NUCLEAR WASTE TECHNICAL REVIEW BOARD
HYDROLOGY AND GEOCHEMISTRY PANEL MEETING

SUBJECT: **TECHNICAL IMPLEMENTATION OF GROUNDWATER TRAVEL TIME ANALYSES**

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Outline

- Implementation of GWTT calculational approach
  - UZ models
  - SZ models
- Example
  - 1994 GWTT analyses
    - implement first stage in GWTT strategy
    - calculate UZ "fast-path" flow
      - parameter and boundary-condition sensitivity studies
      - disturbed zone not explicitly modeled
    - analyses performed using best available data

Overview of Analysis Method

- Use water "particles" to measure GWTT
  - transport modeled by advection and molecular diffusion
    - particle retardation is not included in model
  - mechanical dispersion modeled by:
    - variations in hydraulic and physical properties in UZ
    - explicit parameter in SZ
- Advection is simulated using groundwater-flow fields in UZ and SZ
  - models for UZ flow are sensitive to saturation for fast-path (fracture) flow
    - local saturation is generated by heterogeneities

Analysis Method

(Continued)

- Heterogeneities arise because of
  - variations in unit thicknesses
  - variations in hydraulic and physical properties
  - discontinuities (stratigraphic contacts, fractures, and faults)
- Realizations of values are generated stochastically

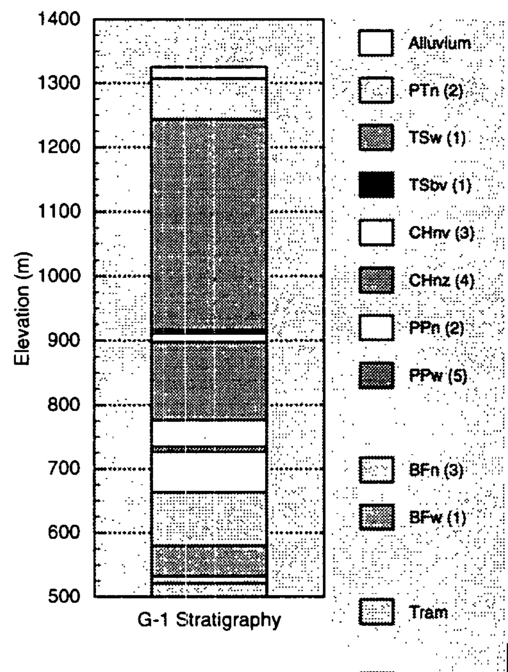
Stochastic Parameter Simulations

- 3-D model of rock types is generated stochastically
  - simulations honor data while estimating unknown values from nearby data
  - deterministic features and trends are included
    - stratigraphic units may vary in thickness and pinch out
  - rock model described by ~7 million geostatistical nodes
- Rock types are chosen to represent unique hydrologic properties

Rock-Type Simulation

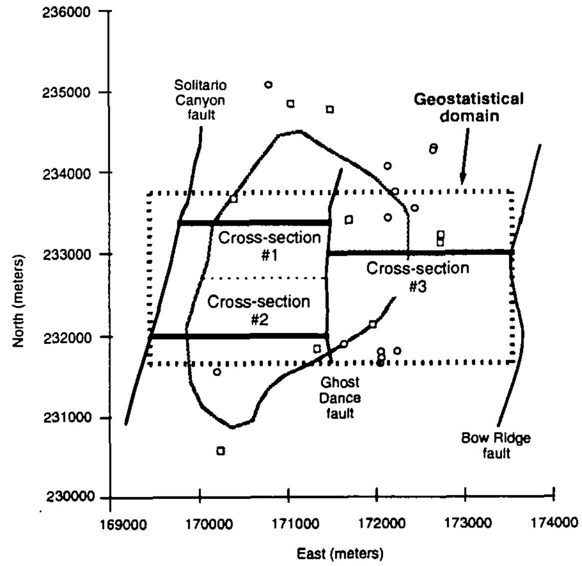
(Hole G-1)

- 3 major indicators; 2 sub-indicators
  - general welded (type 1)
    - PPw (type 5)
  - nonwelded
    - PTn & PPn (type 2)
    - CHnv & BFn (type 3)
  - zeolitic (type 4)
- 10 stratigraphic units
  - (TCw not present in hole G-1)
- Upper alluvium and Tram not modeled



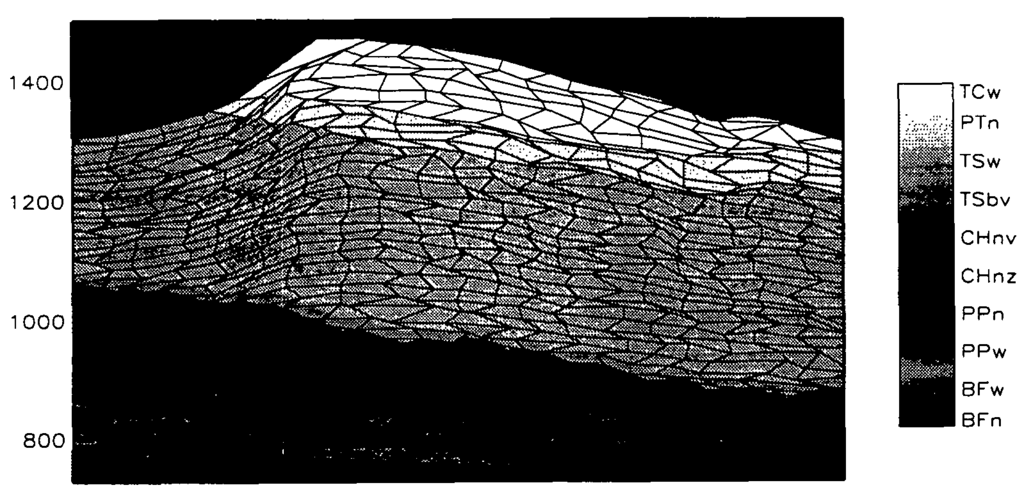
Porosity and Hydrologic-Properties Simulations in UZ

- GWTT simulations use 2-D transects in 3-D rock model
- Transects bounded by faults
- Transects represent approximately equal areas of potential repository



Hydrologic Units in a Transect

(Transect 1, Simulation C)

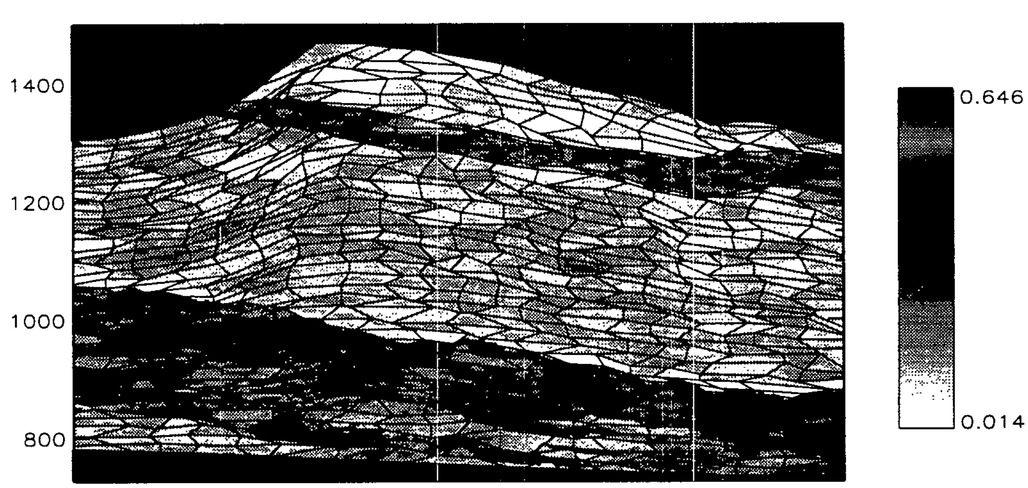


Porosity Simulations

- Stochastically simulated on transects within rock model
  - site porosity data represented by a PDF, giving a range of values and a mean
    - PDFs are modified to account for differences in scale between measurements and simulations
  - porosity values randomly chosen from the PDF for each geostatistical cell
    - values are spatially correlated to reflect stratigraphic structure
  - cells for flow calculation (which include many geostatistical cells) are adjusted to minimize porosity variability

Distribution of Porosities

(Transect 1, Simulation C)

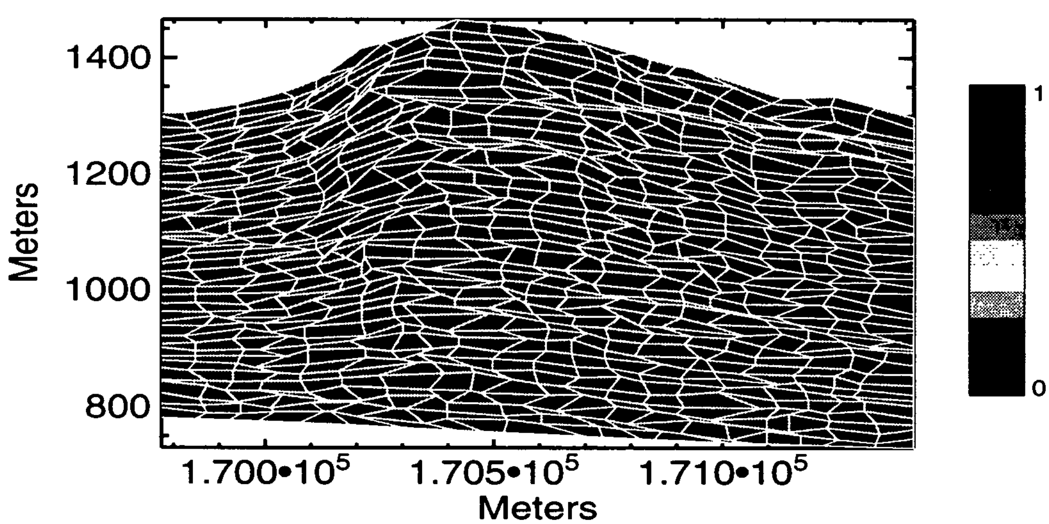


Alternative Numerical Models for UZ Flow

- Models intended to bound fast-path flow processes
  - models represent varying degrees of saturation required for fracture flow
  - Continuum models
    - composite porosity (used in 1994 analyses)
    - dual permeability
  - Discrete-fracture models

Average Saturation Distribution in UZ

(Composite-Porosity Model)



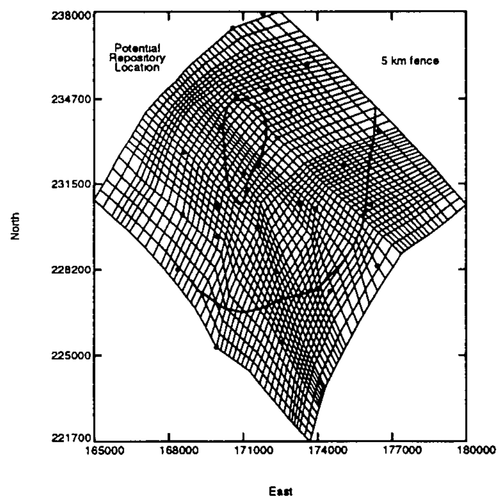
Saturated-Zone Conceptual Model

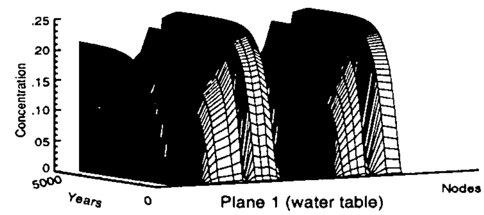
- Based on USGS interpretations of site characteristics (using regional model)
  - large hydraulic gradient
    - currently modeled by diversionary and nondiversionary features
  - vertical zonation and inhomogeneity
    - modeled by limited depth into saturated zone
- Model incorporates faults as hydrologic features
  - fault hydrologic properties were used parametrically
  - Drill Hole Wash and Solitario Canyon faults included

Saturated-Zone Flow Modeling

- STAFF-3D (used in TSPA-93)
  - modeled travel times for unretarded tracer in 8 km x 8 km x 200 m volume
  - transit times were ~1000 years to reach 5-km boundary from potential repository
    - travel times were not uniform along accessible-environment boundary
- FEHM (future use)
  - will permit inclusion of additional data on temperature anomalies at water table in Solitario Canyon

Groundwater Flow Paths in the SZ





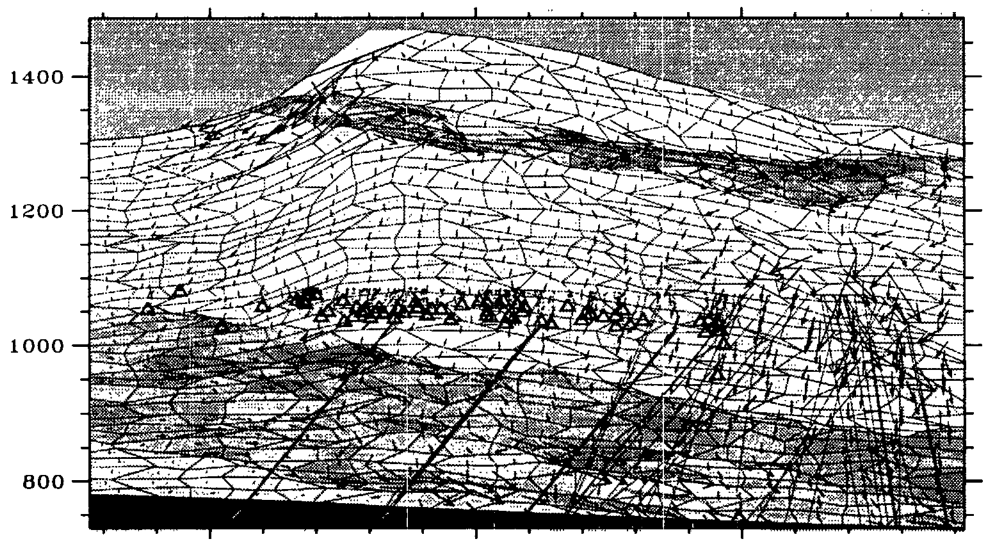
(Non-diversionary model)

ParticleTracker

- Uses flow field produced by flow code
  - in UZ, currently DUAL (steady-state, composite porosity)
  - in SZ, either STAFF-3D or FEHM
  - can use other codes to generate flow fields
  - can include transient effects
- Calculates advective transport of water particles
  - due to matrix flow (low saturations)
  - due to fracture flow (high saturation)
- Uses molecular diffusion to modify advective motion
- Particles are launched from disturbed zone

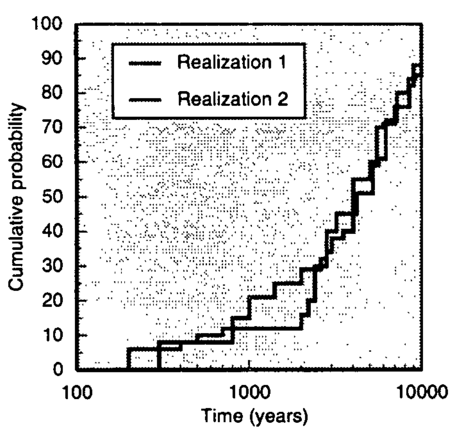
Example of Particle-Tracker Output

(Transect 1, simulation C, 110,000 years)



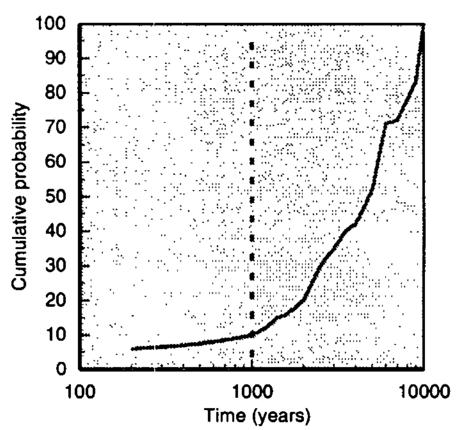
Analyzing Significance of GWTT Results

(Illustration only)



CDFs from individual simulations

(UZ, SZ, various transects, parameter values, etc)



Combined CDF for all simulations

Other Factors in GWTT Calculations

- Disturbed zone
  - can be explicitly included in 2-D transect
    - may be represented by altered hydrologic properties
  - water particles can be distributed in various ways at repository
    - randomly at edge of disturbed zone
    - weighted by amount of waste represented
    - randomly in volume of disturbed zone

Other Factors in GWTT Calculations

(Continued)

- Sensitivity studies
  - homogeneous hydrologic properties in units
    - to see effects on local saturation
  - uniform unit thicknesses
    - to see effects of choice of lateral boundary conditions
  - scaling of parameter PDFs
  - grid-resolution studies
  - studies will contribute to understanding uncertainties

Linkages to Site-Characterization

- USGS
  - near-surface measurements (N-holes)
    - water content
    - transient/non-equilibrium fracture flow (for dual-permeability models)
  - perched-water characterization (UZ-holes)
    - residence time
  - geochemical and isotope data
- USGS, LANL
  - retardation data (for evaluating disturbed zone)

Linkages to Other Modeling Efforts

- LBL/USGS
  - boundary conditions for transects
  - future transects located where LBL/USGS site-scale model suggests
    - located in areas where fast paths are likely
    - located in areas where 2-D modeling is appropriate
- SNL
  - coupled thermal–mechanical–hydrologic modeling to define disturbed zone

Summary

- Current implementation supports general approach to GWTT evaluation
  - includes flow paths in UZ and SZ
  - incorporates alternative conceptual and numerical flow models
  - incorporates disturbed zone consistent with most general interpretation
  - provides tools for evaluating uncertainty in and consequences of travel times < 1000 years
- GWTT models are important components of overall UZ and SZ groundwater flow analyses

Summary

(Continued)

- FY 1994 work demonstrates progress toward an analysis program
  - UZ modeling domain developed
    - heterogeneous properties and hydrologic units
  - one flow model applied on the domain
  - groundwater particle tracker has been developed
  - future data needs and linkages to other programs are identified