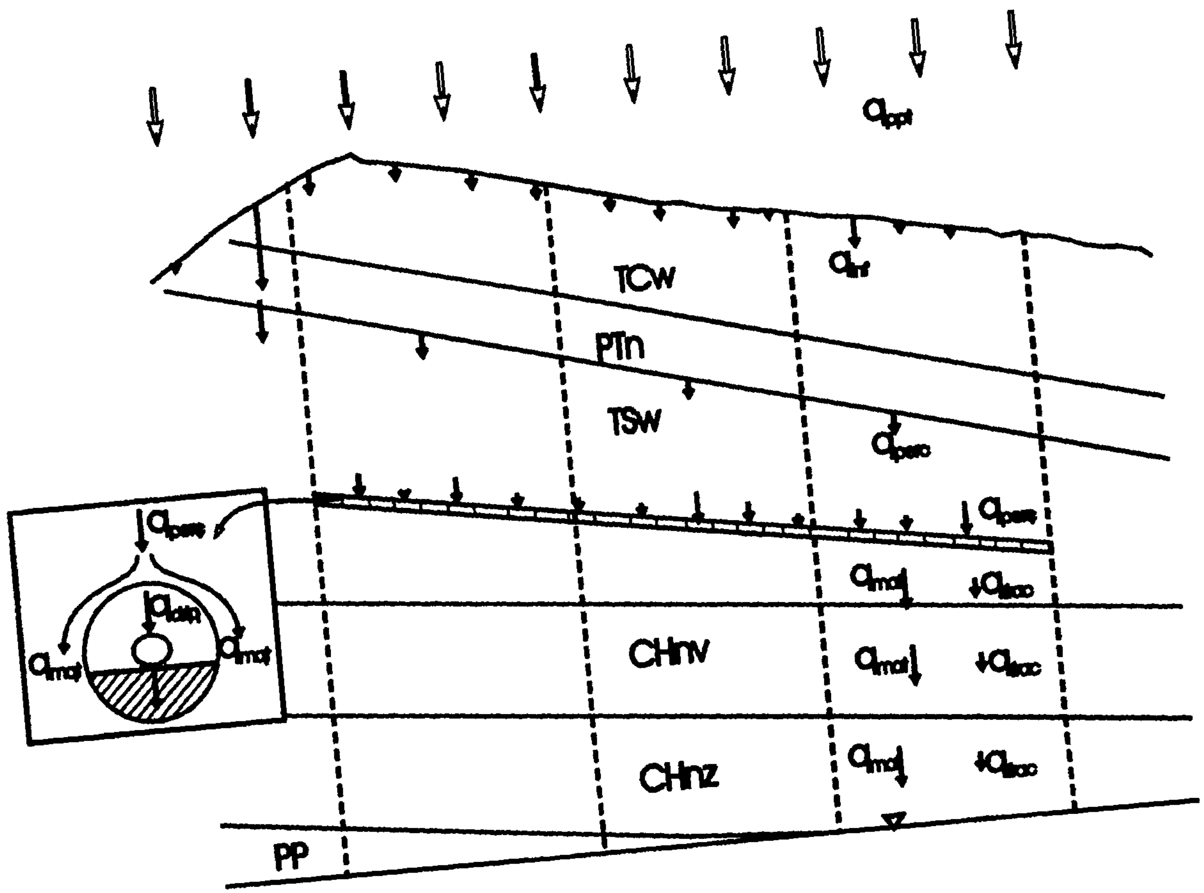
Conceptual Hydrologic Model



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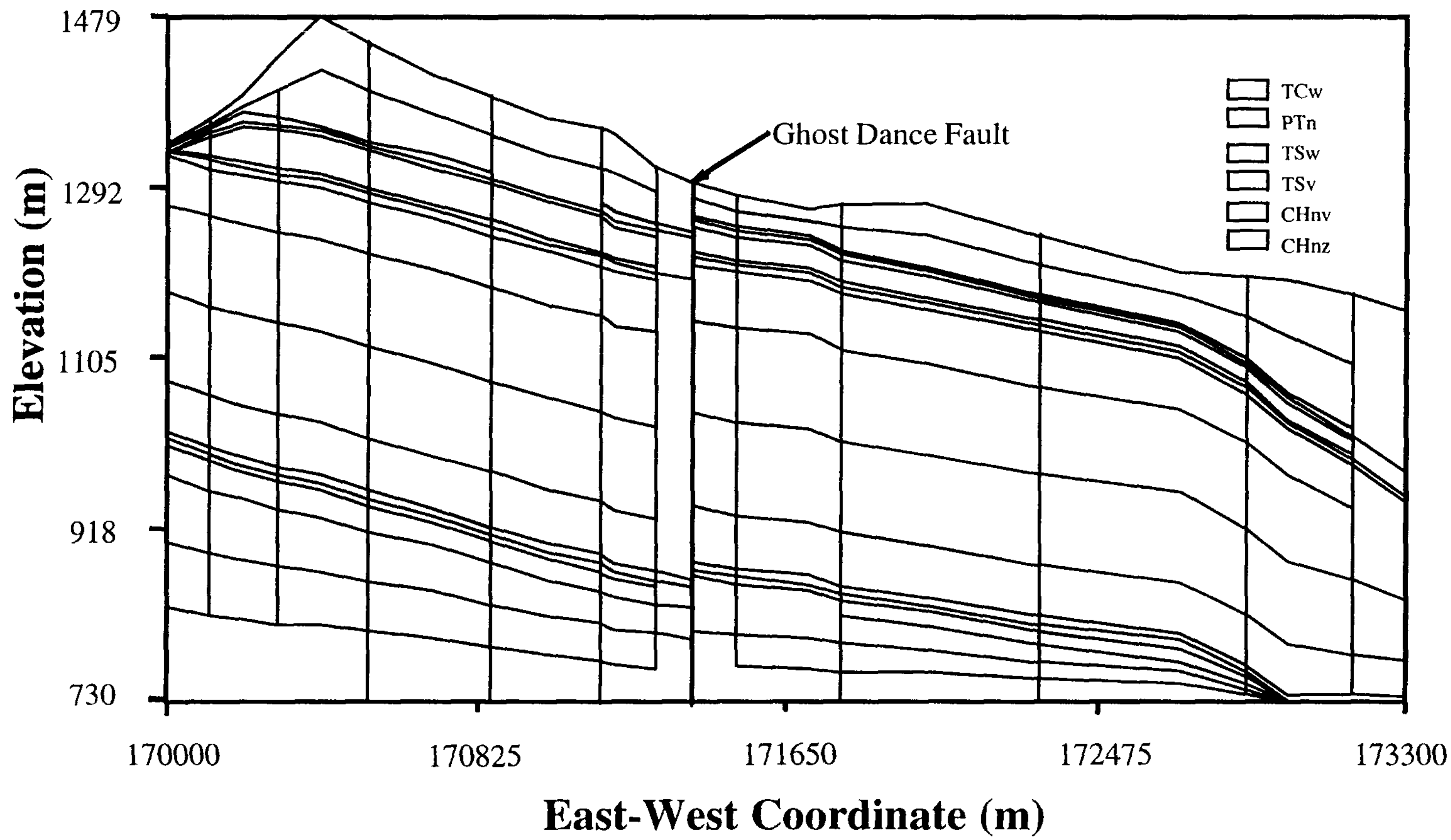
Objectives

- Use LBL-USGS site-scale model to develop repository-scale (UZ) abstractions; for
  - Uncertain / variable flow properties
  - Alternative infiltration scenarios
  - Fracture-matrix flow for equilibrium and non-equilibrium conditions
- Use stochastic fracture flow model to develop drift-scale abstractions
- Assume thermal effects have dissipated prior to onset of EBS/geosphere transport

Simulation Details

- Simulations with LBL-USGS site-scale model to develop correlations between infiltration and fracture / matrix velocity / flux
- Two infiltration flux ranges
  - Low (0.01 - 0.05 mm/yr)
  - High (0.5 - 2.0 mm/yr)
- Multiple realizations for matrix flow properties from *Schenker et al.* (1995)
- Two fracture flow initiation rules
  - After matrix 95% saturated ($\sigma = 0.95$)
  - After matrix fully saturated ($\sigma = 1.0$)

LBL/USGS Site-Scale Model, NW-SE Cross Section



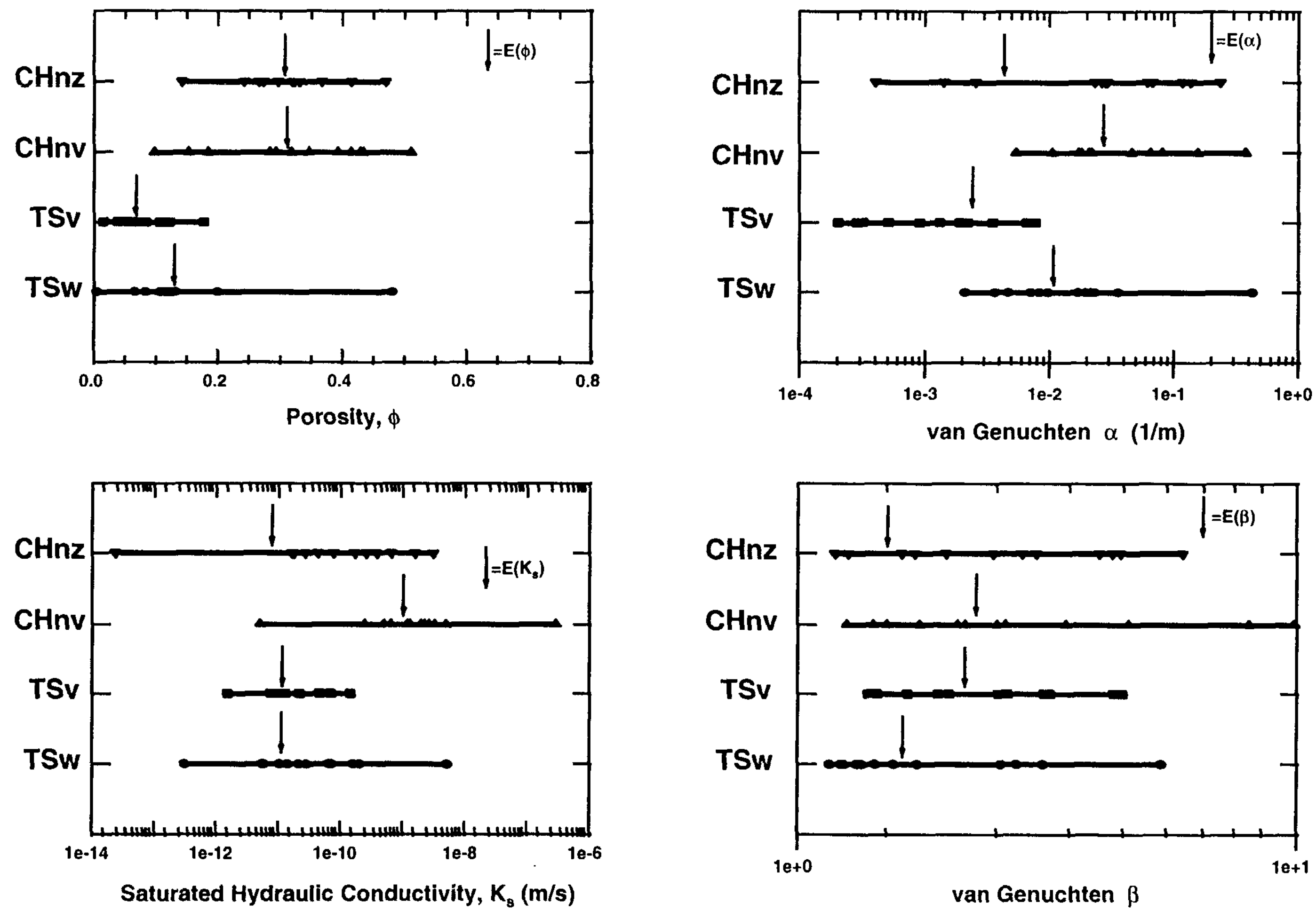
Infiltration Scenarios

- Infiltration map of *Flint & Flint* (1994) [with outcrop-dependent q_{inf} ranging from 0.02 to 13.4 mm/yr] used as basis for two alternative scenarios

- Low q_{inf} => surficial infiltration flux over repository footprint (~0.02 mm/yr) assumed to be invariant with depth due to predominantly 1-D vertical flow

- High q_{inf} => areally weighted average infiltration flux (~1.2 mm/yr) assumed to be uniformly distributed over repository horizon due to significant lateral diversion

Matrix Hydrologic Properties

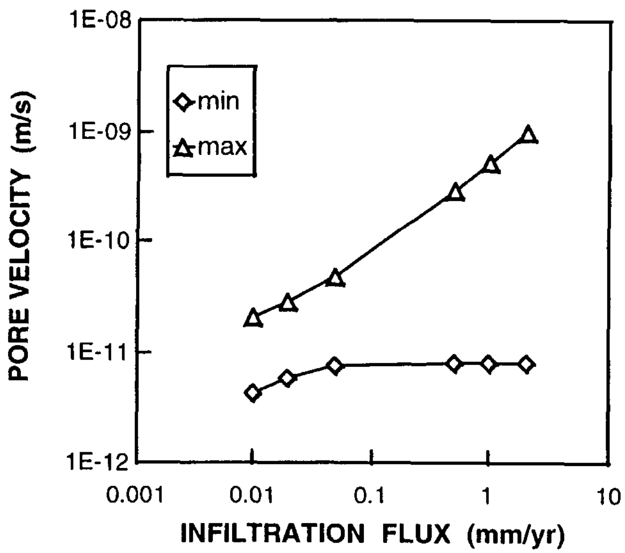


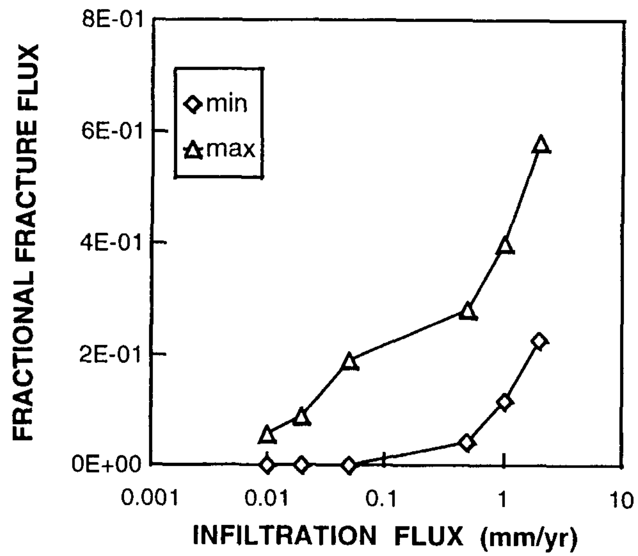
Ref: Schenker et al., 1995, SAND94-0244

Fracture-Matrix Flow Concepts

- Equivalent Continuum Model (ECM) allows fracture flow after matrix fully saturated
- Empirical generalization of ECM used to approximate non-equilibrium flow effects
- "Satiated" matrix saturation σ (saturation at which liquid flow in fractures initiated) used to trigger fracture flow
- $\sigma = 0.95$ chosen based on comparisons with dual-permeability model (*Ho*, 1995)

Repository-Scale Abstractions
(velocity / flux for TSw)

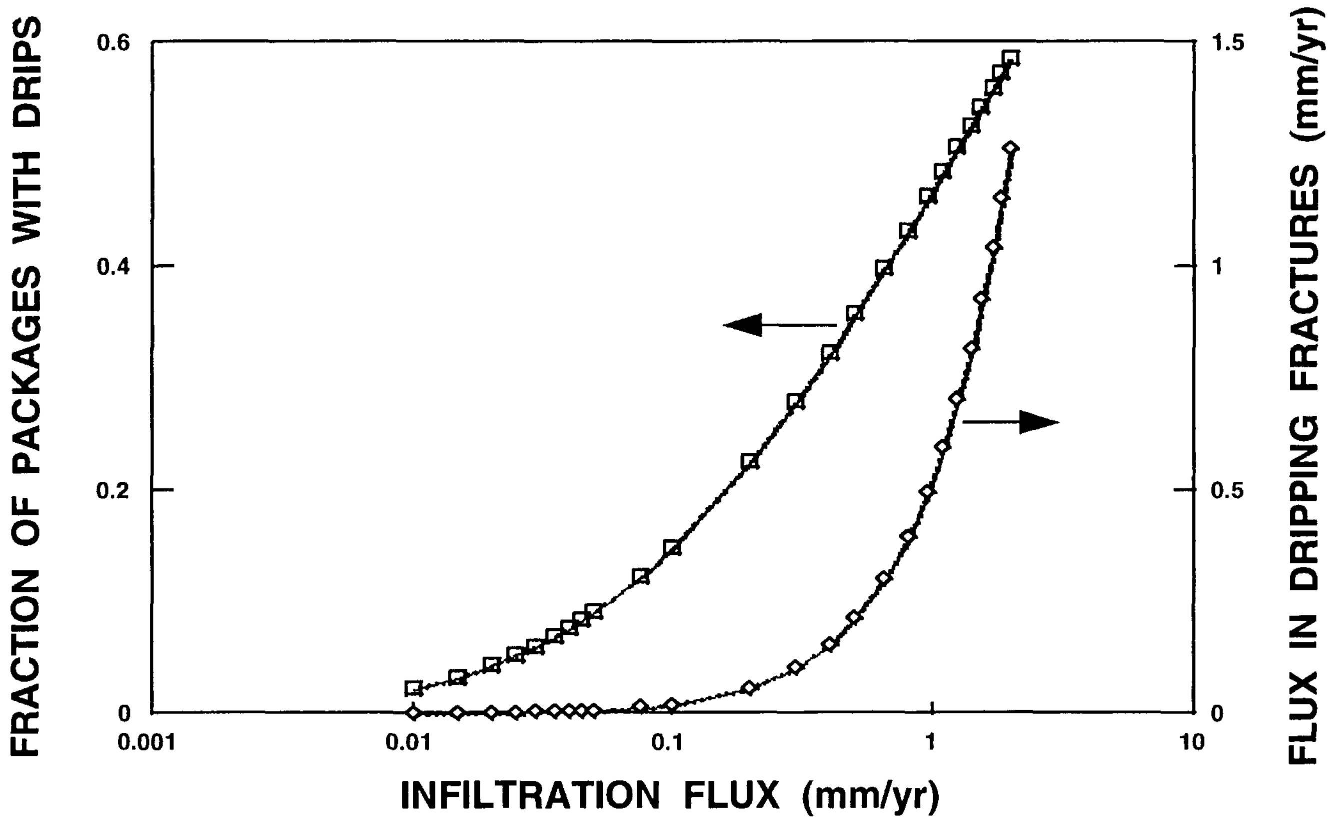




Drift-Scale Hydrology

- Fracture flow at WP / EBS scale influenced by spatial variability in percolation flux and saturated hydraulic conductivity
- Infiltration flux distributed into percolation flux for each WP "catchment area"; diverted into dripping fractures, if percolation flux greater than K_{sat}
- Functional relationships developed for number of (and flux through) dripping fractures for "low" and "high" q_{inf} ranges

Drift-Scale Abstractions



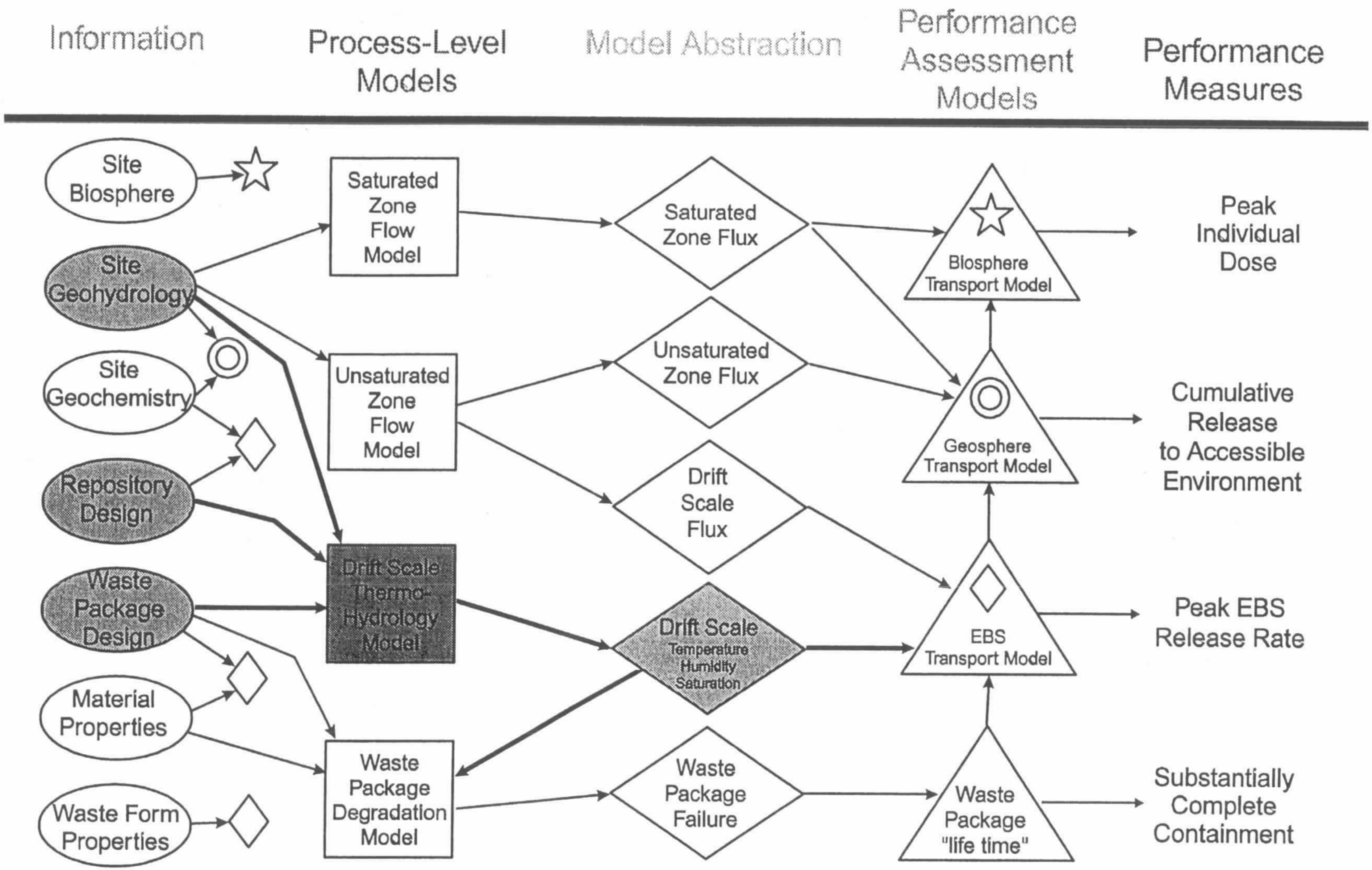
Ambient Flow Models
Summary Remarks

- Repository-scale abstractions developed from *TOUGH2* simulations for input into geosphere transport calculations

- Drift-scale abstractions developed from stochastic fracture flow model for input into EBS advective release calculations

- Uncertainties and limitations
  - Treatment of non-equlibrium fracture flow
  - Incorporation of thermal effects
  - Estimation of percolation flux at depth

TSPA-1995 Information Flow Diagram
Thermo-hydrologic Modeling



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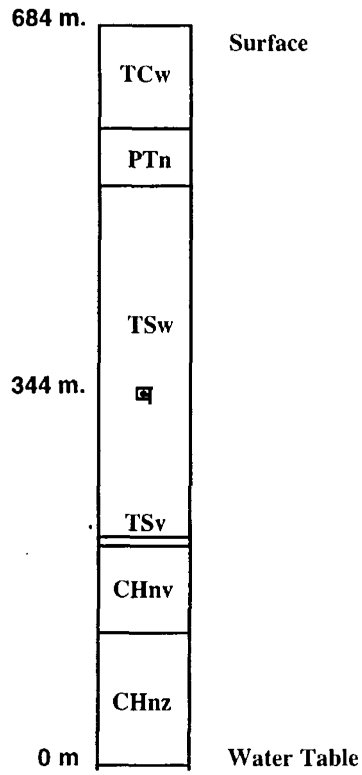
Motivation and Scope

- Near-field thermo-hydrologic conditions affect WP / EBS performance
  - Initiation / rate of corrosion of waste packages depends on T and RH
  - Diffusive release of radionuclides through WP / EBS depends on S_{liq}

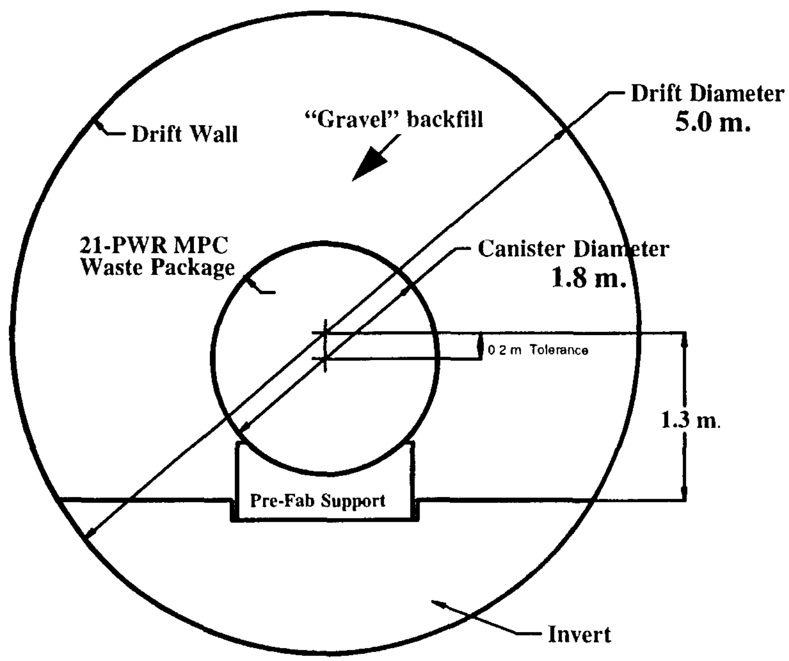
- Develop 2-D drift-scale thermo-hydrologic model to predict T, S_{liq} (and RH) for various
  - Infiltration fluxes (0.05, 0.3 mm/yr)
  - Thermal loadings (25, 83 MTU/ac)
  - Backfill options (with, without)

Model Geometry

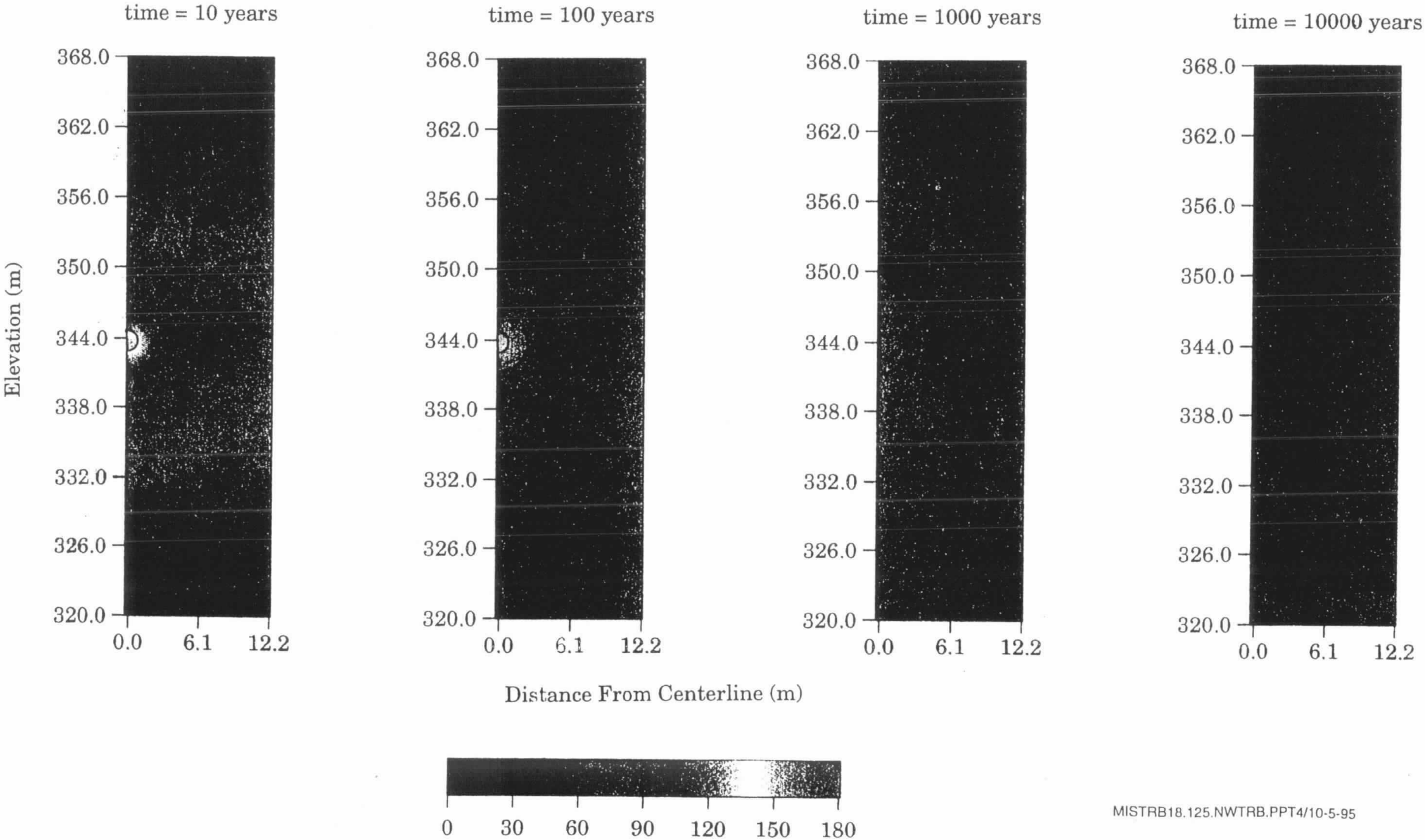
2-D cross-section



Expanded view of WP / Drift



83 MTU/acre - Temperature
(q_{inf} = 0.3 mm/yr, backfill)



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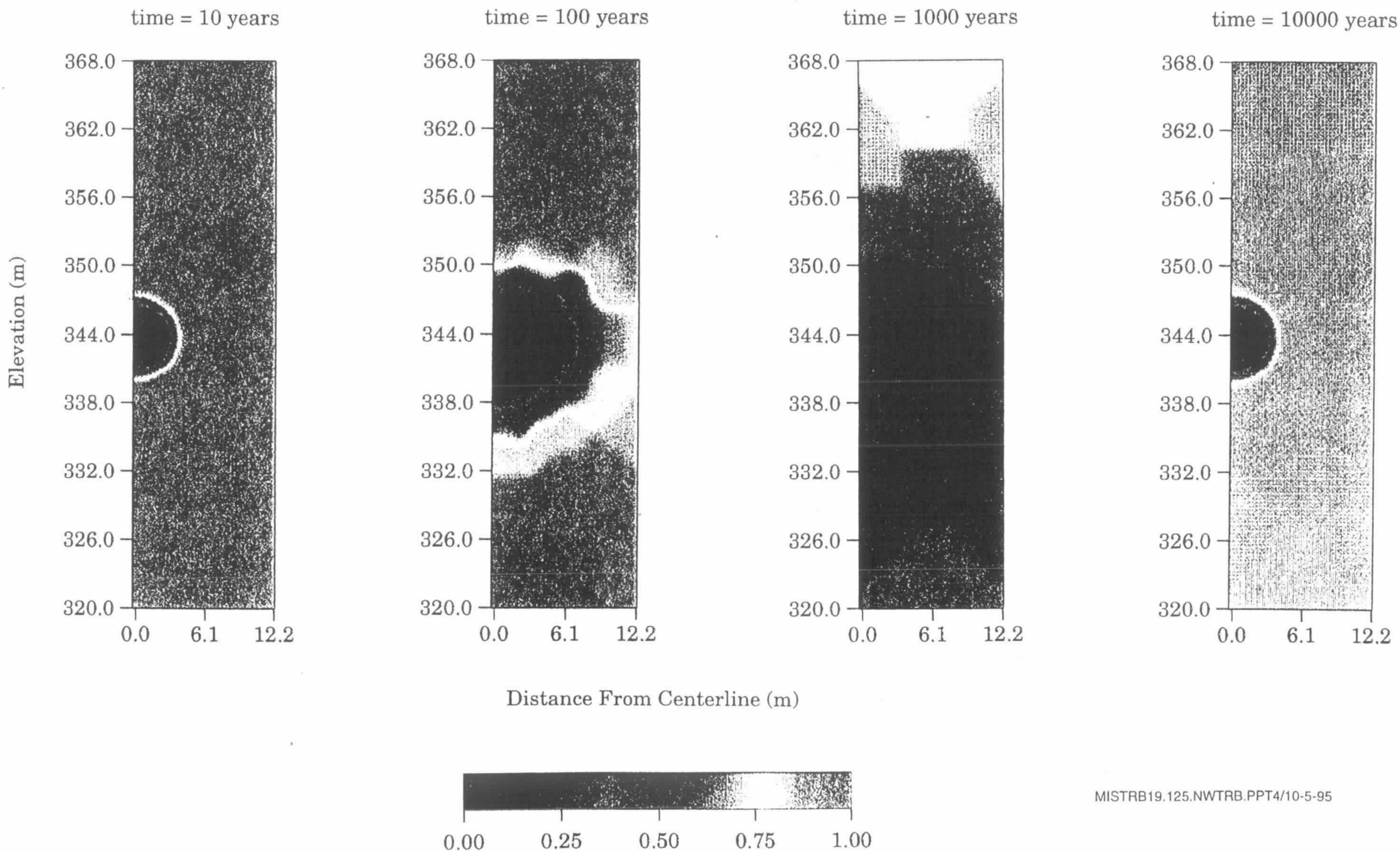
83 MTU/ac - Liquid Saturation
(q_{inf} = 0.3 mm/yr, backfill)



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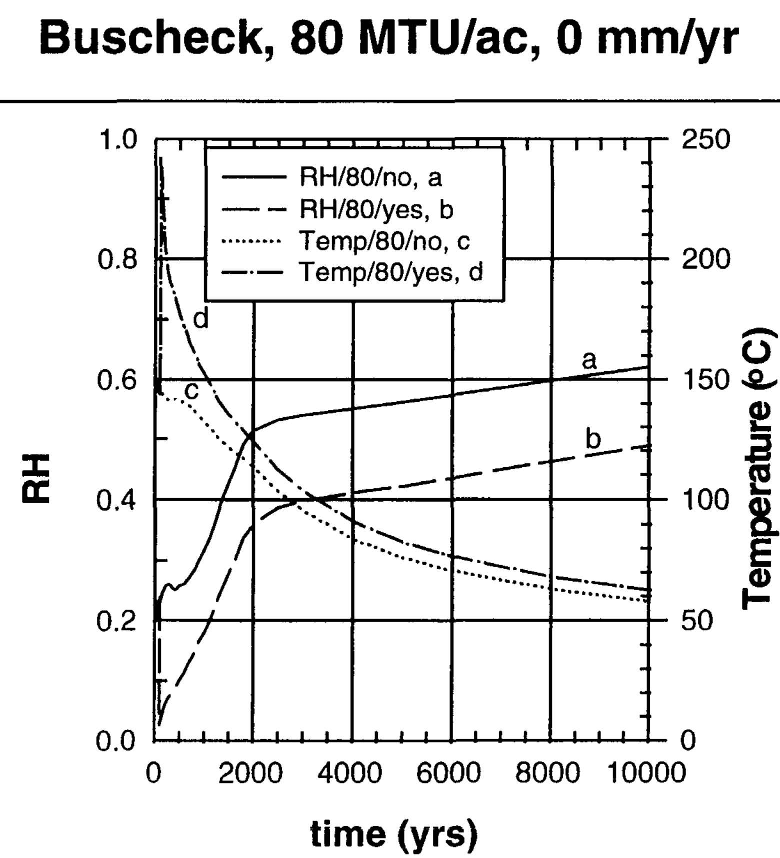
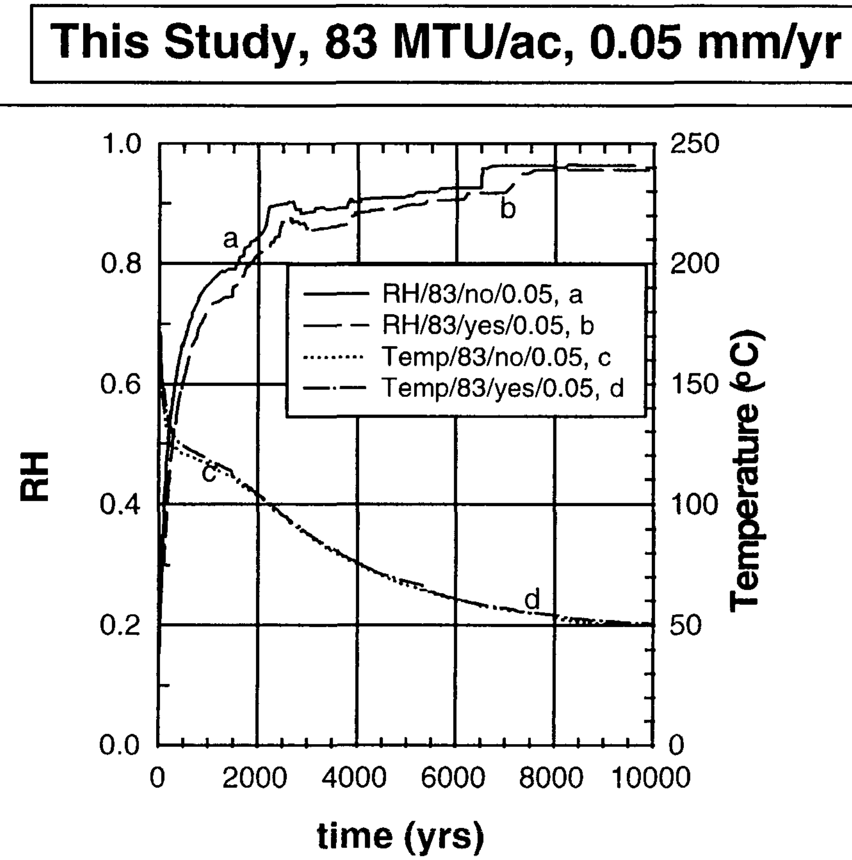
Alternative Thermo-hydrologic Models

	THIS STUDY	BUSCHECK
GEOMETRY	- Circular Drift (5 m) - Circular WP (1.8 m)	- Square Drift (6 m) - Square WP (1.6 m)
BACKFILL CAPILLARY CHARACTERISTICS	Similar to typical 'gravel'	Similar to PTn
BACKFILL THERMAL CONDUCTIVITY	0.6 W/m-°K	0.3 W/m-°K
BACKFILL ABSOLUTE PERMEABILITY	50 E-3 darcy	40 darcy
RELATIVE HUMIDITY CALCULATIONS	P_V (waste pkg) = P_V (dry-out front)	Directly from backfill water vapor mass fraction

RH and T Predictions
Alternative Thermo-hydrologic Models





Thermo-hydrologic Models
Summary Remarks

- Abstractions from drift-scale thermo-hydrology model (T - RH - S_{liq}) developed

- Alternative conceptual / numerical models yield different T - RH predictions

- Limitations and/or uncertainties
  - Backfill thermo-hydrologic properties
  - RH calculation methodology
  - ECM assumptions re. fracture flow