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

NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: DOE PLANS FOR REDUCING HYDROLOGIC UNCERTAINTY

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EXECUTIVE SUMMARY

In the second quarter of Fiscal Year 1997 we will have supplemented the FY97 program with an additional $13.1 M

The work includes 39 individual tasks that cover all four major product areas with the majority contributing to the Design and TSPA products

This work is intended to provide more confidence in the four major products of the VA and ultimately the License Application

Because a great deal of the scientific uncertainty is associated with the hydrologic program, this presentation and discussion will focus on a set of key hydrologic uncertainties

OUTLINE

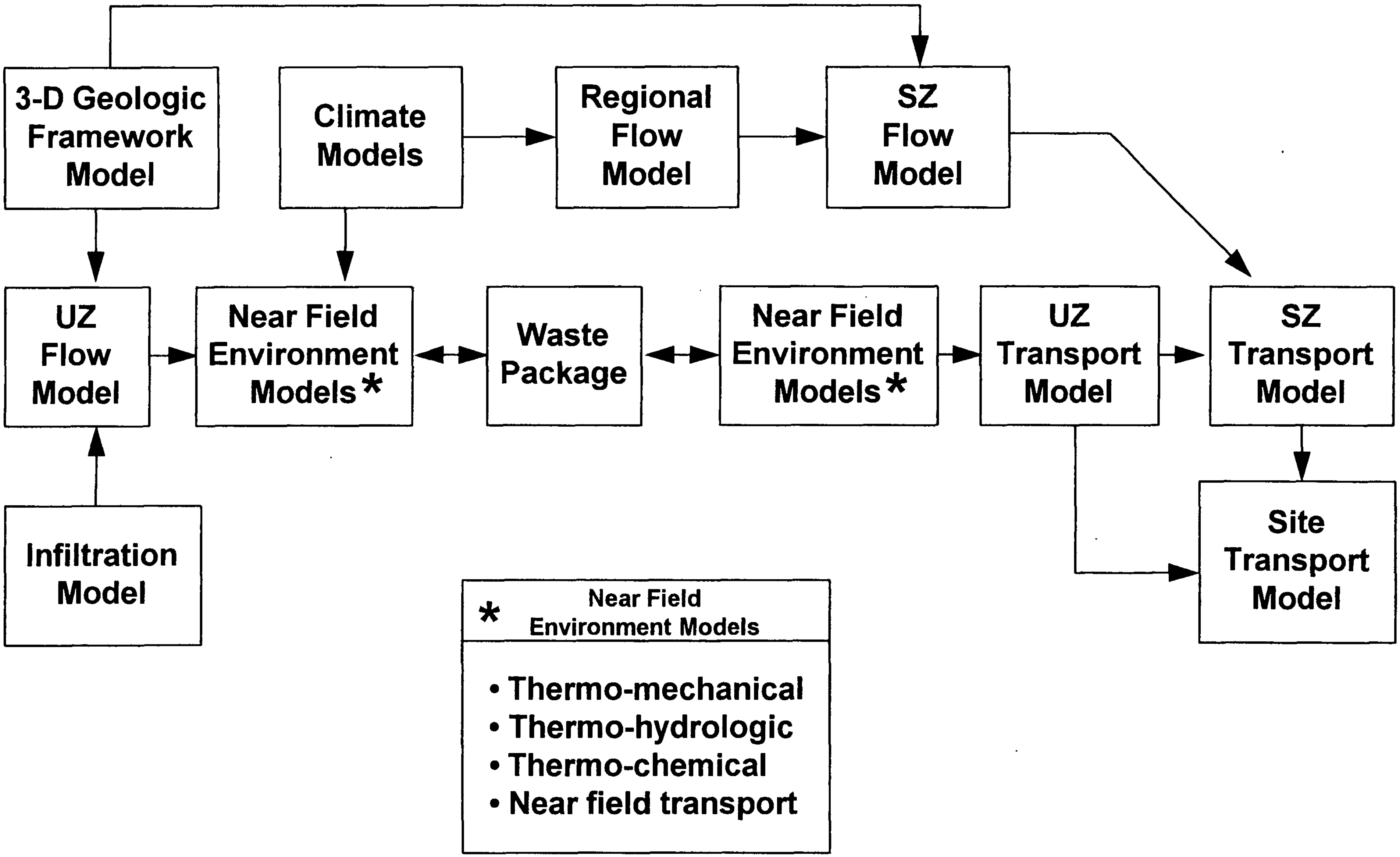
- Review of the Waste Containment and Isolation Strategy
- What Do We Know?: A Review of the Progress Report
- Process Modeling Ties/Linkages
- Discussion of Selected Key Uncertainties in Hydrology
- Testing Strategies being Implemented to Address each of the Selected Key Uncertainties
- Conclusions

Waste Containment and Isolation Strategy

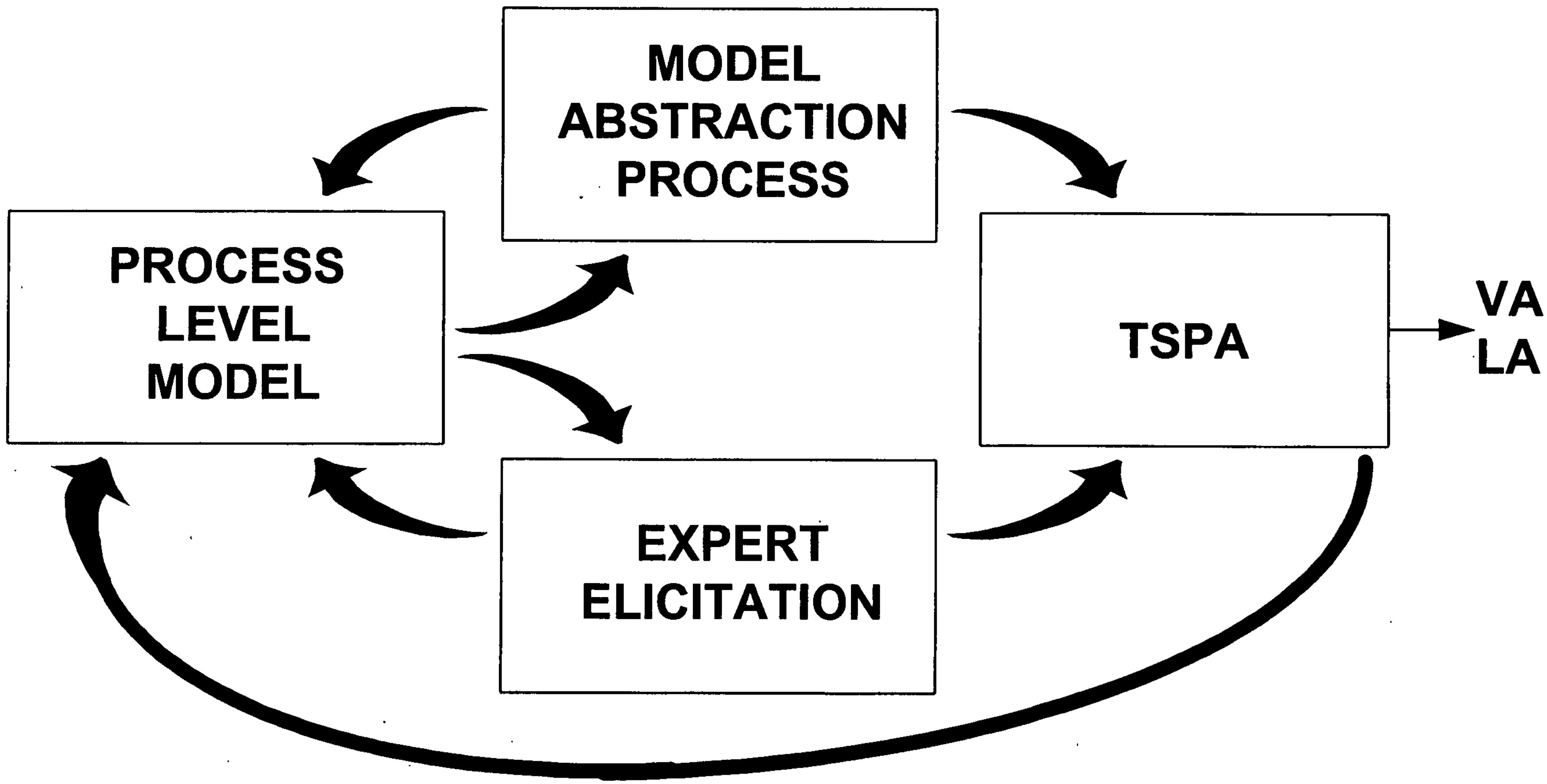
- Key Attributes of Waste Containment and Isolation Strategy
  - ***RATE OF SEEPAGE INTO REPOSITORY***
  - Integrity of Waste Packages
  - Rate of Release of Radionuclides from Waste in Breached Canisters
  - ***Radionuclide Transport through*** Engineered and ***Natural Barriers***, and
  - ***DILUTION IN THE GROUNDWATER BELOW THE REPOSITORY***

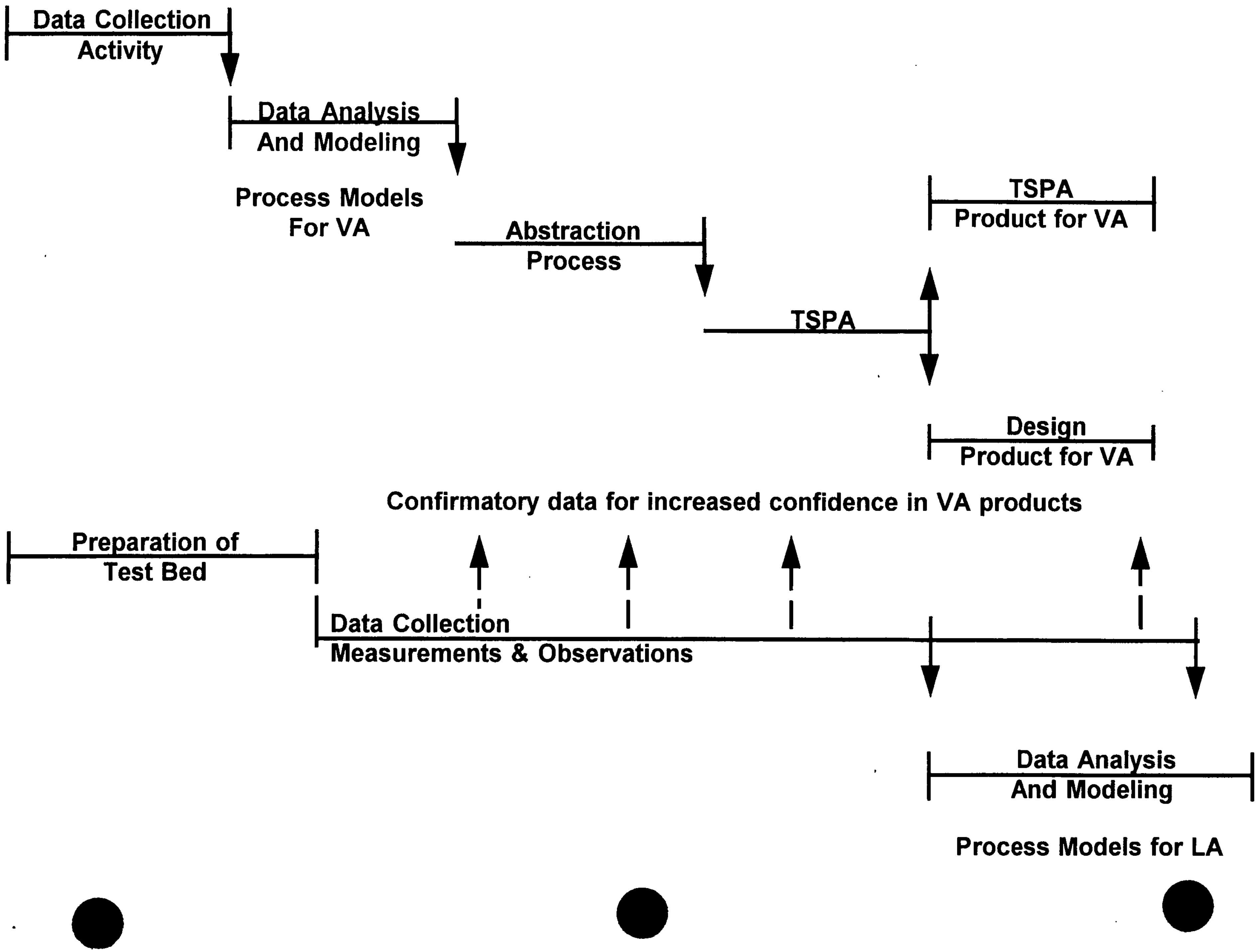
WHAT DO WE KNOW
"The Progress Report"

- C-Well Complex
- Underground Testing
- Unsaturated Zone Flow - Last October
- Unsaturated and Saturated Zone Transport


3-D Geologic Framework Model
Climate Models
Regional Flow Model
SZ Flow Model
UZ Flow Model
Near Field Environment Models *
Waste Package
Near Field Environment Models *
UZ Transport Model
SZ Transport Model
Infiltration Model
Site Transport Model
* Near Field Environment Models
• Thermo-mechanical
• Thermo-hydrologic
• Thermo-chemical
• Near field transport

PROCESS MODEL INTERACTIONS WITH PERFORMANCE ASSESSMENT





Data Collection
Activity
Data Analysis
And Modeling
Process Models
For VA
Abstraction
Process
TSPA
TSPA
Product for VA
Design
Product for VA
Confirmatory data for increased confidence in VA products
Preparation of
Test Bed
Data Collection
Measurements & Observations
Data Analysis
And Modeling
Process Models for LA

SELECTED KEY UNCERTAINTIES

- Percolation Flux
- Fast Paths
- Dilution, Transport Parameters, and Mixing Depth
- Saturated Zone Hydrochemistry

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- ***Percolation Flux***
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Percolation Flux

Definition: Percolation flux is that portion of the infiltrating water that passes through the first few meters of bedrock (zone of evapo-transpiration) and penetrates to deeper levels

Importance: The percolation flux effects 4 of 5 attributes of the WCIS

Present estimates of percolation flux derived from various UZ site characterization activities range from <u>1 to 10 mm/yr</u>

Previous estimates (TSPA-95) assumed mean percolation fluxes ranging from <u>0.03 to 1.25</u> mm/yr

Percolation Flux - continued

- Uncertainties:
  - Distribution of flux at the repository horizon in time and space
  - Role of PTn in buffering infiltration and diverting flux
  - Degree of fracture-matrix interaction
  - Spatial variability within hydrogeologic units
  - Role of faults and fast pathways
- Because percolation flux cannot be measured directly, DOE is pursuing a multi-faceted approach to reducing uncertainty

UZ Percolation Flux
- Ongoing Investigations

- Various components of the present UZ site characterization program are contributing to determination of percolation flux
    - Infiltration Measurements and Modeling
    - Saturation and Moisture Potential Data
    - Pneumatic Data
    - Environmental Isotope Studies
    - Fracture Coatings
    - Temperature Data
    - Perched Water Data

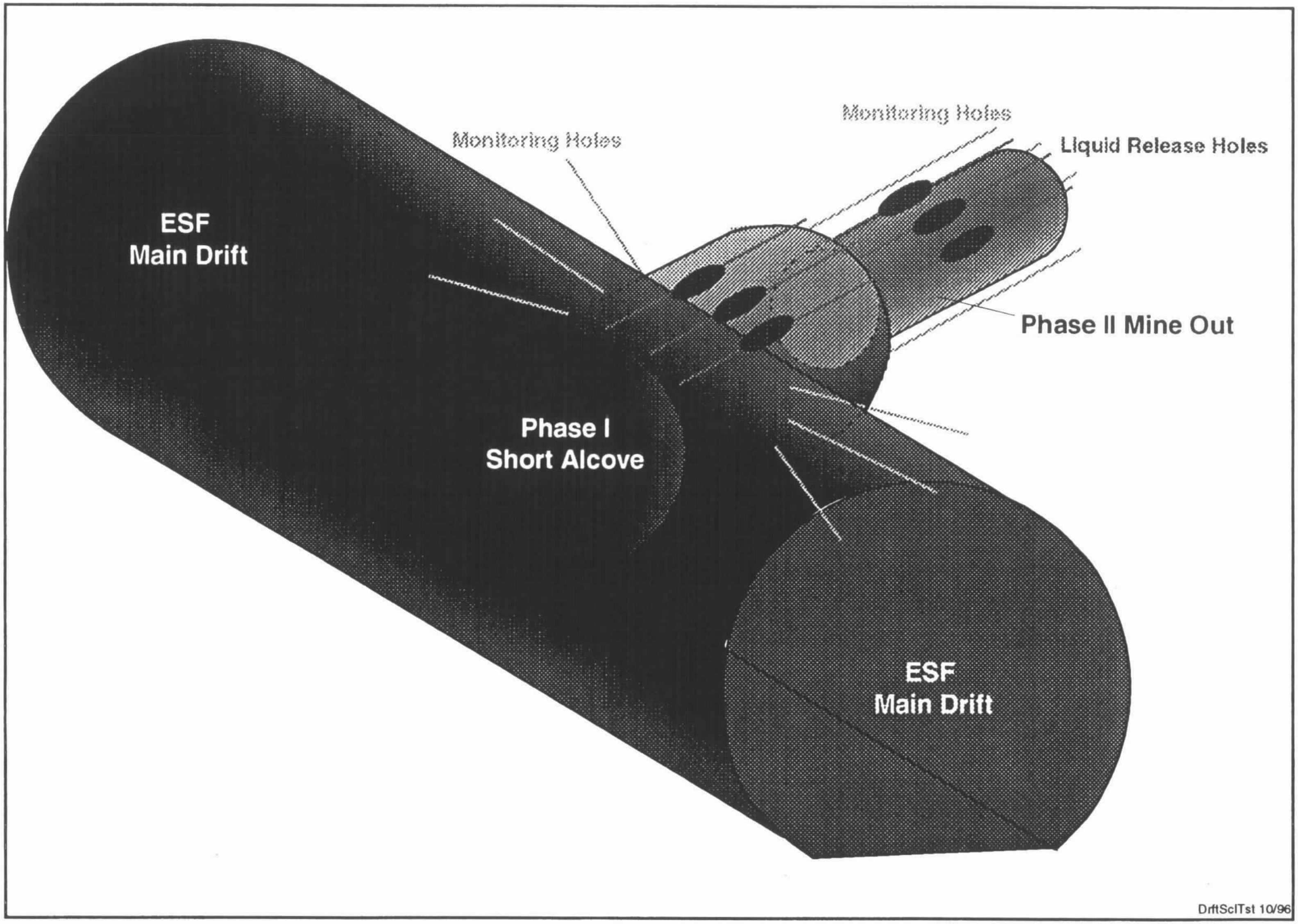
Enhanced Testing Program for Further Reducing Uncertainty in Percolation Flux

- ESF Drift Scale Percolation Flux Test
  - Network of horizontal boreholes to collect minimally disturbed core over large areas
  - Instrument, monitor, and test boreholes
  - Flux quantification of data with inverse modeling
- Percolation Testing - South Ramp
  - Excavate small rooms; drill and instrument boreholes
  - Install bulkhead; monitor effects

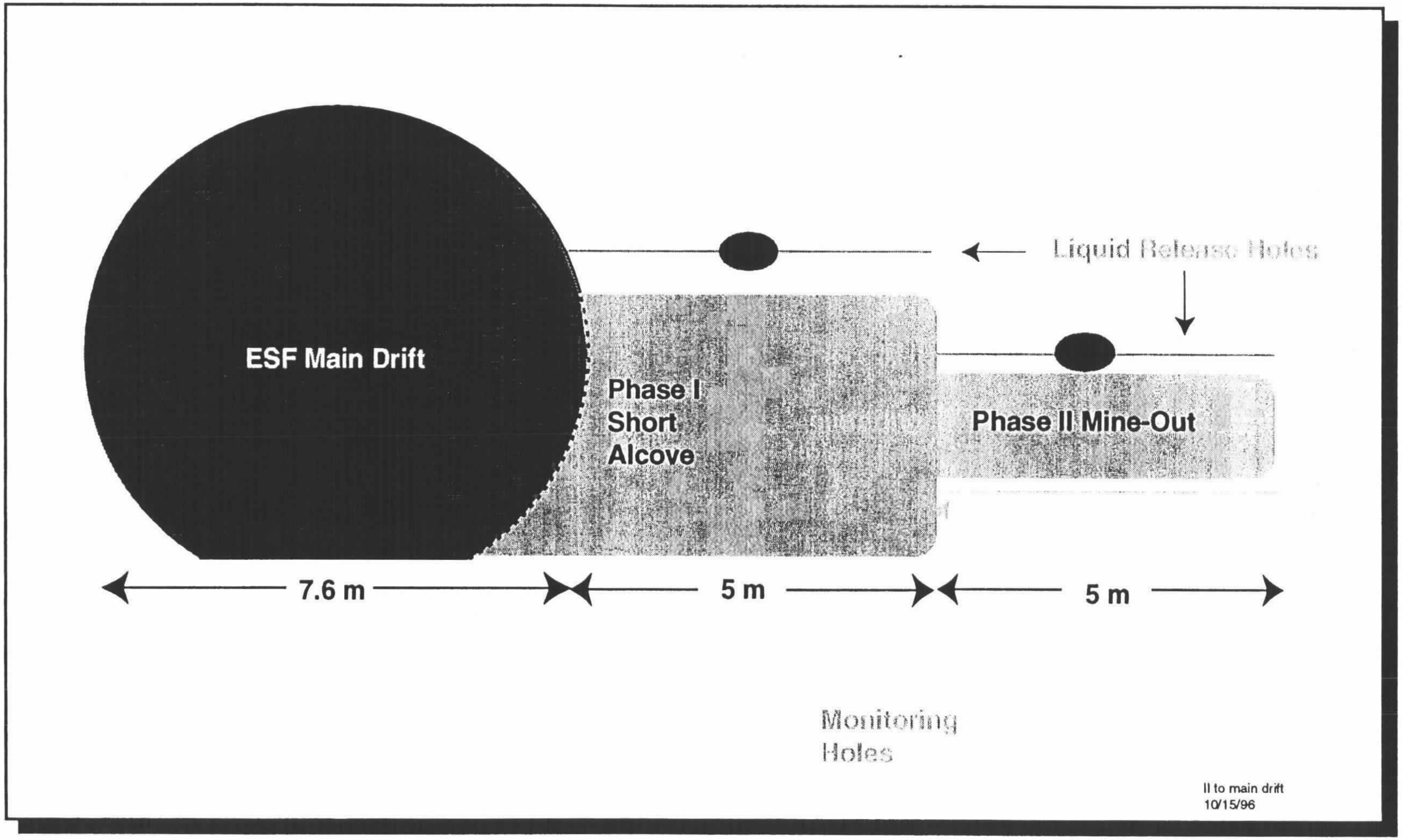
Reducing Uncertainty in Percolation Flux - continued

- Lateral Diversion in the PTn
  - Instrument vertical boreholes drilled into the PTn from North Ramp alcoves
  - Measure in-situ conditions and water potential near faults
- Environmental Isotope Studies
  - Cl-36, Tc-99, H-3 analysis will provide data on flux, fast paths, and age of percolating waters
  - C-14 ages from TSw2 pore water
- Role of Faults (Ghost Dance Fault Alcoves)
  - Geothermal boreholes provide data on heat flow near faults
  - Pneumatic testing
  - Gas chemistry sampling

Drift Scale Flow Test



Parallel to the Main Drift



Perpendicular to the Main Drift

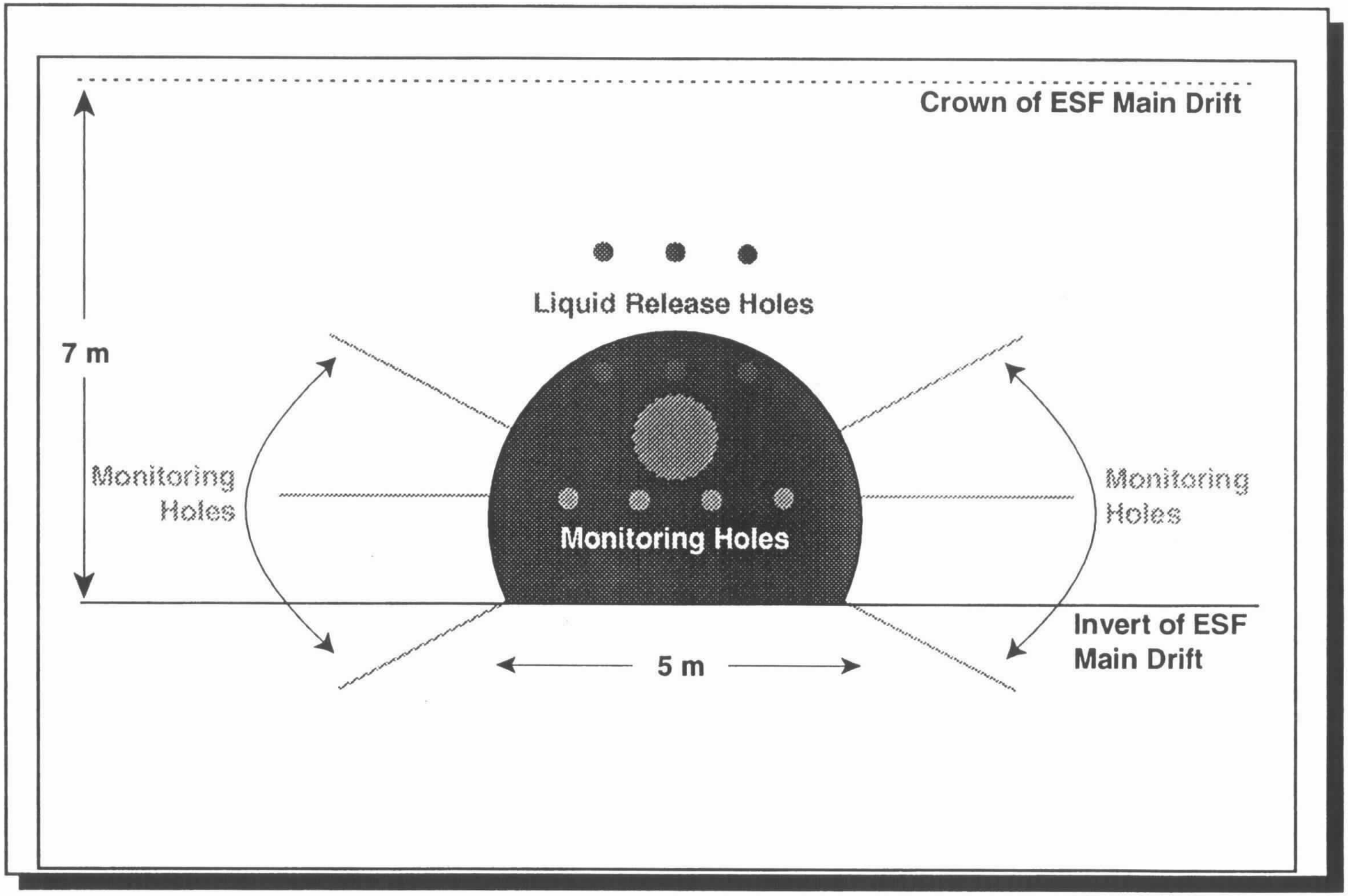
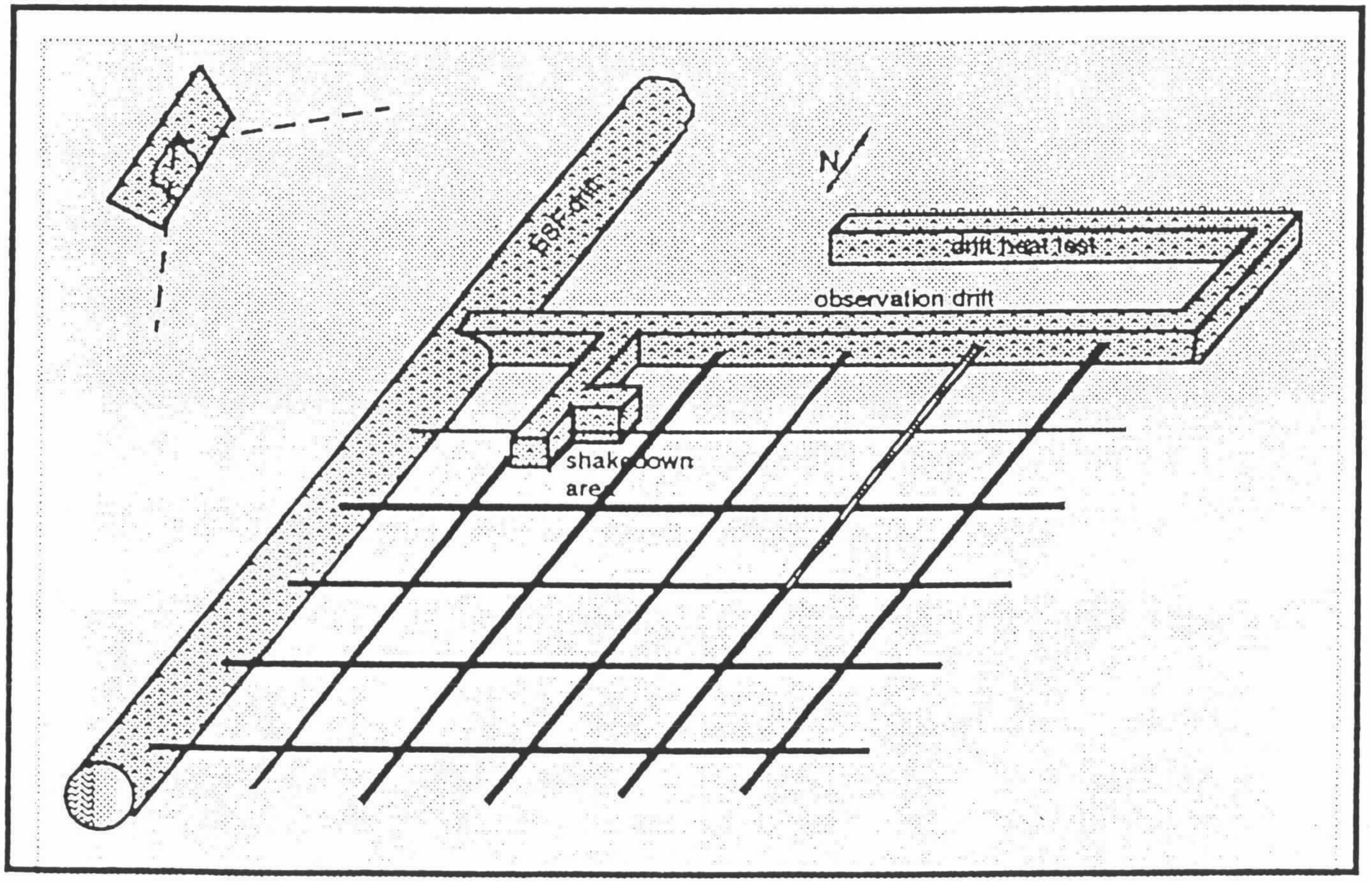


Figure 2. A general flow diagram of the major components of the proposed percolation flux study.



SELECTED KEY UNCERTAINTIES

- Percolation Flux
- ***Fast Paths***
- Dilution, Transport Parameters, and Mixing Depth
- Saturated Zone Hydrochemistry

Fast Pathways

- Definition: Fast pathways are places where liquid water can move rapidly in fractures or faults (under gravity in the UZ). Matrix flow is very slow, but liquid flow can be very fast in fractures, especially in the well drained welded tuffs.
- Importance:
  - Flow down mapped features may bypass the drifts, avoiding the repository
  - Fast transport of radionuclides will only occur where water seeps into the drifts and there are fast pathways from the repository to the water table
  - Fast pathways beneath the repository may allow bypassing of the zeolitic non-welded tuffs
  - Fast pathways may not be associated only with mapped faults

Fast Pathways -
Present Understanding

- Pneumatic testing of boreholes indicate that the Paintbrush Tuff non-welded (PTn) unit above the repository horizon acts as a partial barrier to gas, and possibly liquid flow
- Bomb pulse isotopes occur in many mapped fracture zones in the ESF
- ESF mineral coatings sampling indicates that liquid water has flowed in fractures without completely filling the fractures
- The apparent age dates of perched water found below the proposed repository suggests fast paths, such as faults, and possible lateral flow near the top of the Calico Hills formation
- The apparent age dates of saturated zone water samples collected are older with recharge originating in topographically higher areas to the north of the proposed repository

Fast Pathways - Present Understanding

- Hydrochemical evidence indicates that downward percolation in the unsaturated zone is in fractures and matrix
- Infiltration studies indicate that a small increase in precipitation could lead to a large increase in infiltration. However we still do not have a firm grasp on how surface infiltration is related to deep percolation, especially percolation through the proposed repository block

Fast Pathways - Uncertainties

- Location of fast pathways:
  - from the surface to the repository
  - from the repository to the water table
- Distribution in relation to the geologic framework (only associated with faults or distributed within potential repository block?)
- Nature of flow in and near fast paths
  - connectivity across stratigraphic units
  - nature of fracture-matrix interaction
  - threshold flux to induce flow in fast paths

Fast Pathways -
Ongoing Investigations

- Mineralogy, petrology, and rock chemistry of transport pathways
- Structural features within the site area
- 3-D integrated site model (ISM 2.0)
- Laboratory determination of rock properties
- Occurrence and distribution of perched water
- Borehole and ESF instrumentation and monitoring
- Fluid flow in UZ fractured rock
- Ghost Dance Fault boreholes and alcoves
- UZ site scale flow model

Fast Pathways -
Ongoing Investigations (cont.)

- Environmental Isotopes
  - Chlorine 36 (^{36}Cl / Cl)
  - Technetium 99 (^{99}Tc)
  - Iodide 129 (^{129}I)
  - Tritium (^{3}H)
  - Carbon 14 (^{14}C)
  - Strontium 87 (^{87}Sr)
- Geochronology of fracture fill materials
- Transport through fractured and intact tuff
- Prepare for UZ transport test
- UZ flow and transport model

Fast Pathways -
Enhanced Testing Program

- ESF drift-scale flux and niche studies (Phase 1)
- PTn lateral diversion (Phase 1)
- South ramp hydrology
- Additional analyses of environmental isotopes
  - Chlorine-36 (Cl^{36} / Cl)
  - Tritium (H^3)
  - Carbon-14 (C^{14})
- Drift-scale modeling
- West block borehole

BOREHOLE SD-6 PARTICULARS

- 2500' Dry Drilled with Reverse Circulation
- Located on West Side of the Repository Block Along Yucca Crest
- To be Drilled with LM 300
- Will be used to:
  - Calibrate and validate 3-D Framework Model
  - Provide Additional Data for UZ Model, Design
  - Examine Cost and Schedule Efficiency
- Only sidewall core well be taken
- Extensive Geophysical Logging to be Completed
- Source of LA Data for UZ and SZ Variables

SELECTED KEY UNCERTAINTIES

- Percolation Flux
- Fast Paths
- ***Dilution, Transport Parameters, and Mixing Depth***
- Saturated Zone Hydrochemistry

Dilution, Transport Parameters, and Mixing Depth in the SZ - Definitions

Dilution - decrease in radionuclide concentration resulting from combined effects of matrix diffusion, sorption, dispersion, and mixing with the SZ flow

Dispersion - tendency for solute to spread out due to advective hydraulics of flow system (decreases concentration)

Mixing Depth - Effective depth of radionuclide interaction with flow system (impacts extent of dilution)

Matrix Diffusion - Process whereby solute moves from regions of high concentration to lower concentration (fractures to matrix)

Sorption - Adherence of radionuclides to rock and mineral surfaces

Dilution,Transport Parameters, and Mixing Depth - continued

- Importance: Mixing depth and the transport parameters are critical in the determination of how much dilution will occur when radionuclide-bearing waters encounter the SZ (WCIS attribute)
- Uncertainties:
  - Degree of hydraulic connection between individual hydrogeologic units
  - Darcy velocities in the SZ
  - Role of heterogeneities (faults and contacts) in controling flow
  - Sorption and matrix diffusion
- TSPA estimates are conjectural, and little hard data exist to refine estimates

SZ Hydrology - Ongoing Investigations

Various components of the present SZ site characterization program are contributing to the understanding of SZ hydrology

- Water Table Monitoring
- Regional SZ Flow Model
- Site Scale SZ Flow and Transport Model
- Sub-Site Scale SZ Flow Model
- C-Well Hydraulic and Tracer Testing

Enhanced Testing Program for Reducing Uncertainty in the SZ

- C-Well Tracer Tests
  - Perform hydrologic and tracer testing in the Prow Pass (uppermost SZ and zone of low flow)
- Aquifer Testing of Water Table (WT) Boreholes
  - Obtain transmissivity values for uppermost SZ from various locations

SELECTED KEY UNCERTAINTIES

- Percolation Flux
- Fast Paths
- Dilution, Transport Parameters, and Mixing Depth
- ***Saturated Zone Hydrochemistry***

SATURATED ZONE HYDROCHEMISTRY

Importance: Hydrochemical data are needed to define the chemical composition and conditions that control concentrations of radionuclides in the groundwater. The data include:

- Water-chemical composition and conditions, particularly redox potential and pH.

SATURATED ZONE HYDROCHEMISTRY (cont.)

– Water-chemical composition is bounded by the compositions of the groundwaters from wells J-13 (volcanic aquifer) and UE-25 p#1(carbonate aquifer) which cover the observed variability, and is used in laboratory measurements of transport parameters.

SATURATED ZONE HYDROCHEMISTRY (cont.)

- Redox potential is assumed to be oxidizing for all radionuclides. However, groundwater may be reducing for critical radionuclides Np and Tc.
- The model pH is controlled by the hydrolysis reactions of silica and alkali feldspars, and partial pressure of CO_2.

SATURATED ZONE HYDROCHEMISTRY- KEY UNCERTAINTIES

Is the Np solubility lower by several orders of magnitude than the currently used value for transport calculations?

- The Np solubility value currently used based on Np(V) carbonate, could be reduced by several orders of magnitude if the Np(IV) oxide is found stable in YMP waters.

SATURATED ZONE HYDROCHEMISTRY- KEY UNCERTAINTIES (cont.)

Is the SZ groundwater redox potential low enough to induce Np and Tc precipitation?

- If yes, drastically lower concentrations than are currently used based on an assumption of oxidizing condition, would be available for transport to the accessible environment.

SATURATED ZONE HYDROCHEMISTRY- KEY UNCERTAINTIES (Cont.)

On-going experiments for removing uncertainty on Np-solubility

- Np(IV/V) stability with known redox-potential values in J-13 water with Fe and Mn couples
- Test of kinetic barrier for formation of NpO from Np(V) in J-13 water, at 300C.
- Extrapolation of kinetic barrier, if it exists, to YMP condition to predict formation of NpO.

SATURATED ZONE HYDROCHEMISTRY-KEY UNCERTAINTIES (cont.)

Enhanced data collection: Measurements to determine redox potential of the YMP groundwater in FY97 - 98

- Direct measurements of redox potential, pH and related water chemistry data in SZ wells.
- Measurements of dissolved redox couples (e.g., S, N_2, Fe) to assist interpretation.

CONCLUSIONS

- We Have Enhanced Our Investigations in Key Areas Through Supplemental FY97 Funding of $13.1 M
- The Hydrologic Issues are Our Main Concern
- We Have Chosen What We Consider to be the Best Data Collection and Exploration Techniques to Utilize the Existing ESF Excavations to the Fullest Extent Possible
- We Are Resuming Surface Drilling Operations to a Limited Extent