U.S. Department of Energy

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

# Performance Confirmation Program
## Background, Status, and Path Forward

**Presented to:**
**Nuclear Waste Technical Review Board**


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# Outline of Presentation

- **Role and Requirements for Performance Confirmation**
- **Elements of the Performance Confirmation (PC) Program**
- **Example of Testing and Monitoring Categories**
- **Approach to Selecting PC Activities**
- **PC Plan Revision 5**
- **PC Activities Confirm Barrier Performance and Capability**
- **Ongoing Activities**
- **Construction Phase Activities**
- **Operations Phase Activities**
- **Status and Path Forward**

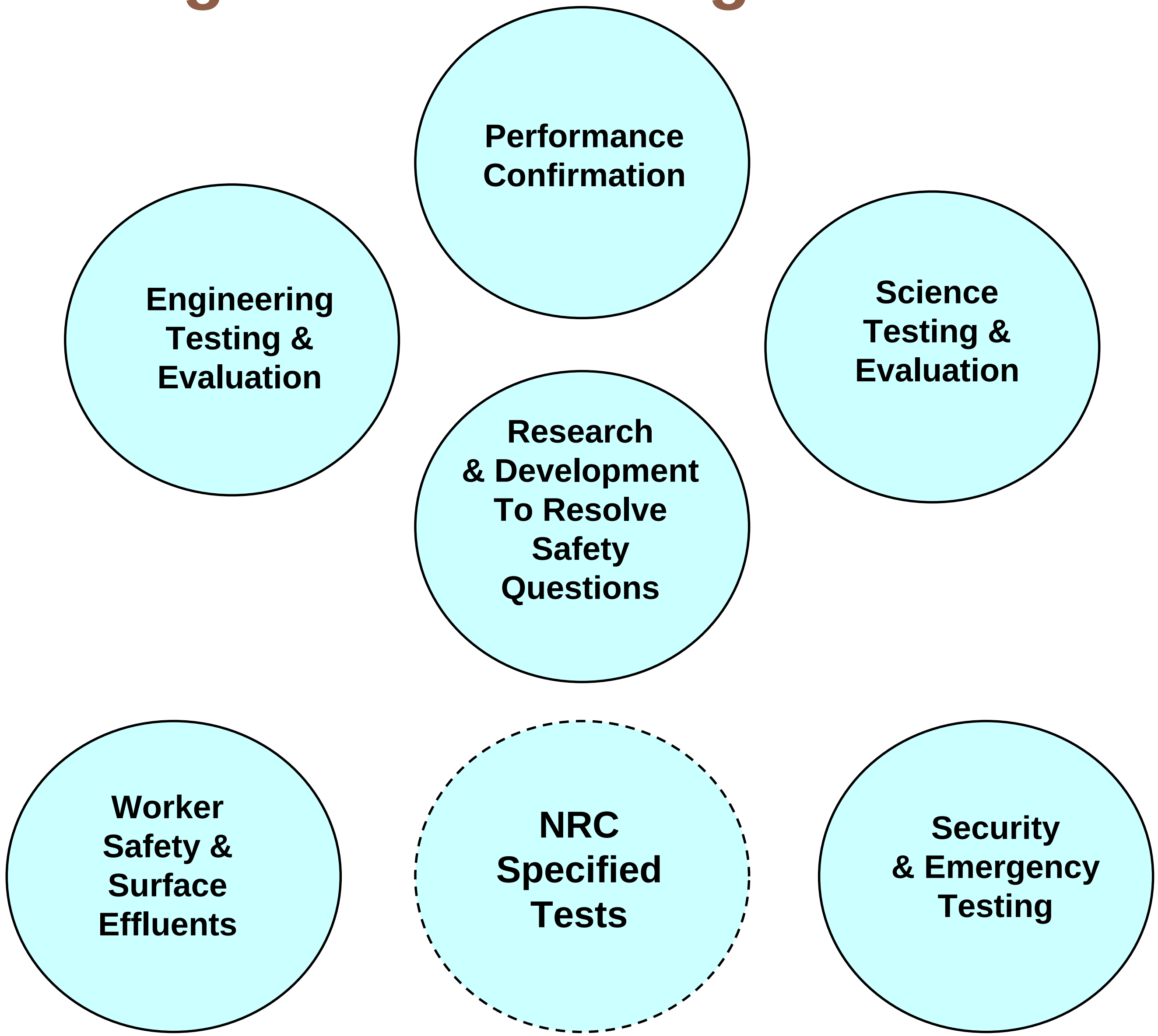
# Role and Requirements for Performance Confirmation

- NRC requires a description of the performance confirmation program as part of a License Application for the repository
  - "Performance confirmation means the program of tests, experiments, and analyses that is conducted to evaluate the adequacy of the information used to demonstrate compliance with the performance objectives …" (10 CFR 63.2)
- Performance confirmation should demonstrate that system components (i.e., barriers) are operating as predicted
  - "The performance confirmation program must provide data that indicate, where practicable, whether natural and engineered systems and components required for repository operation, and that are designed or assumed to operate as barriers after permanent closure, are functioning as intended and anticipated" (10 CFR 63.131(a)(2))

# Elements of the YMP Performance Confirmation Program

- Based on 10 CFR 63 requirements and *Yucca Mountain Review Plan* expectations
- Provides a comprehensive and thorough look at critical aspects of the overall system and the barriers
- Uses a risk-informed performance-based approach to determine complexity, extent, and number of activities needed to test the functionality of barriers important to waste isolation
- Supports an eventual License Amendment for repository closure
- Strong Integration with TSPA
  - The development of the PC program was based on an in-process understanding of performance and barrier capability, including a qualitative evaluation based on the most current TSPA
  - PC and TSPA will continue to coordinate, including a quantitative evaluation against the TSPA using the model input database and sensitivity evaluations

# Testing and Monitoring in 10 CFR 63



# Approach to Selecting PC Activities

- The PC Plan is a product of a formal, rigorous process
- Implemented a multi-attribute decision analysis
  - Criteria included sensitivity, confidence and accuracy
- Involved management judgment and review

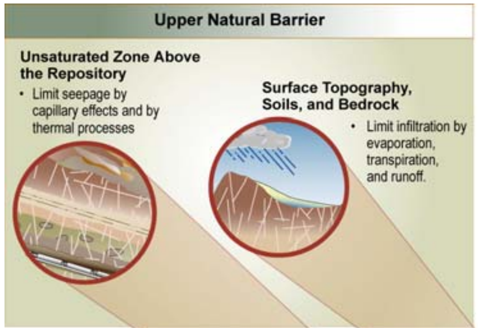
# PC Plan Revision 5

- Completed in November, 2004
- Provides crosswalk of requirements and guidance to the Program
- Describes PC activities selected to support the license application
- Provides expanded detail for PC activities and control processes (e.g., general description of data management, analysis and reporting)
- Describes general test planning and implementation
- Provides a discussion of a high level proposed schedule
- Provides guidance for the definition of ranges and condition limits for PC parameters
- Discusses evaluation processes and notification criteria
- Introduces role and function of PC integration group
  – Examines overall repository behavior and to ensure continuity and integration with other testing and monitoring programs, analysis departments, and repository design and operations
  – Is part of the process to retain flexibility by re-examining, re-evaluating and modifying PC activities as the state of knowledge changes

# PC Activities Confirm Barrier Performance and Capability

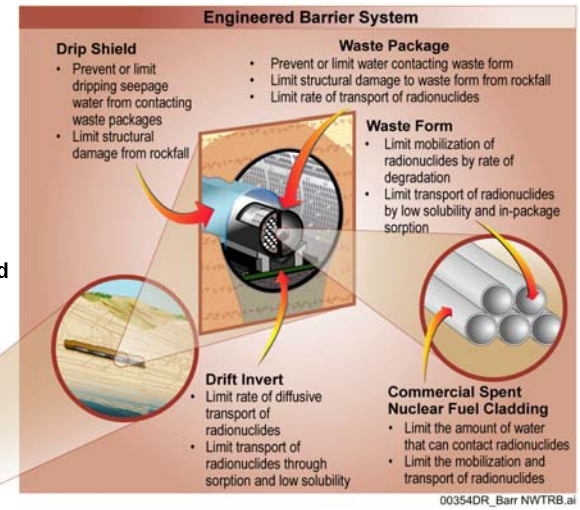
## PC activities evaluating the Upper Natural Barrier:

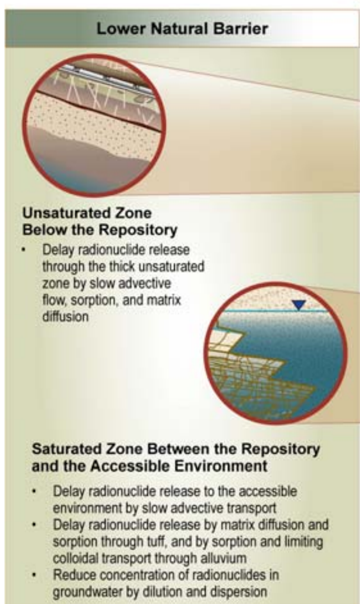
- Precipitation Monitoring
- Subsurface Water and Rock Testing
- UZ Testing
- Seepage Monitoring
- Thermally Accelerated Drift In-Drift Environment Monitoring
- Subsurface Mapping
- Seismicity Monitoring
- *Seals Testing*
- *Thermally Accelerated Drift Near-Field Environment Monitoring*

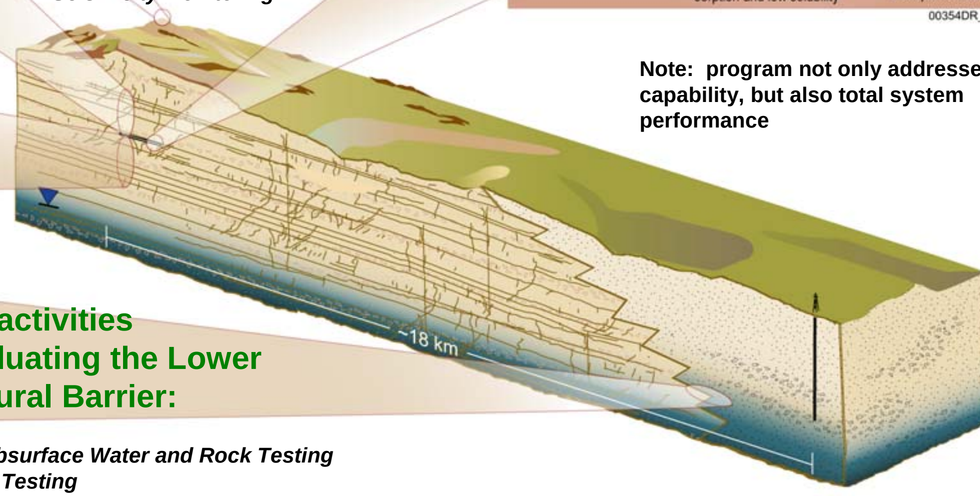



## PC activities evaluating the Engineered Barrier:

- Drift Inspection
- Construction Effects Monitoring
- Thermally Accelerated Drift Thermal-Mechanical Monitoring
- Thermally Accelerated Drift Near-Field Environment Monitoring
- Corrosion Testing
- Corrosion Testing of Thermally Accelerated Drift Samples
- Dust Buildup Monitoring
- Waste Package Monitoring
- Waste Form Testing
- Seals Testing
- *UZ Testing*
- *Thermally Accelerated Drift In-Drift Environment Monitoring*
- *Seismicity Monitoring*




Note: program not only addresses barrier capability, but also total system performance

## PC activities evaluating the Lower Natural Barrier:

- *Subsurface Water and Rock Testing*
- *UZ Testing*
- *Subsurface Mapping*
- SZ Monitoring
- SZ Fault Hydrology Testing
- SZ Alluvium Testing

Note: Activities in italics indicates it confirms performance of more than one barrier

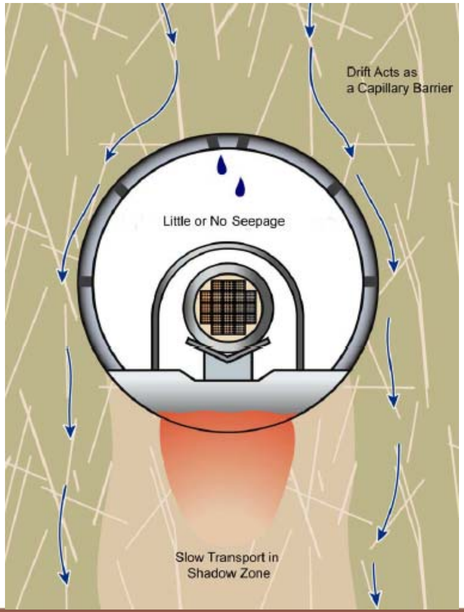
# PC Activities

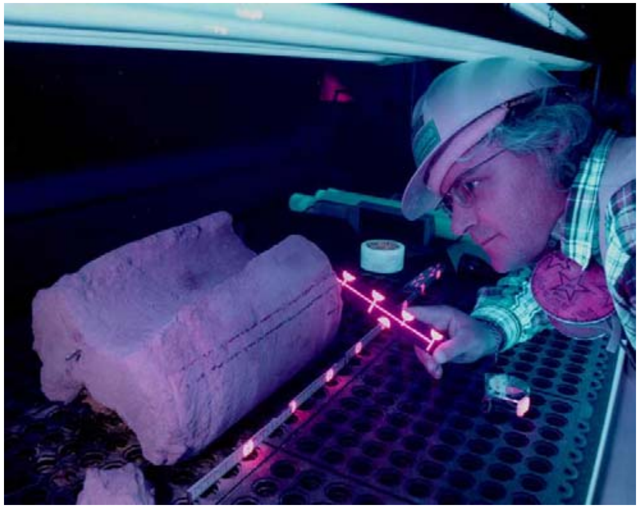
- The Decision Analysis process and subsequent evaluations yielded twenty PC Activities.
- These activities are described in detail in the PC plan.
  - The plan lists each individual activities purpose, selection justification (both technical and regulatory), the current understanding for that activity, and anticipated methodology that may be appropriate to test and monitor parameters in that activity.
- The activities are initiated in three phases:
  - Ongoing Activities
    - Continuation of activities (or similar activities) initiated during site characterization
  - Construction
    - As early as practicable
  - Operations
    - During and after waste emplacement

# Ongoing PC Activities

## Ongoing monitoring and testing activities are:

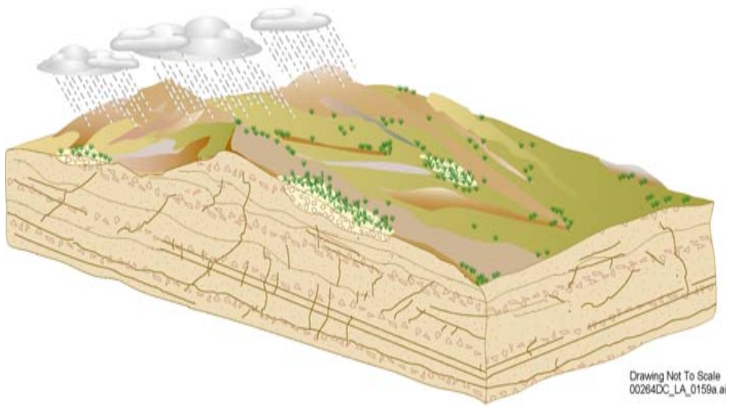
- **Precipitation monitoring -** precipitation quantities and composition measured at the Yucca Mountain site to place seepage data in context
- **Seepage monitoring -** seepage monitoring and analysis in alcoves on the repository intake side and in repository thermally accelerated drifts
- **Subsurface water and rock testing -** chloride mass balance and isotope chemistry analysis of water samples collected at selected underground locations



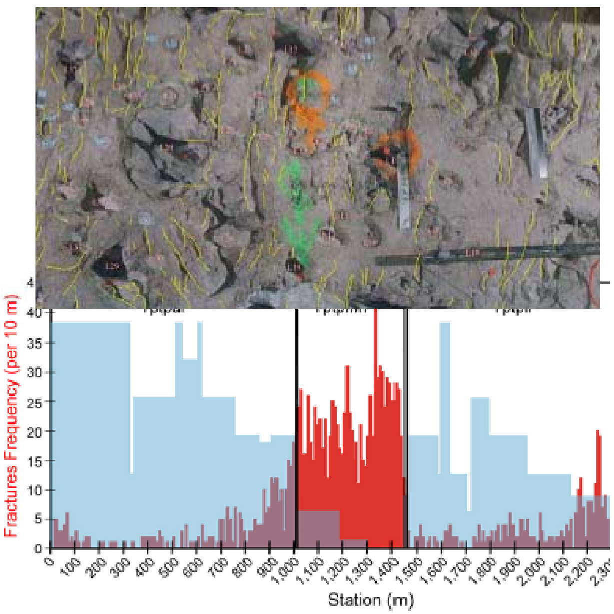
# Ongoing PC Activities (continued)

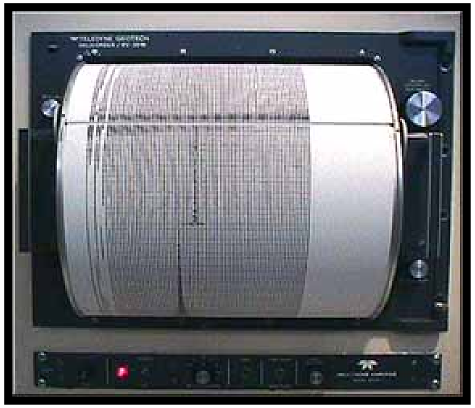
- **Unsaturated zone testing -** field-testing of transport and sorptive properties of unsaturated zone rock in an ambient seepage alcove or a drift with no waste packages emplaced
- **Saturated zone monitoring -** measurements of water level, electrochemical potential, hydrogen potential, and background radionuclide concentrations in saturated zone wells at the repository site and in Nye County
- **Saturated zone alluvium testing -** tracer testing of alluvium transport properties in the Alluvial Test Complex




# Ongoing PC Activities (continued)

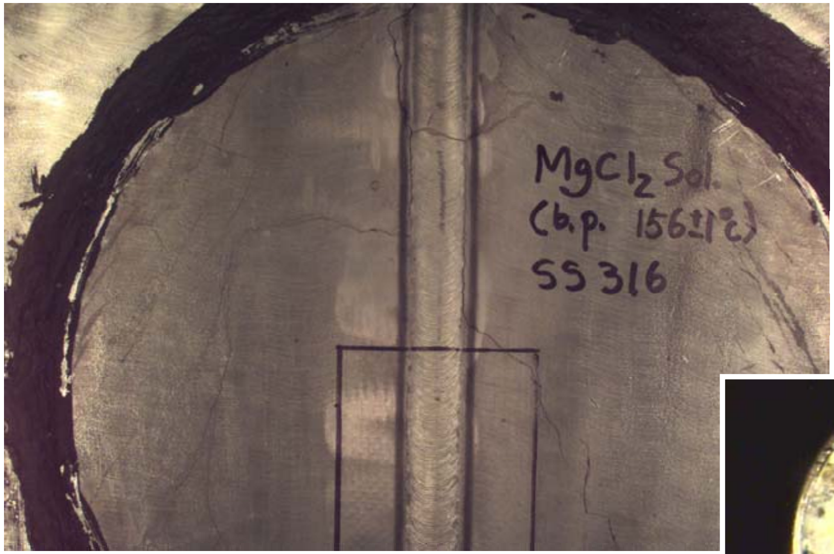
- **Subsurface mapping - mapping of fractures, faults, stratigraphic contacts and lithophysal characteristics of rock in the underground openings**
- **Seismicity monitoring - monitoring of regional seismic activity and observation of fault displacements following significant seismic events**
- **Construction effects monitoring - measurement of construction deformation in underground openings/confirmation of related rock mechanical properties**



# Ongoing PC Activities (concluded)

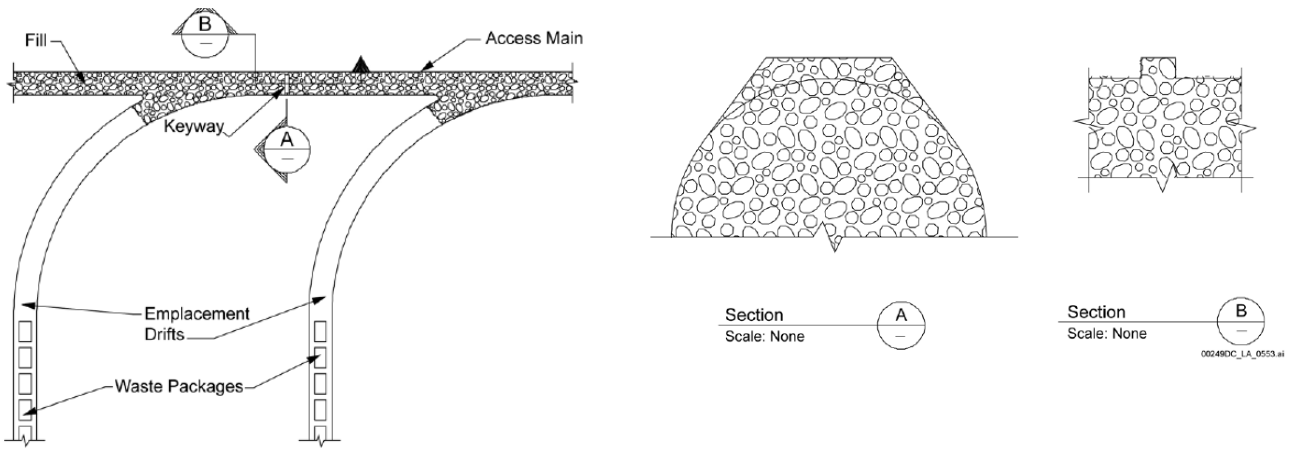
- **Corrosion testing -** laboratory samples testing of waste package and drip shield materials corrosion behavior in the range of expected repository environments
- **Waste form testing -** laboratory testing of waste form dissolution and waste package coupled effects including use of scale mockups of waste package




# Construction Phase PC Activities

## New activities beginning during the construction phase are:

- **Saturated zone fault zone hydrology testing - hydraulic and tracer testing in fault zones**
- **Seal testing - testing of effectiveness of borehole seals in the laboratory, shaft and ramp seals in the field, and backfill emplacement techniques**




# Operations Phase PC Activities

## New activities to begin during the operations phase are:

- **Drift inspection** - periodic inspection of emplacement drifts and thermally accelerated drifts using remote inspection and measurement techniques
- **Dust buildup monitoring** - monitoring and laboratory evaluations of quantity and composition of dust on engineered barrier surfaces and samples (also occurs in the Thermally Accelerated Drift)
- **Waste package monitoring** - monitoring of integrity of waste packages using visual inspection and/or internal pressure measurement employing remote monitoring techniques

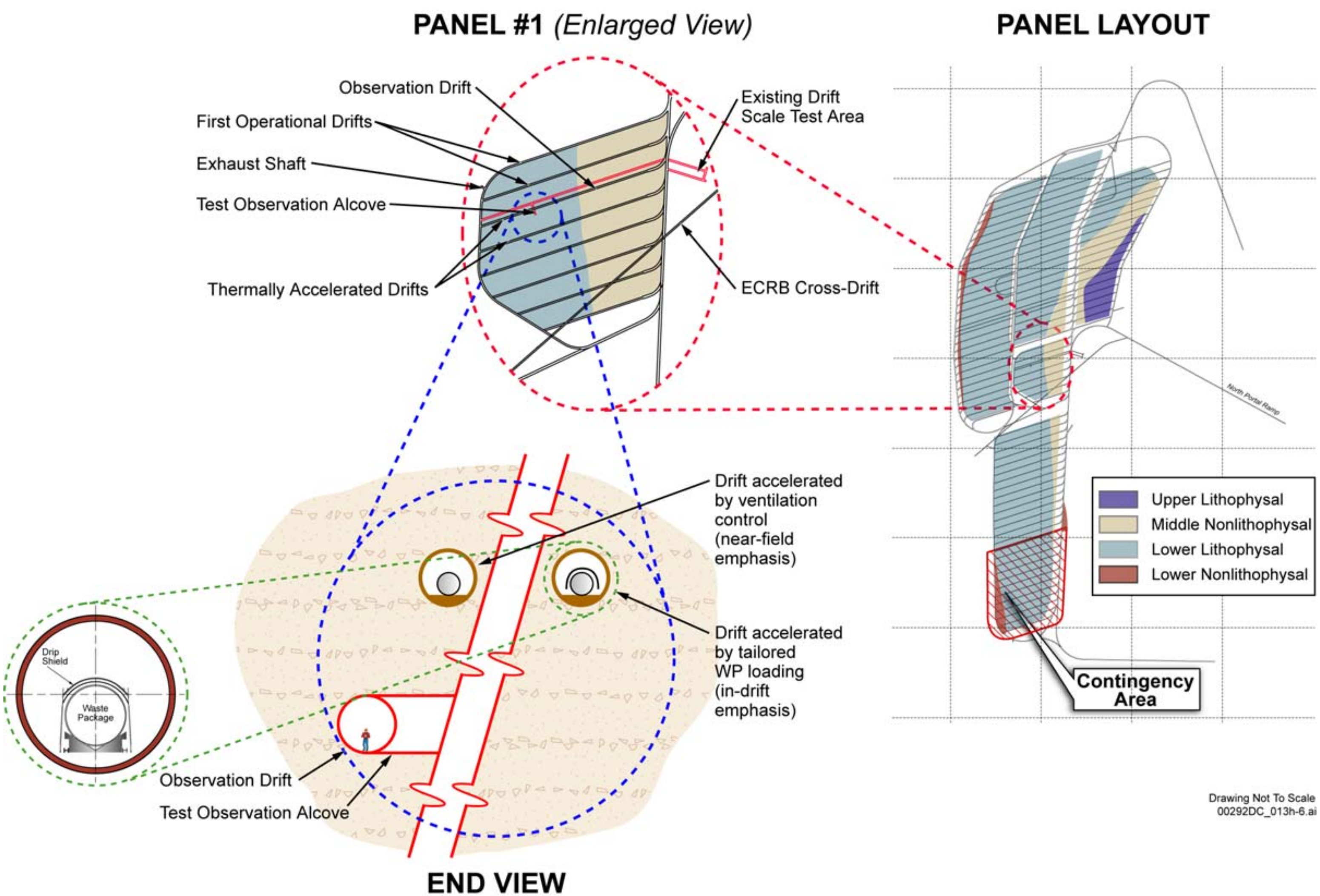


# Operations Phase PC Activities (continued)

- **Near-field monitoring** - monitoring of rock mass and water properties in the near-field of a thermally accelerated emplacement drift
- **Environment monitoring** - monitoring and laboratory evaluations of environmental conditions including gas and water compositions, temperatures, film depositions, microbes, radiation and radiolysis effects using remote techniques
- **Thermal-mechanical effects monitoring** - measurement of construction deformation of underground openings/confirmation of related rock mechanical properties
- **Corrosion testing** - laboratory testing of waste package, emplacement pallet and drip shield samples obtained from the thermally accelerated drift

* These four activities are conducted exclusively in the Thermally Accelerated Drift Test Bed

# Dedicated Performance Confirmation Drifts With an Accelerated Thermal Cycle



# Path Forward

- Continued iteration with TSPA and underlying process modeling
- Analyze and evaluate data by activity (including site characterization baseline, TSPA-LA, supporting process models, and design bases) to establish data ranges and condition limits for PC parameters
- Develop procedures that would implement and control the PC Program
- Prepare PC Test Plans
- Engage NRC regulators on PC program and control processes
- Continue monitoring, testing, and data collection (for ongoing tests)
- Further integrate PC test needs and requirements with construction and operations planning
- Update and maintain the PC Plan as needed

# Backup Detailed Material

# PC Activities - Description and Purpose

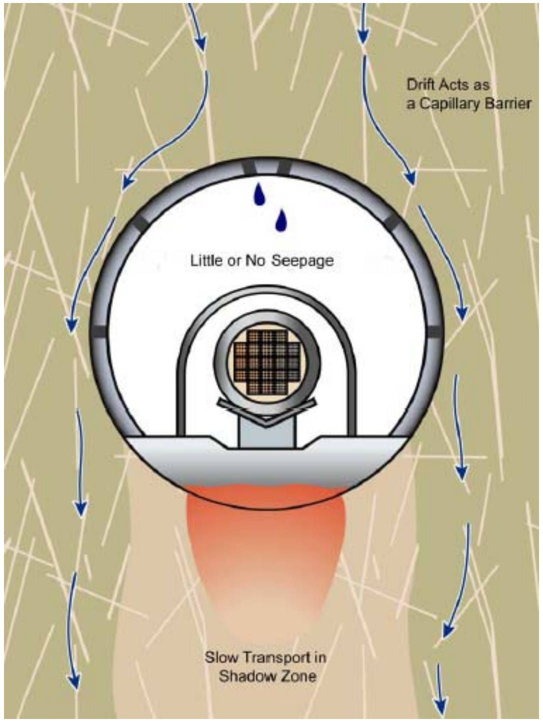
- **Precipitation Monitoring**

  – **Activity consists of monitoring of precipitation and composition analysis to evaluate the precipitation input parameter that relates to seepage modeling.**

  – **This activity directly addresses one of the bases for evaluating the performance of the Upper Natural Barrier and serves as the maximum input of water to the repository system from the environment. As such, it's important to understanding seepage monitoring and the input/output values of the process that carries water from the surface, through the UZ, and potentially to the emplacement drifts.**

# Description and Purpose (continued)

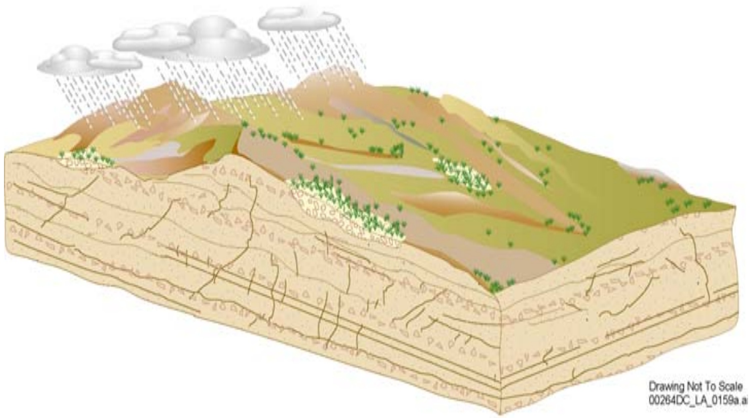
- **Seepage Monitoring**
  - **This activity consists of seepage monitoring and laboratory analysis of water samples (from bulkheaded alcoves on the intake side of the repository and in thermally accelerated drifts) too evaluate results from the seepage model.**
  - **While precipitation serves as the maximum input of water to the repository system from the environment, seepage represents the output from the Upper Natural Barrier as it enters the Engineered Barrier System.  As such, this activity is important as it evaluates the expected results of the infiltration, unsaturated zone flow in the rock above the repository, and seepage into drift models.**



# Description and Purpose (continued)

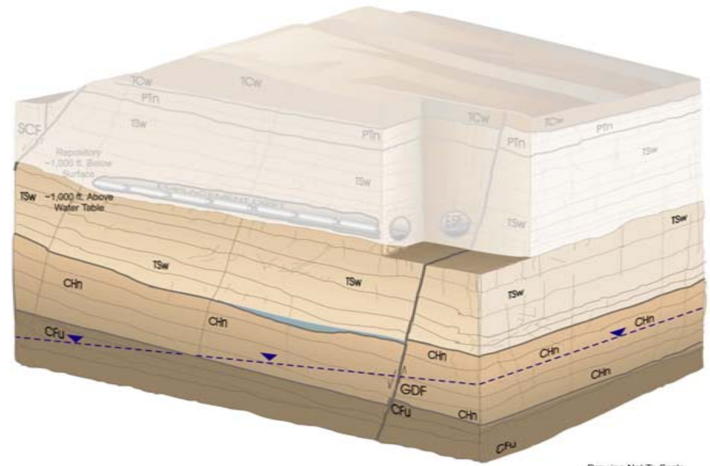
- **Subsurface Water and Rock Testing**
  - **This activity consists of laboratory analysis of chloride mass balance and isotope chemistry based on samples taken at selected locations of the underground facility to evaluate assumptions for fast paths used in unsaturated zone model.**
  - **This activity will obtain field observations to evaluate assumptions and inputs used in chemical models that indicate flow in the unsaturated zone.**
    - Chloride mass balance and isotopic composition can be used to understand historic infiltration rates. This activity will extend the dataset to cover areas of the repository not yet sampled.
    - Rock matrix water records a long-term history of past events in the vicinity of the repository openings. As such, this activity is very important to evaluating the expected results and assumptions related to the infiltration and unsaturated zone flow in the rock above the repository models.

# Description and Purpose (continued)



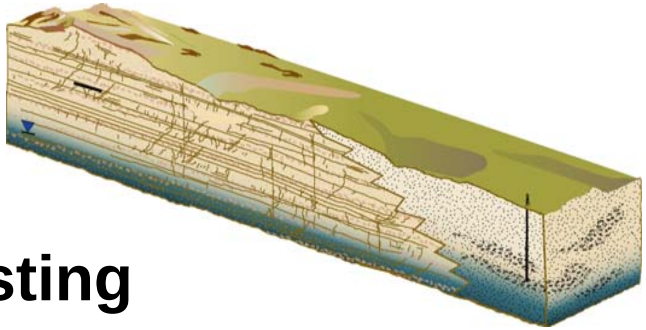

- **Unsaturated Zone Testing**
  - **This activity consists of testing of transport properties and field sorptive properties of the crystal-poor member of the Topopah Spring Tuff, in an ambient seepage alcove or a drift to evaluate sorption coefficients used in the unsaturated zone model.**
  - **Transport of radionuclides through the unsaturated zone mainly occurs in fractures within the welded units. Because fractures are difficult to sample and test in the laboratory, in situ testing in alcoves will better assess heterogeneous effects and ultimately improve the confirmation of parameter values used in performance assessment. The uncertainty associated with modeling the nonwelded units is not the transport properties, but rather their spatial distribution in relation to the flow paths from the repository to the saturated zone.**

# Description and Purpose (continued)




- **Saturated Zone Monitoring**
  - **This activity consists of monitoring of water level and hydrochemical sampling of the saturated zone upgradient, beneath and downgradient of Yucca Mountain to evaluate hydrologic and chemical parameters used with the saturated zone flow model.**
  - **This activity is important because water level changes indirectly control the flow components of the saturated zone feature. Changes in gradient may increase the rate of radionuclide transport. Water chemistry can also impact radionuclide transport. Eh and pH are very important indicators of conditions that could cause radionuclides to exhibit different transport behaviors.**

# Description and Purpose (continued)



- **Saturated Zone Fault Hydrology Testing**
  - This activity includes hydraulic and tracer testing of fault zone hydrologic characteristics, including anisotropy, in the saturated zone to evaluate fault parameter assumptions in the saturated zone flow and transport models.
  - This activity is important as the results from this activity will be used to evaluate whether the flow in the saturated zone of the Lower Natural Barrier performs as anticipated. Major fault zones may act as barriers to flow or as preferential pathways and both conditions have been identified near Yucca Mountain. Fault zones could affect the spreading of a contaminant plume, but might not significantly affect the unretarded radionuclide travel time. A permeable fault zone could spread flow paths vertically while retaining the general leading-edge shape of the plume.

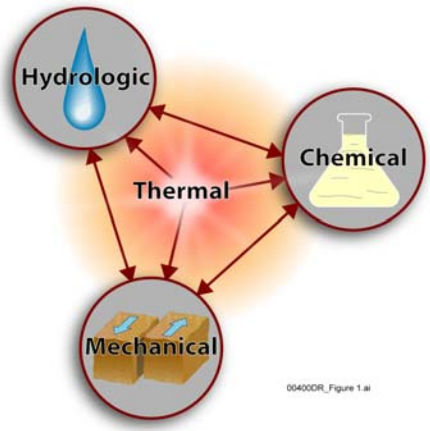
# Description and Purpose (continued)

- **Saturated Zone Alluvium Testing**
  - Tracer testing at the Alluvial Test Complex using multiple boreholes measuring parameters in the alluvium to evaluate inputs and assumptions for the saturated zone flow and transport models.
  - This activity is important as alluvium properties could influence evaluation of the performance of the Lower Natural Barrier. If, in the unlikely event that the transport parameters for alluvium are outside of the expected range in the adverse direction, then the ability of the alluvial feature of the Lower Natural Barrier to meet the objectives of the barrier capability would be evaluated.

# Description and Purpose (continued)

- **Drift Inspection**
  - This activity consists of regular inspection of nonemplacement drifts and periodic inspection of emplacement drifts, thermally accelerated drifts, and other underground openings using remote measurement techniques, as appropriate, to evaluate drift stability assumptions and rockfall size or probability distributions. This activity also supports confirmation of retrievability.
  - Mechanical effects from rockfall associated with drift degradation over time may lead to failure of the drip shields and waste packages. Failure of the EBS may depend on the rate of accumulation of rubble and rate of rockfall in the drift and the threshold load-bearing capacity of the systems. The accumulation in the drift will increase the waste package temperatures and may affect the water seepage into the drifts. As such, this observation activity is important to the drift stability modeling and has impacts on seepage and thermal processes within the drifts.

# Description and Purpose (continued)




- **Thermally Accelerated Drift Near-Field Monitoring**
  - This activity consists of monitoring of near-field coupled processes (thermal-hydrologic-mechanical-chemical) properties and parameters associated with the thermally accelerated drifts to evaluate coupled process results from the thermal-hydrologic-chemical-mechanical models.
  - Monitoring of thermal-hydrologic-mechanical-chemical coupled processes are important to the evaluation of the near-field coupled processes surrounding the repository emplacement drifts. Changes in the near-field environment during the thermal pulse could change seepage patterns and compositions as well as drift stability.

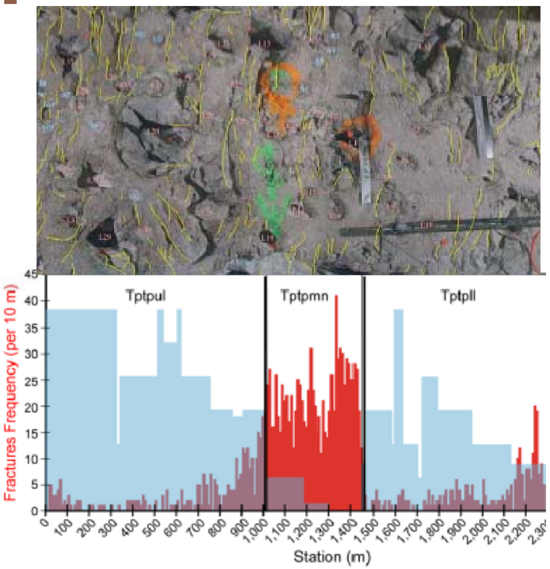
# Description and Purpose (continued)

- **Dust Buildup Monitoring**
  - This activity consists of monitoring and laboratory testing of quantity and composition of dust on engineered barrier surfaces to evaluate assumptions of dust buildup and potential chemical effects.
  - Dust buildup contributes to corrosion of the waste package, drip shield, and other engineered components, because of possible impacts on water chemistry and deliquescence. Because dust contributes in determining the chemical characteristics of the environment in which Engineered Barrier System components will operate in the repository, this activity is important to evaluating the bases for the expected conditions and to assess if the environments being used in the waste package and waste form testing are representative.

# Description and Purpose (continued)

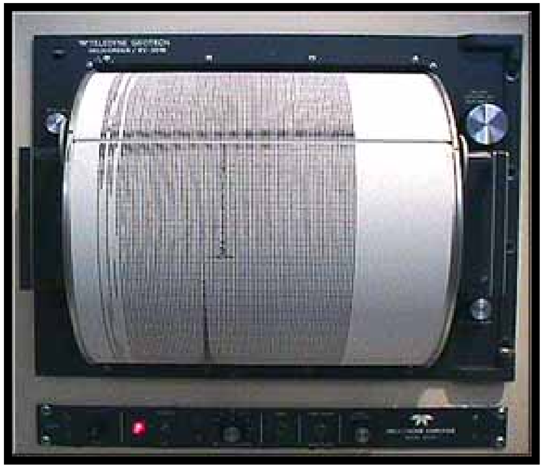
- **Thermally Accelerated Drift In-Drift Environment Monitoring**
  - Monitoring and laboratory testing of gas composition; water quantities, composition, and ionic characteristics (including thin films); microbial types and amounts; and radiation and radiolysis within a thermally accelerated drift to evaluate assumptions used in in-drift physical and chemical environment models.
  - This activity is important as confirmation of the environment that immediately surrounds the Engineered Barrier System components is important for evaluating the performance life times of these components (the kinds of corrosion and the rates of corrosion are highly dependent on the environment).

# Description and Purpose (continued)




- **Subsurface Mapping**
  - This activity consists of mapping fractures, faults, stratigraphic contacts, and lithophysal characteristics in underground openings (behind the excavation) to evaluate results from integrated site models.
  - This activity is important (and required by the regulation) because mapping of repository excavations ensures that any variations from the expected geologic conditions (e.g., lithology, lithophysal characteristics, fracture characteristics, unexpected structural features) described in the License Application are documented. If the conditions vary widely from the range expected, the conceptual models may not change, but it may be necessary to reevaluate the rate of water movement because stratigraphic sequences, rock properties and mineralogy in the vicinity of drifts account for about 50 percent of the calculated range in performance assessment.

# Description and Purpose (continued)



- **Seismicity Monitoring**
  - This activity consists of monitoring regional seismic activity and making observations of subsurface and surface (large magnitude) fault displacement after significant local or regional seismic events to evaluate annual probability distribution as a function of intensity.
  - This activity is important because the effects of potential mechanical interactions between the drip shield and waste package under rockfall and seismic conditions are an uncertainty in performance assessment models.

# Description and Purpose (continued)

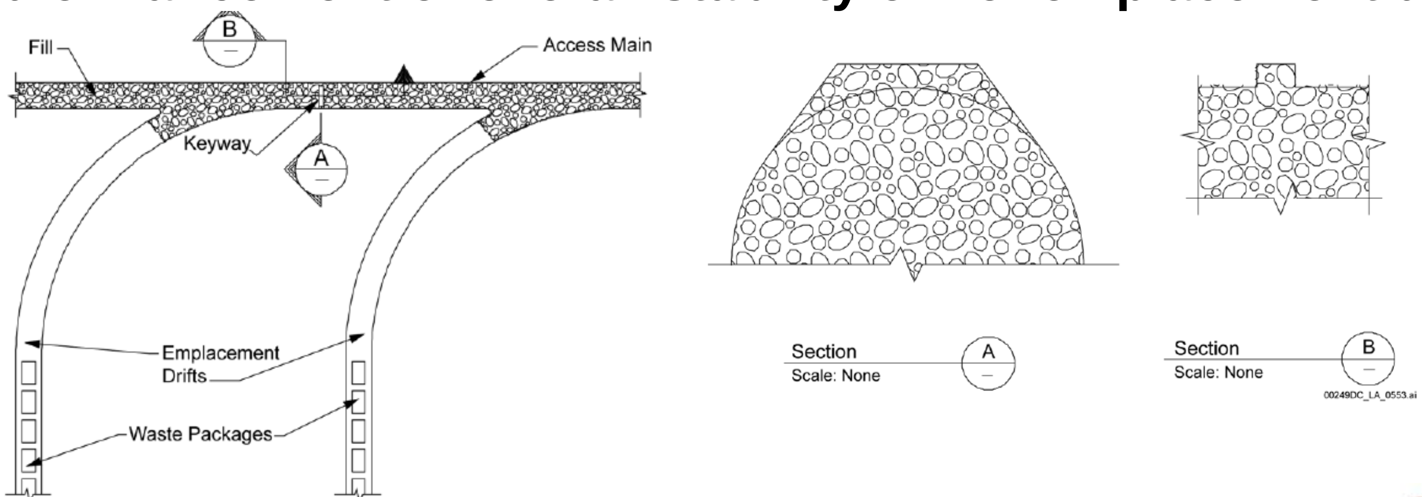
- **Construction Effects Monitoring**
  - Monitoring construction deformation and measurements of mechanical properties in underground openings to evaluate tunnel stability assumptions under ambient conditions.
  - This activity is important as it supports evaluation of the performance of the Upper and Lower Natural Barriers in the vicinity of the repository drifts and mains by confirming the mechanical properties.

# Description and Purpose (continued)

- **Thermally Accelerated Drift Thermal-Mechanical Monitoring**
  - This activity consists of monitoring drift and invert shape and integrity in a thermally accelerated drift to evaluate drift degradation assumptions under thermal conditions.
  - This activity is focused on assessments of drift stability that in turn, have impacts on the environment which EBS components will endure in the repository. This activity is important to collect data for drift stability modeling and has impacts on models for seepage and thermal processes within the drifts.

# Description and Purpose (continued)

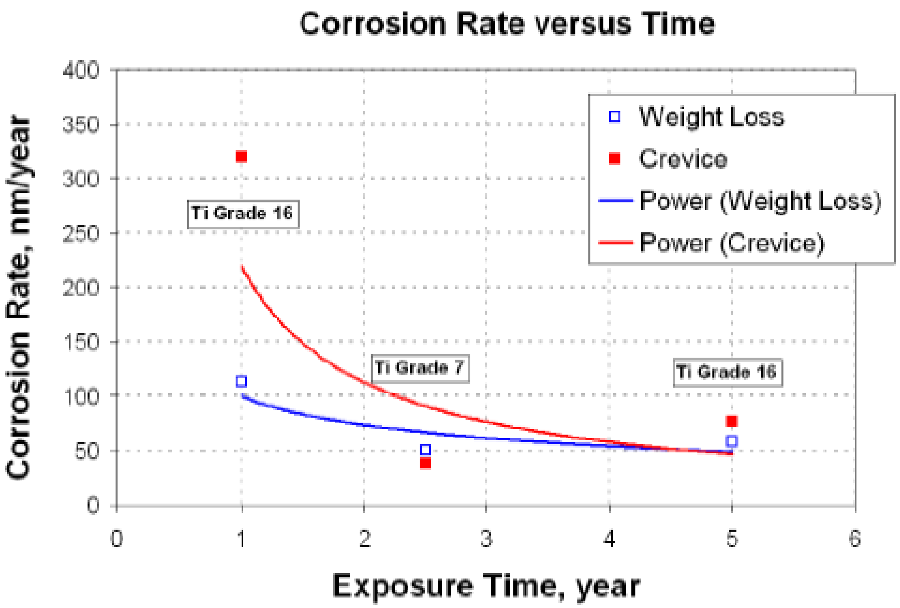
- **Seal Testing**
  - Laboratory testing of effectiveness of borehole seals followed by field-testing of effectiveness of ramp and shaft seals. Testing, as appropriate, to evaluate the effectiveness of backfill placement.
  - Seal testing is an important activity because seals and backfill are components installed for repository closure which contribute to: precluding human intrusion; limiting preferential pathways for water towards the emplacement drifts; precluding magma flow between drifts in the unlikely igneous disruptive event scenario; and enhancement of overall stability of nonemplacement drifts.



# Description and Purpose (continued)

- **Waste Package Monitoring**
  - Remote monitoring for evidence of external corrosion of the waste package to evaluate waste package integrity and confirm the absence of leakage and leak paths.
  - This activity is important as it is focused on directly observing waste package performance, which in turn has a direct impact on the Engineered Barrier System performance. The intact waste packages can protect the waste form from dripping water. However, the Engineered Barrier System SSCs may be compromised by various degradation processes, including corrosion and mechanical damage, therefore, it is important to observe them during this period to assure their performance.

# Description and Purpose (continued)

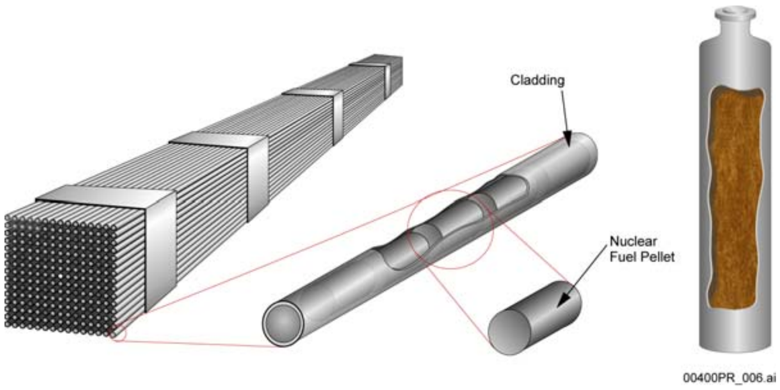



- **Corrosion Testing**
  - **Corrosion testing in the laboratory of waste package, waste package pallet, and drip shield samples in the range of representative repository thermal and chemical environments. Includes laboratory testing of general corrosion, phase transformations of Alloy 22; and localized corrosion.**
  - **Understanding the corrosion modes of the Engineered Barrier System components is key to evaluating the Engineered Barrier System performance. This activity is very important in assessing the expected conditions and provides for evaluation of the Engineered Barrier System functionality.**

# Description and Purpose (continued)

- **Corrosion Testing of Thermally Accelerated Drift Samples**
  - Corrosion testing in the laboratory of waste package, waste package pallet, and drip shield samples exposed to conditions in the thermally accelerated drifts. Includes corrosion model applicability and laboratory testing of general corrosion, phase transformations of Alloy 22; and localized corrosion.
  - Understanding the corrosion modes of the Engineered Barrier System components is key to evaluating the barrier performance. This activity is very important to assessing the expected conditions and provides for evaluation of the Engineered Barrier System functionality.

# Description and Purpose (continued)




- **Waste Form Testing in the Laboratory**
  - This activity is consists of waste form testing (including waste package coupled effects) in the laboratory under anticipated in- package conditions to evaluate results of waste form degradation models and evaluate in-package expected conditions.
  - This activity will evaluate if waste package source-term processes are within the uncertainty range used in the LA. This activity will likely reduce the uncertainty, by explicitly considering the cross coupling and other factors not considered to remain conservative. Understanding the waste package source-term processes is essential to evaluating the EBS performance.