

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

**NUCLEAR WASTE TECHNICAL REVIEW BOARD
FULL BOARD MEETING**

**SUBJECT: UPDATE ON WASTE CONTAINMENT
AND ISOLATION STRATEGY**

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**BEATTY, NEVADA
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Outline of Presentation

- **Role of waste containment and isolation strategy in the overall Program Approach (Brocoum)**
- **Implementation of the strategy (Younker)**
- **Linkages to testing activities**
 - **Surface-based testing program: Susan Jones**
 - **Testing in the Exploratory Studies Facility (ESF): Dennis Williams**

Role of Waste Containment and Isolation Strategy in the Program Approach

Role of Waste Containment and Isolation Strategy in Overall Program

- **Although long-term repository performance is important, testing also addresses other data needs:**
 - **Detection of unsuitable site features or conditions**
 - **Compliance with preclosure criteria**
 - **Testing to support design development**
 - **Testing to support other tests**
 - **Scientific confidence**
- **Not all testing is linked directly to the waste containment and isolation strategy**

Top-Level Strategy 1988 Site Characterization Plan

(Section 8.0, pgs. 4-9)

- **The strategy places primary reliance on low flux conditions, slow water movement, and long radionuclide transport times in the unsaturated zone**
- **Low-probability, potentially disruptive processes and events that could have significant impacts on performance of the repository will be identified and characterized**
- **Preclosure repository designs will incorporate appropriate seismic design criteria**

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Schematic of Top Level Strategy

(SCP Section 8.0, pgs. 4-6)

POSTCLOSURE		PRECLOSURE		
E B N G R I N E E R S	<u>COMPONENT</u>	<u>OBJECTIVES</u>	<u>COMPONENT</u>	<u>OBJECTIVES</u>
	UNSATURATED ROCK/AIR GAP	LIMIT THE WATER AVAILABLE TO CONTACT AND CORRODE CONTAINERS AND DISSOLVE WASTE	SURFACE AND UNDERGROUND FACILITY CONSTRUCTION	PROVIDES BENEFICIAL OR NO IMPACT ON POSTCLOSURE SYSTEM PERFORMANCE
	CONTAINER	SERVE AS PRINCIPAL CONTAINMENT BARRIER DURING EARLY RADIATION AND HEAT PEAK	SURFACE AND UNDERGROUND FACILITY OPERATION	SAFE OPERATION UNDER NORMAL AND ACCIDENT CONDITIONS
	WASTE FORM	LIMIT DISSOLUTION AND LEACHING OF RADIONUCLIDES DUE TO LIMITED WATER CONTACT		
N B A R R I E R S	<u>COMPONENT</u>	<u>OBJECTIVES</u>		
	UNSATURATED ROCK UNITS BELOW THE REPOSITORY	ACT AS BARRIER TO RADIONUCLIDE TRANSPORT BY PROVIDING LONG RADIONUCLIDE TRAVEL TIMES		
	SATURATED ROCK BELOW THE UNSATURATED ROCK	EXTEND THE TOTAL TRAVEL-TIME OF RADIONUCLIDES		

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Details of Strategy Have Matured Since Site Characterization Plan

- **Increased recognitions of potential for fast flow paths**
- **Potential role of thermal load on performance**
- **Multi-purpose canister as component in repository system**
- **Large, robust waste packages**
- **In-drift emplacement and new backfill/airgap options**
- **Increased role of saturated zone under a dose-based standard**
- **Consideration of extended performance-confirmation testing period**

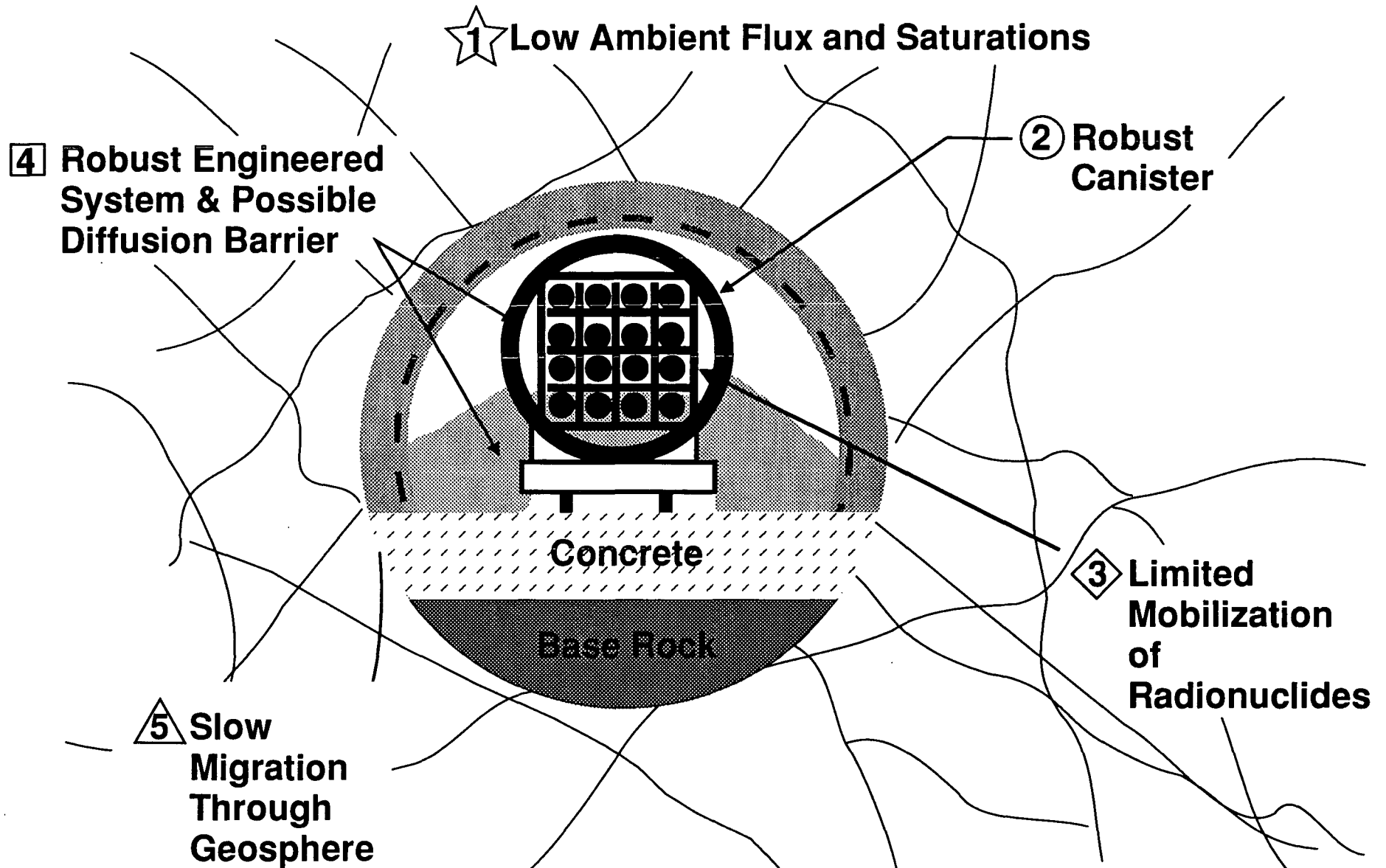
Implementation of Program Approach

- **Testing prioritized to support milestones, to measure progress toward those milestones, and to manage resources**
- **Early emphasis on Technical Site Suitability Evaluation**
- **Increased emphasis on near-field environment and substantially complete containment for 2001 License Application**
- **Testing after 2001 will provide increased confidence about long-term performance and may support higher thermal load for 2008 update to License Application**

Key Elements of Waste Containment and Isolation Strategy

- ★ 1 Favorable environment for waste package provided by unsaturated rock
- ② 2 Robust waste packages to address near-field uncertainties
- ◇ 3 Limited mobilization of radionuclides within waste packages
- 4 Slow release of radionuclides through engineered barriers
- △ 5 Slow migration of radionuclides in the geosphere

Top-Level Strategy for Waste Containment and Isolation

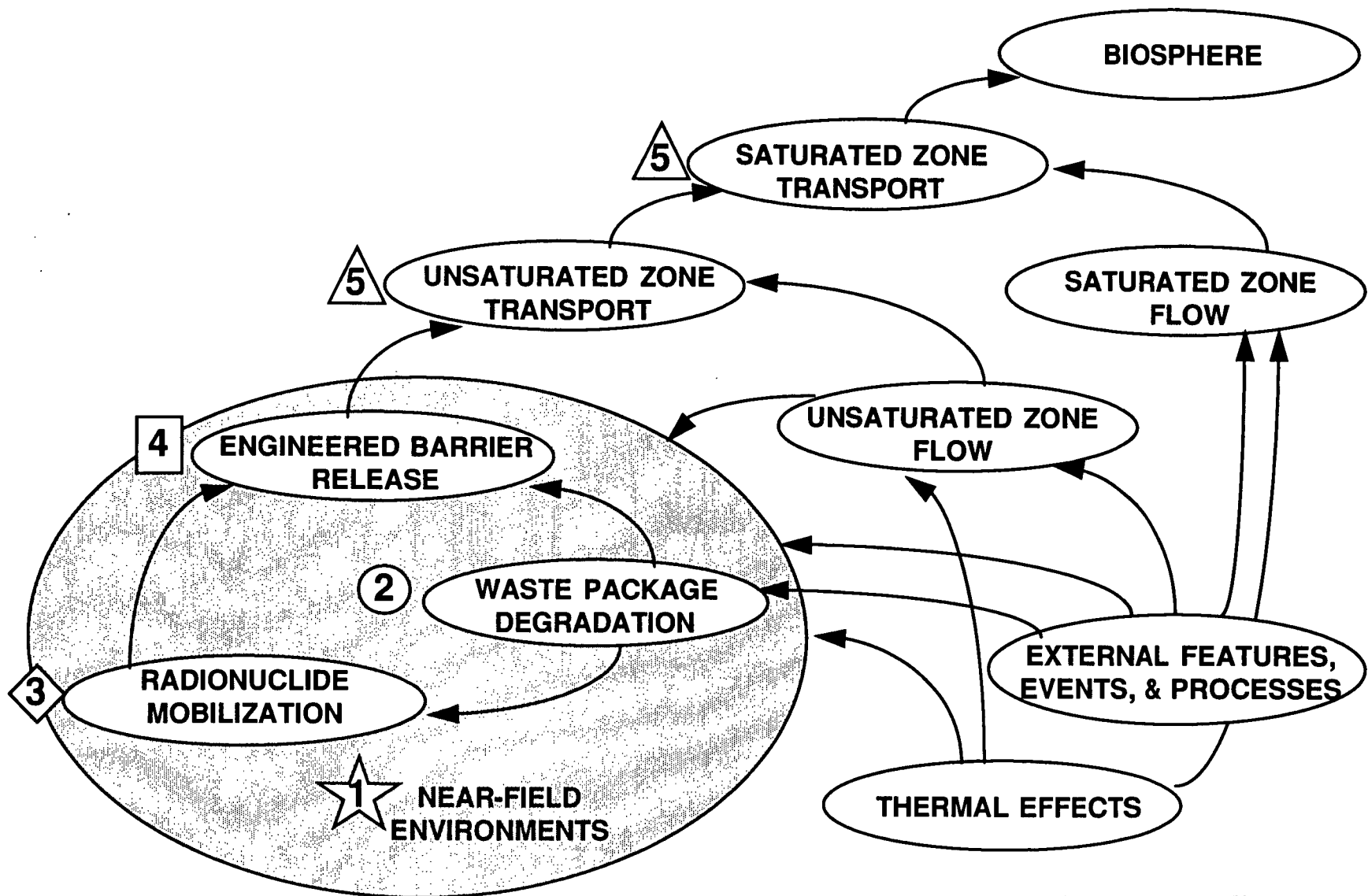


Implementing the Strategy

- **Review key uncertainties in the elements of the strategy and the approaches to address them**
- **The uncertainties are reviewed in three areas:**
 - **Nominal, undisturbed conditions**
 - **Thermal effects**
 - **Effects of disruptive features, events, and processes**
- **Review specific testing activities and their linkages to the strategy**

Implementation of the Strategy

Barriers and Elements of the Strategy



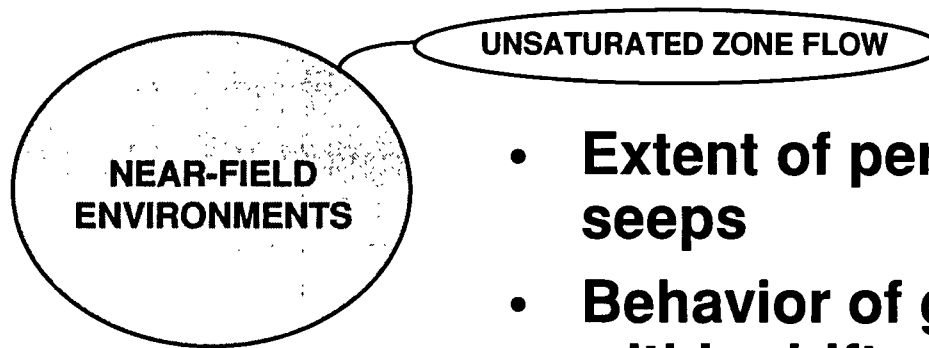
Relative Roles of Barriers and Strategy Elements

- **Strategy utilizes multi-barrier approach to increase confidence in postclosure performance**
- **Near-field elements contribute as a system--unsaturated environment and engineered barriers equally important in this system**
- **Far-field barriers add confidence that waste isolation will be achieved**
- **Uncertainties in all these elements and barriers must be addressed**



Waste Package Environment

Key Uncertainties



- **Extent of perched water and seeps**
- **Behavior of ground water within drifts (e.g., in backfill or airgap)**
- **Time for water to reach repository horizon**
- **Focusing/channeling of infiltration flux**
- **Water chemistry**

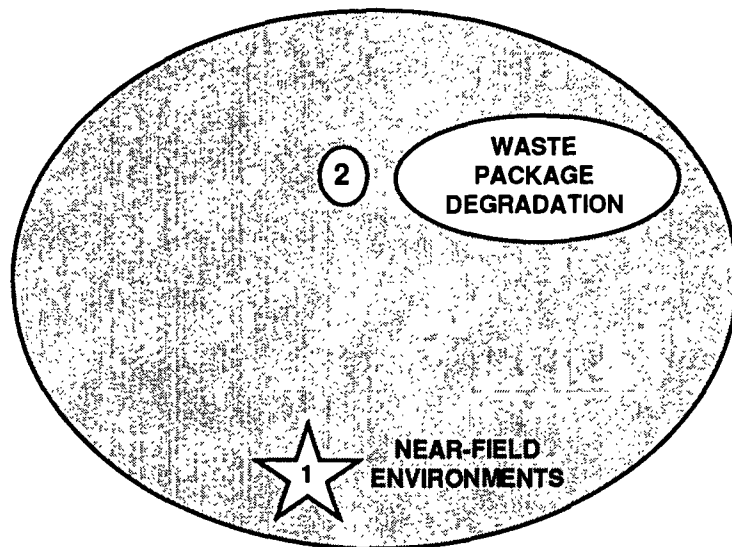


Waste Package Environment

Approaches to Address Uncertainties

- **Infiltration monitoring**
- **Observations in ESF**
 - **Water chemistry**
 - **Isotopic analyses**
 - **Behavior of seeps**
 - **Comparison with model predictions**
- **Site and drift-scale hydrogeologic modeling**
- **Hydrogeologic testing and analysis of fracture-matrix coupling**
- **Observations from deep boreholes**

② Waste Package Performance *Key Uncertainties*



- **Pitting corrosion of corrosion-resistant materials**
 - Inner barrier of disposal container
 - Zircaloy cladding

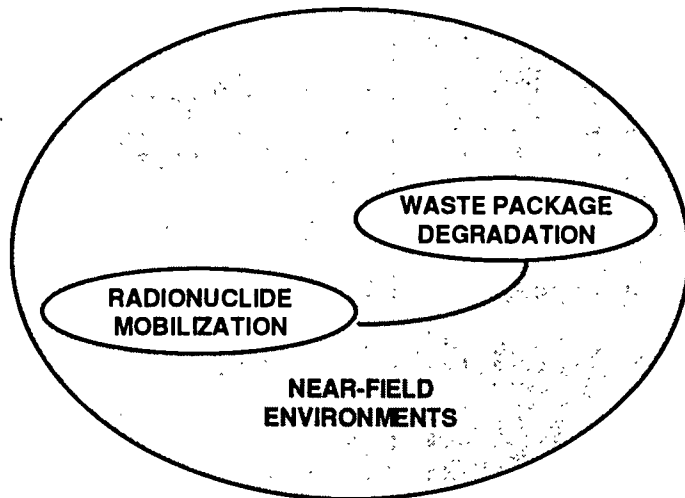
- **Potential extent of microbiologically-induced corrosion**

② **Waste Package Performance** *Approaches to Address Uncertainties*

- **Modeling laboratory testing of pit corrosion processes**
- **Evaluation of analogs showing material durability**
- **Identification of mechanisms and laboratory testing of materials for resistance to microbiologically-induced corrosion**

3 Radionuclide Mobilization

Key Uncertainties



- Oxidation state of spent fuel
- Cladding breaching and surface area of waste matrix available for dissolution
- Waste dissolution in presence of limited water
- Existence and stability of colloids
- Bounding neptunium and technetium solubilities
- Probability of events leading to criticality

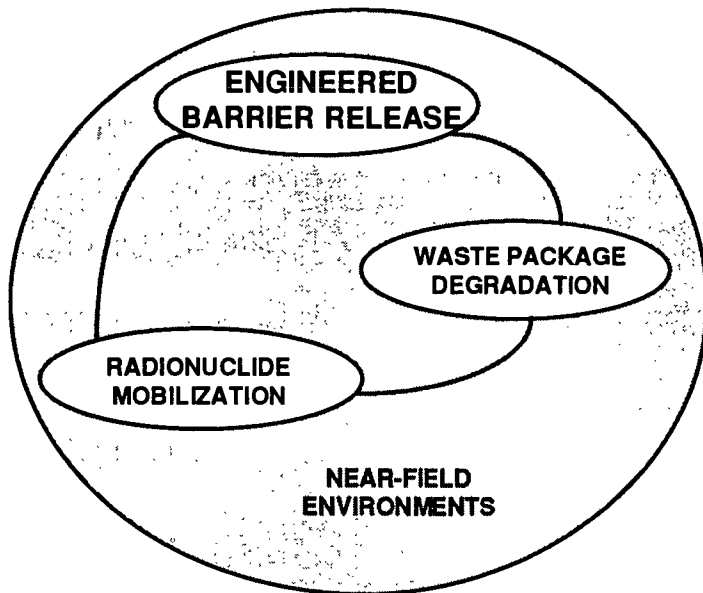
3 Radionuclide Mobilization

Approaches to Address Uncertainties

- **Establish conservative assumptions for cladding performance from observations**
- **Waste form dissolution laboratory testing**
- **Colloid investigations**
- **Neptunium and technetium solubility experiments**
- **Probabilistic analyses of criticality potential to guide design**

4 Release Through EBS

Key Uncertainties



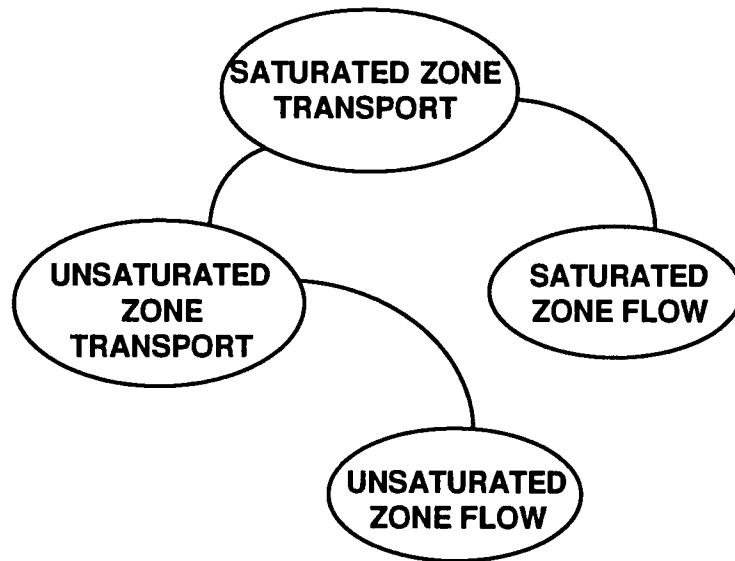
- Fraction of waste package surface degraded
- Potential for liquid film to support diffusive release
- Diffusion rates in backfill material
- Advective flow in engineered barriers

4 **Release Through EBS** *Approaches to Address Uncertainties*

- **Monitor inflows in the Exploratory Studies Facility and alcoves**
- **Laboratory measurements of diffusion rates in variably saturated media**
- **Sensitivity analyses for drift-scale thermohydrologic models**

5 Radionuclide Migration in Geosphere

Key Uncertainties



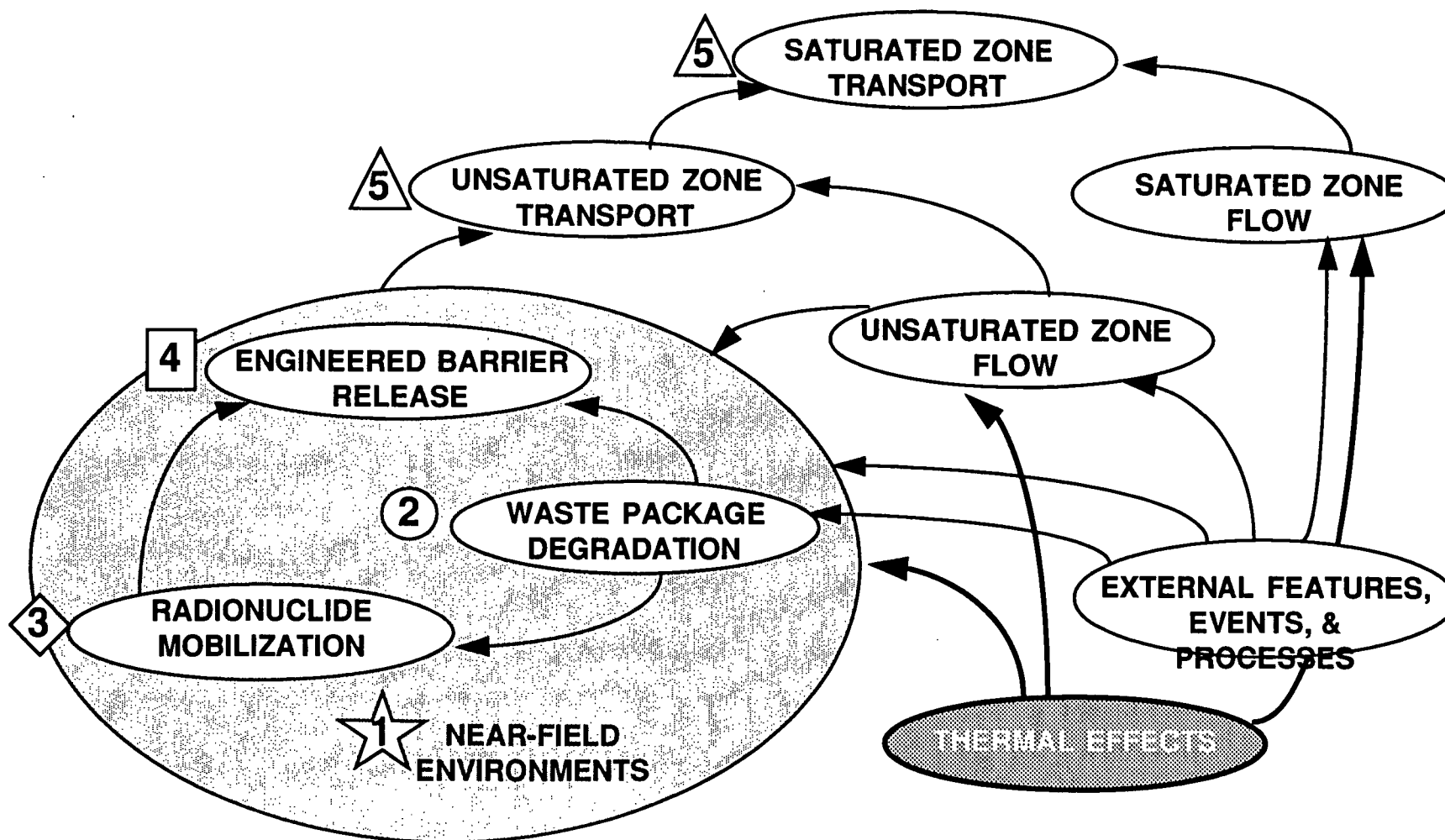
- **Magnitude of infiltration flux**
- **Travel time of water in unsaturated zone**
- **Conceptual model for fracture-matrix coupling in partially saturated media**
- **Dispersion caused by small-scale heterogeneity**
- **Nature and role of steep gradient to the north**
- **Extent of dilution by vertical ground-water mixing**

5 Radionuclide Migration in Geosphere

Approaches to Address Uncertainties

- **C-well tracer experiments and aquifer testing**
- **Investigate steep gradient in water table**
- **Bounding analysis of range of mixing depths**
- **Sensitivity analysis for unsaturated and saturated flow and transport models**
- **Regional-scale aquifer testing**
- **Obtain ages of samples from Exploratory Studies Facility seeps and boreholes**

Thermal Effects On Barriers and Elements



Thermal Effects

Key Uncertainties

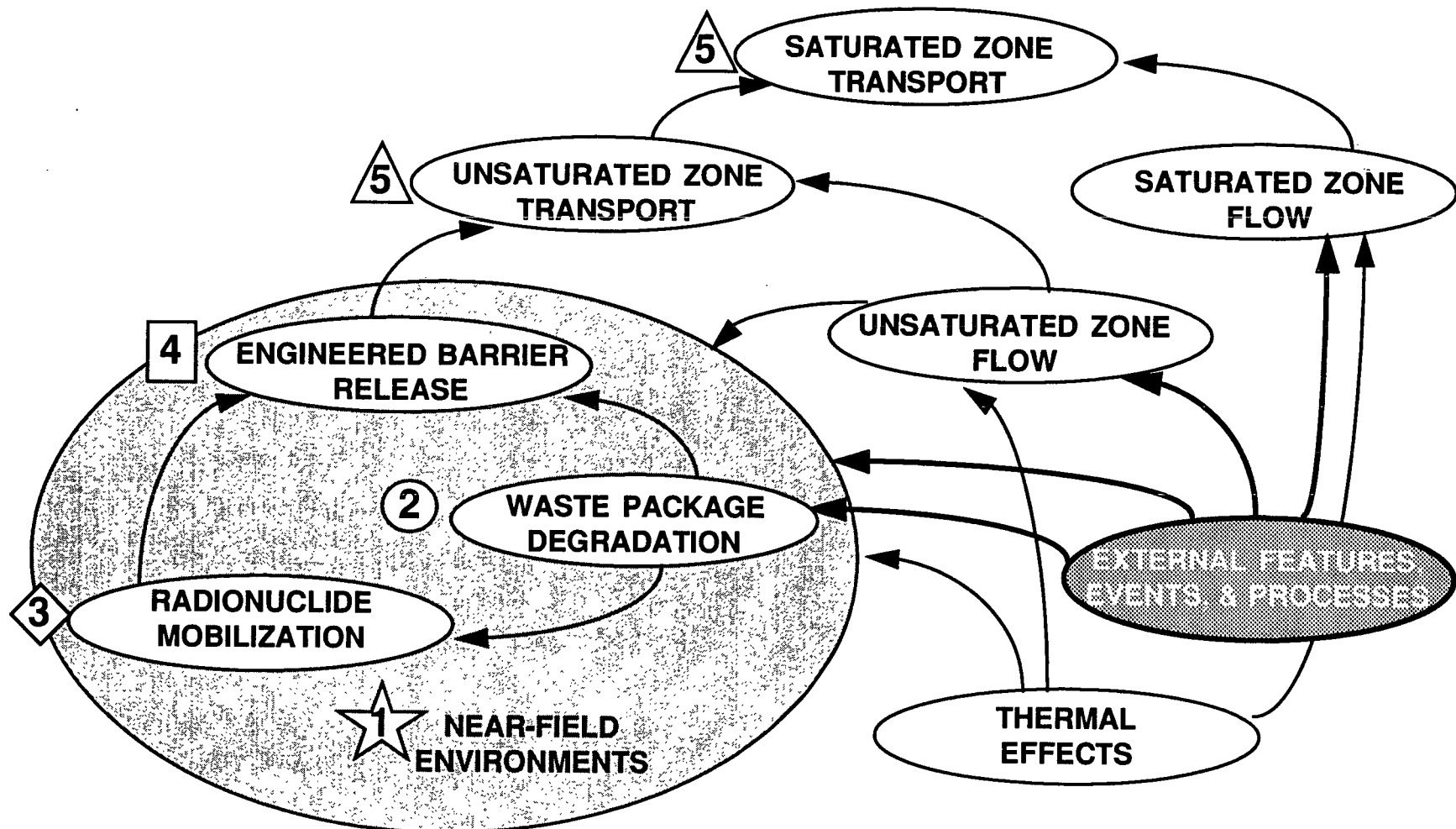
- **Elevation of temperature and impacts on EBS**
- **Effect of thermal load on rock mass stability**
- **Effect of thermal load on near-field humidity**
- **Effect on waste package material corrosion rates**
- **Effect on radionuclide mobilization rates**
- **Effect on release of mobilized radionuclides from EBS**
- **Effect of thermal load on moisture distribution in unsaturate host rock**
- **Effect on minerals along flow paths**

Thermal Effects

Approaches to Address Uncertainties

- **Short-term heater tests in Exploratory Studies Facility to evaluate near-field perturbations to moisture distribution**
- **Long-duration thermal-mechanical-hydrologic-chemical testing in Exploratory Studies Facility**
- **Laboratory tests of corrosion rates under various temperature/humidity conditions**
- **Laboratory tests of waste form dissolution and radionuclide solubility under a range of conditions**
- **Rock properties testing**

Effects of Features, Events, and Processes on Barriers and Elements



Potential Features, Events and Processes That Could Affect Waste Containment and Isolation

- **Future climate changes**
- **Tectonics**
- **Igneous activity/volcanism**
- **Human interference**

Effects of Future Climate Changes

Key Uncertainties

- **Potential increased infiltration and wetting of engineered barriers**
- **Potential changes in saturation of unsaturated zone rocks**
- **Potential increased recharge to regional ground-water system**
 - **Possible changes to water table elevation**
 - **Possible changes to ground-water velocities in saturated zone**

Effects of Future Climate Changes

Approaches to Address Uncertainties

- **Use paleoclimate models and present climate conditions to develop models for future climates**
- **Determine relationship between climate and hydrologic characteristics**
- **Estimate effect of changes in climatic conditions on infiltration rates**
- **Use unsaturated zone model to estimate effect of increased infiltration on saturation profiles**
- **Evaluate response of saturated zone to increased recharge using regional hydrologic models**

Effects of Tectonics

Key Uncertainties

- **Potential effect of faulting and ground motion on engineered barriers**
- **Potential development or renewal of flow paths along faults**
- **Potential for water table rise**

Effects of Tectonics

Approaches to Address Uncertainties

- **Constrain Quaternary fault displacement histories**
- **Characterize seismic sources**
- **Evaluate alternate tectonic models for Yucca Mountain area**
- **Measure and model ground motion attenuation with depth**
- **Model water table response to earthquakes**
- **Evaluate consequences of tectonic effects**

Effects of Volcanism

Key Uncertainties

- **Direct effects of igneous activity on repository**
- **Effects of igneous activity on water table**
- **Effects of corrosive gases, steam on waste packages**
- **Induced fluid movement along faults or fracture zones**

Effects of Volcanism

Approaches to Address Uncertainties

- **Investigate magnetic anomalies with boreholes in Crater Flat**
- **Study evolution of basaltic volcanism patterns in the Yucca Mountain region**
- **Evaluate the probability of basaltic igneous activity in the Yucca Mountain region**
- **Study physical processes of magmatism to bound volcanic effects**
- **Evaluate consequences of igneous activity**

Effects of Human Interference

Key Uncertainties

- **Direct intrusion from exploratory drilling**
- **Introduction of fluids as result of exploratory drilling**

Effects of Human Interference

Approaches to Address Uncertainties

- **Evaluate probability of exploratory drilling through evaluation of natural resources at site**
- **Model consequences of direct intrusion or introduction of drilling fluids**

Components in Evaluation of Uncertainties

- **Characterize features and conditions**
 - **Rigorous review of assumptions**
 - **Adequate testing to support characterization**
 - **Consideration of alternate hypotheses**
- **Evaluate significance with respect to waste containment or isolation**
 - **Through iterative performance assessments**
 - **Realistic representation of effects in assessments**
- **Determine whether significant adverse effects are compensated by favorable conditions at the site or if they can be remedied**