U.S. DEPARTMENT OF ENERGY | Nuclear Energy

SAND2015-3247PE

Fuel Cycle Technologies

Deep Borehole Disposal (DBD) Summary

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Sandia National Laboratories

JFCS-FCAWG Meeting
Jeju, Korea
April 28-30, 2015

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US – ROK Technical Engagement Task 8: Borehole Research

- **May, 2013 –** Teleconference with researchers at KAERI
  - Discuss collaboration on DBD research
  - Exchange of technical documents
- **July-August, 2013 –** Visit to KAERI by Bill Arnold
  - Meetings with KAERI and KORAD staff on DBD research
  - Exchange of modeling and geological information
- **December, 2013**
  - Supplemental results from thermal-hydrologic modeling for DBD provided to KAERI DBD team for use in KAERI PA modeling and evaluation project.
- **January, 2014 –** Visit by Jong Youl Lee and Heui Joo Choi from KAERI to SNL
  - Technical meetings and attendance at DBD industrial Consortium meeting
- **June, 2014 –** JFCS-FCAWG Workshop in Richland WA
  - Specific deliverable status provided by K. McMahon

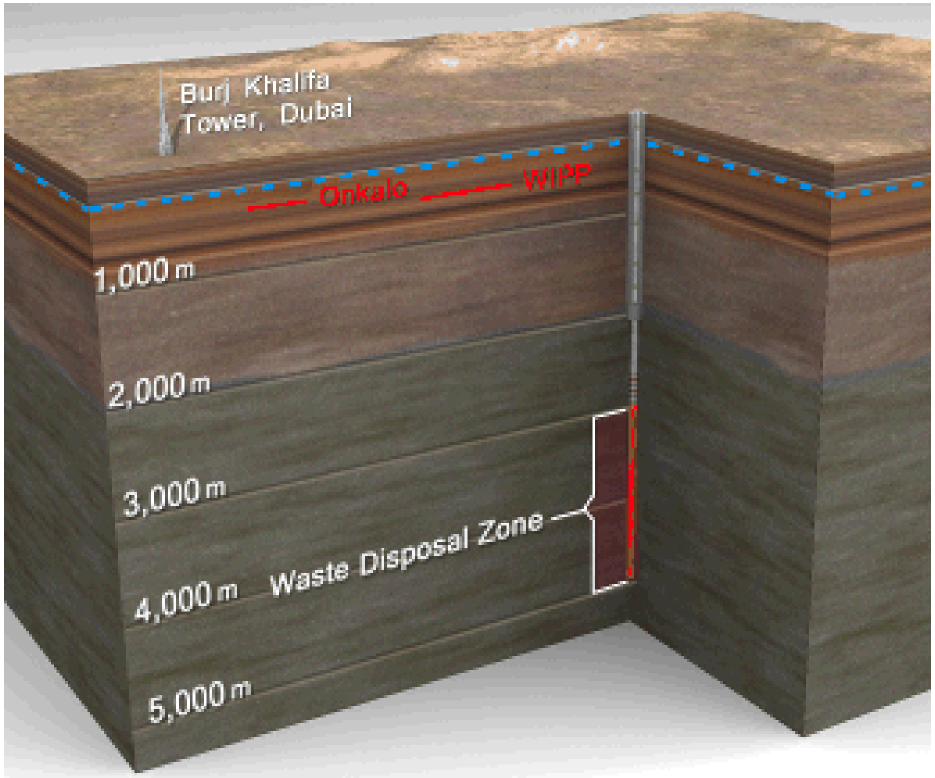
DBD Introduction

- **Research on deep borehole disposal (DBD) of high-level radioactive waste (HLW) and spent nuclear fuel (SNF) has been pursued at Sandia National Laboratories (SNL) since 2009**
  - Collaboration with groups at the Massachusetts Institute of Technology (MIT) and the University of Sheffield has been ongoing since that time
  - A DBD Consortium was organized to form a partnership with industrial and academic partners to further DBD research
- **DOE funding through the Used Fuel Disposition Campaign (UFDC) for DBD research began in 2012**
  - The Deep Borehole Field Test (DBFT) is a 5-year RD&D project initiated at the end of FY2014 and planned to be completed in FY2019

DBD Concept

- **5,000 m deep borehole(s) in crystalline basement rock, well below fresh groundwater resources**
  - Waste canisters in bottom 2,000 m
  - Seals in upper 3,000 m

- **Bottom hole diameter**
  - 17 in. for bulk waste forms or SNF/HLW
  - 8.5 in. for smaller DOE-managed waste forms



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DBD Safety Case – Preclosure and Postclosure

Waste canister and emplacement system can be engineered to maintain structural integrity and operational safety during handling and emplacement

Borehole seals (and DRZ) can be engineered/evolve to maintain a low-permeability barrier over the period of thermally-induced upward flow

Deep crystalline rocks typically have low permeability and lack hydraulic connection to shallow groundwater

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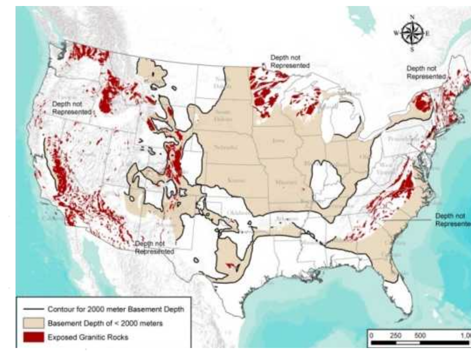
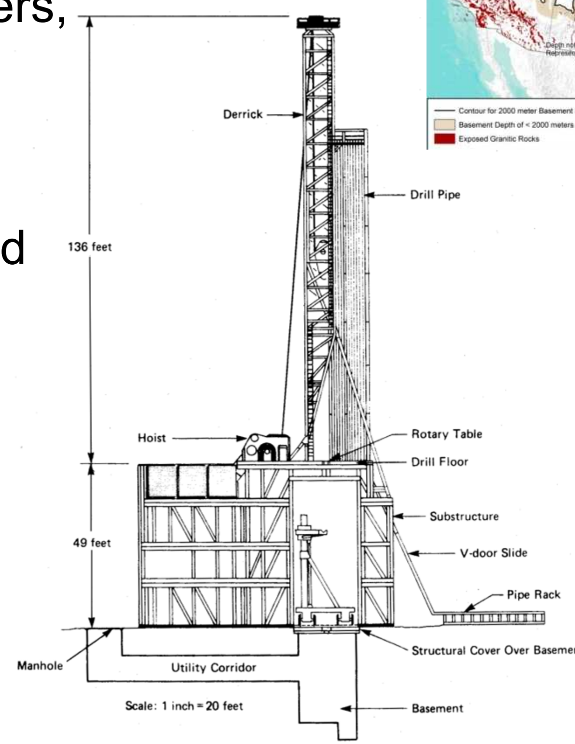
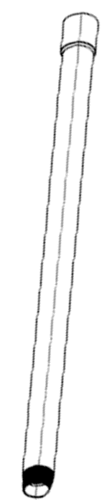
Deep Borehole Field Test (DBFT) – Objectives

- **DOE research, development, and demonstration (RD&D) to assess the viability of the DBD concept, without actual radioactive waste**
  - Site selection
  - Site characterization and downhole testing/confirmation
  - Design of boreholes, surrogate canisters, and emplacement system
  - Demonstration of deep drilling and construction technology
  - Demonstration of canister handling and emplacement in a deep borehole







Deep Borehole Field Test (DBFT) – Timeline

- **2014**
  - Siting RFI Issued
- **2015**
  - Draft Siting RFP Issued
  - Final Siting RFP and Siting Decision Planned
- **2016**
  - 8.5 in. Characterization Borehole: Drilling and Downhole Testing
- **2017-18**
  - 17 in. Field Test Borehole: Drilling and Canister Emplacement Demonstration
- **2019**
  - Test Analysis and Evaluation of Concept

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Deep Borehole Field Test (DBFT) – Siting Considerations

- **Technical**
  - Depth to crystalline basement
  - Crystalline basement geology
  - Horizontal stress
  - Seismicity and volcanism
  - Topographic relief and hydraulic gradient
  - Geochemical environment
  - Geothermal gradient
  - Natural resources potential
- **Logistical**
  - Availability of drilling services
  - Regulations and permitting
  - Site area and access
- **Sociopolitical**
  - Proximity to population centers
  - Local and stakeholder opinion

DBD FY2015 Technical Milestones

- September, 2014 – Deep Borehole Disposal Research: Geological Data Evaluation, Alternative Waste Forms, and Borehole Seals (FCRD-USED-2014-000332, SAND2014-17430R)
- September, 2014 – Project Plan: Deep Borehole Field Test (FCRD-UFD-2014-000592, SAND2014-18559R)
- June, 2015 – Site Evaluation for Deep Borehole Field Test (M2FT-15SN0817061)
- September, 2015 – Conceptual Design and Requirements for Characterization and Field Test Boreholes (M2FT-15SN0817081)
- September, 2015 - Deep Borehole Field Test Design and Requirements (M2FT-15SN0817091)

Backup Slides

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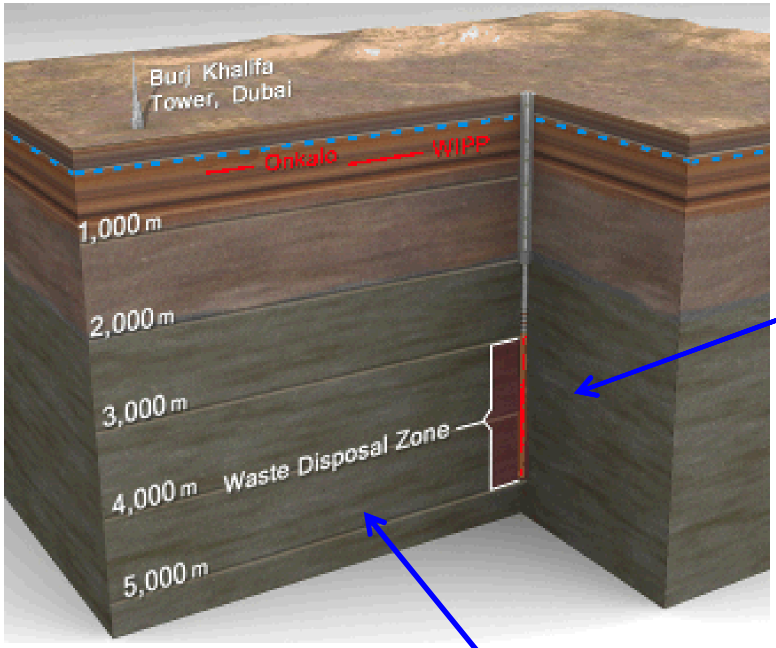
DBD Safety and Viability – Postclosure (Hydrogeochemistry and Waste Isolation)



Waste emplacement is deep in crystalline basement

- at least 1,000 m of crystalline rock (seal zone) overlying the waste disposal zone
- Crystalline basement within 2,000 m of the surface is common in many stable continental regions

Deep groundwater in the crystalline basement:

- has very long residence times – isolated from shallow groundwater
- has high salinity and is geochemically reducing – limits the solubility and enhances the sorption of many radionuclides in wastes
- exhibits density stratification (saline groundwater underlying fresh groundwater) – opposes thermally-induced upward groundwater convection

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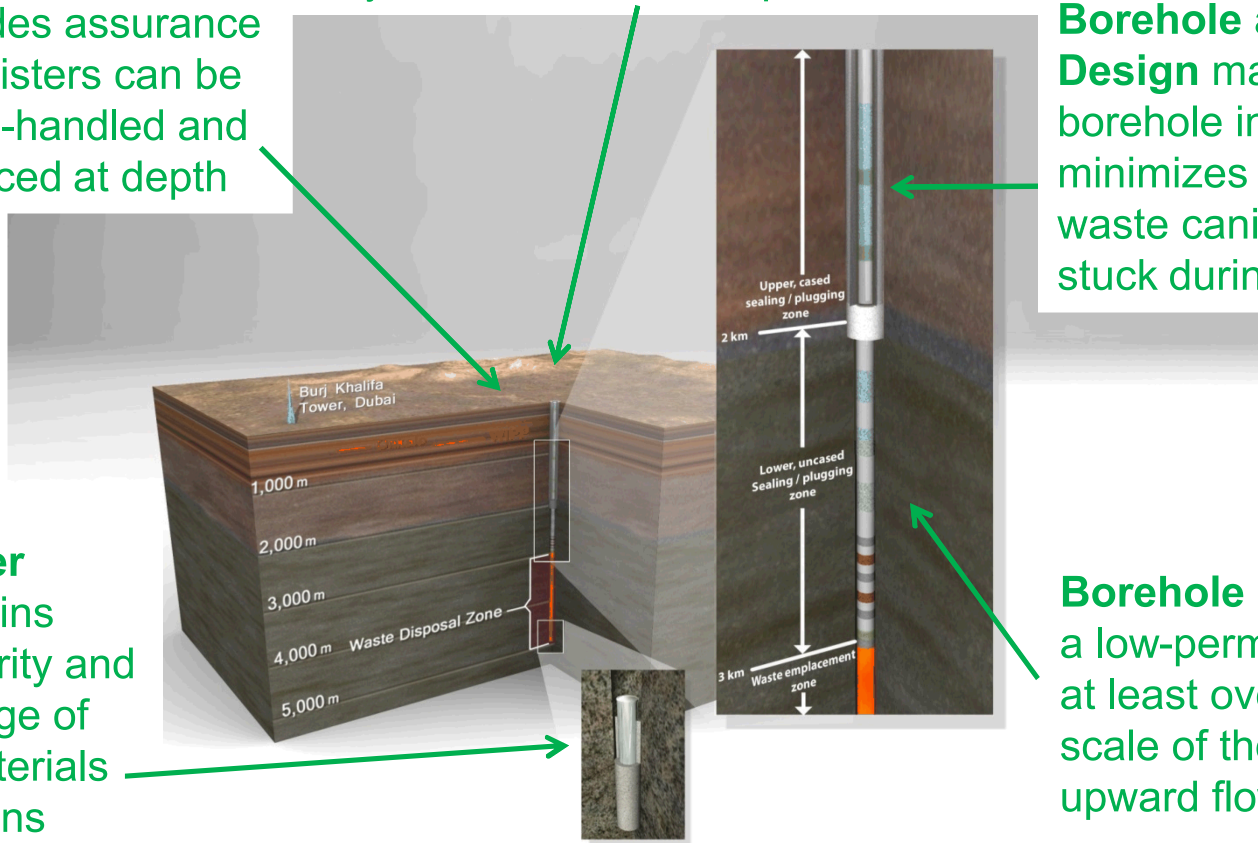
DBD Safety and Viability – Preclosure (Engineering and Operational Safety)

Drilling Technology exists to drill and case a large-diameter boreholes to 5,000 m depth in crystalline rock at acceptable cost

Emplacement System Design provides assurance the waste canisters can be safely surface-handled and can be emplaced at depth

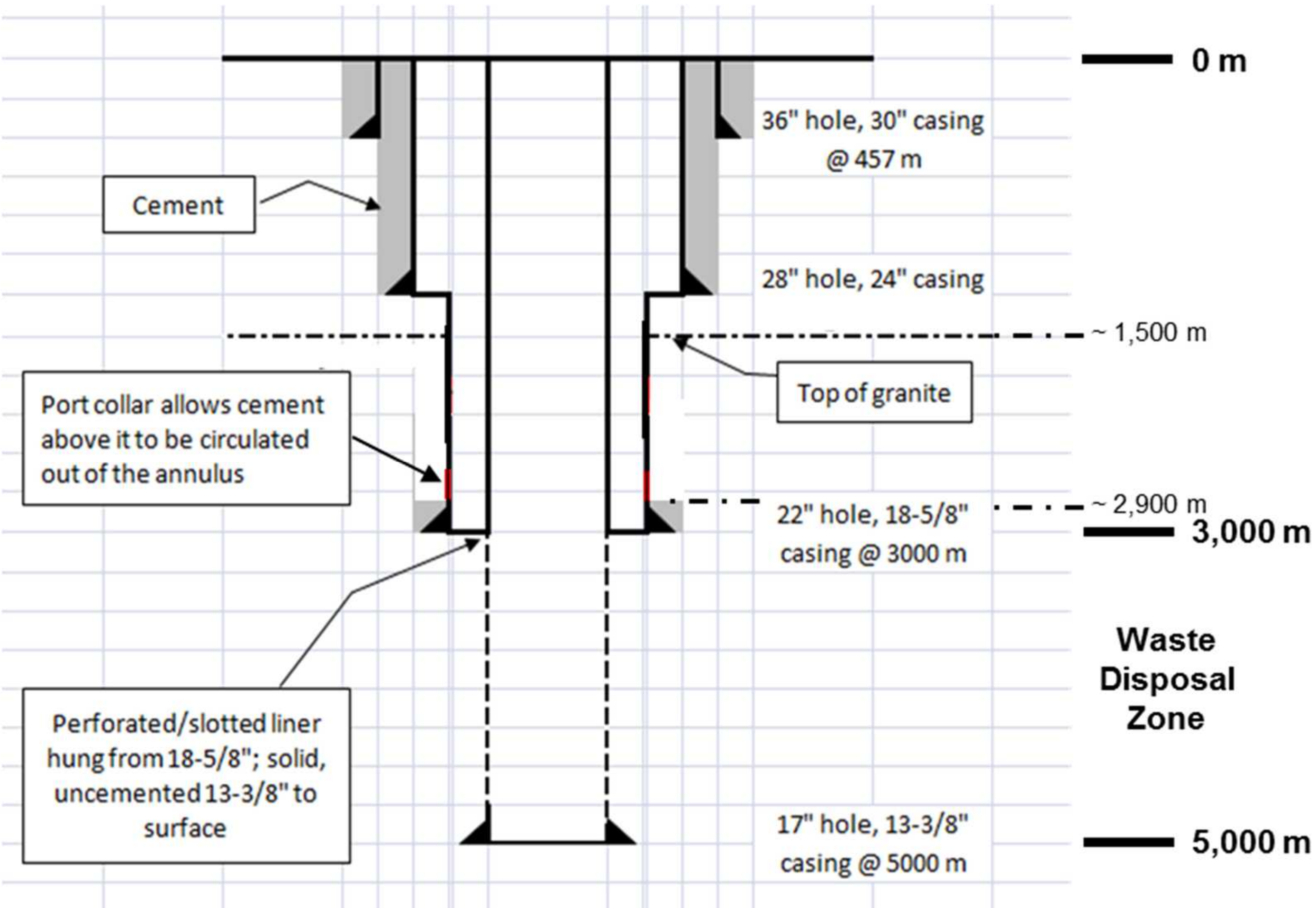
Borehole and Casing Design maintains borehole integrity and minimizes probability of waste canisters becoming stuck during emplacement



Waste Canister Design maintains structural integrity and prevents leakage of radioactive materials during operations

Borehole Seals maintain a low-permeability barrier, at least over the time scale of thermally-induced upward flow

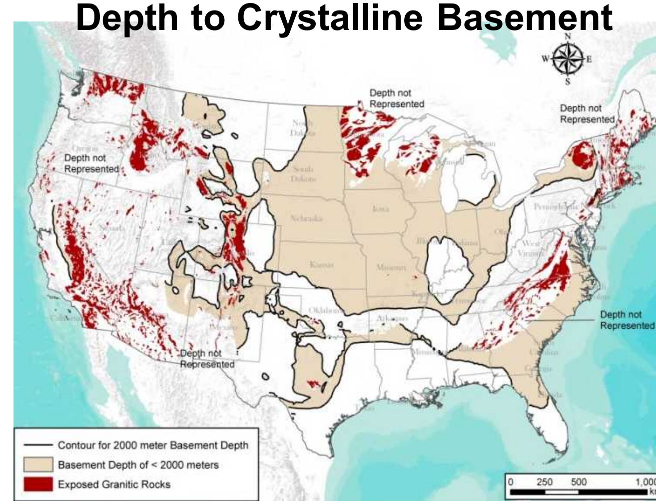
DBD Reference Borehole Design



Siting Considerations – Technical Factors

- **Depth to crystalline basement**
  - Depth less than 2,000 m allows for adequate disposal and seal zones within the crystalline basement
- **Crystalline basement geology**
  - Avoid known or suspected structural complexity (e.g., major faults, shear zones, rift basins)
  - Large plutons of felsic intrusive rocks are generally less heterogeneous and are more desirable
- **Horizontal stress**
  - Large differential in horizontal stress at depth can be an indicator of potential difficulties in drilling a vertical hole and of borehole instability (e.g., borehole breakouts and/or an enhanced disturbed rock zone around the borehole)
- **Seismicity and volcanism**
  - Seismic ground motion risk during operations
  - Quaternary-age faulting and volcanism are indicators for structural complexity and potential future tectonic activity or volcanism

Depth to Crystalline Basement

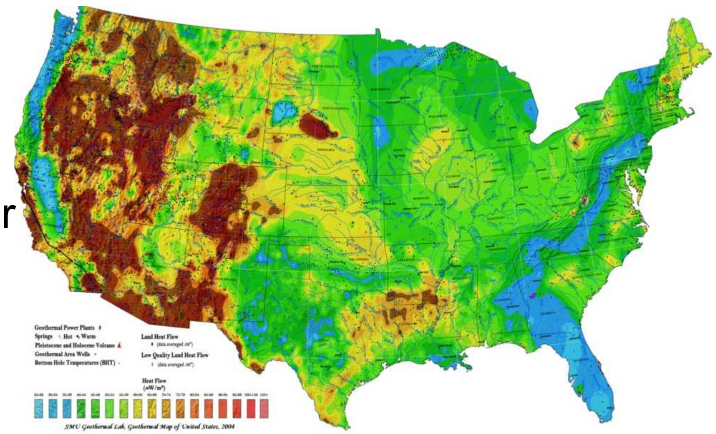


Volcanism and Recent Faults

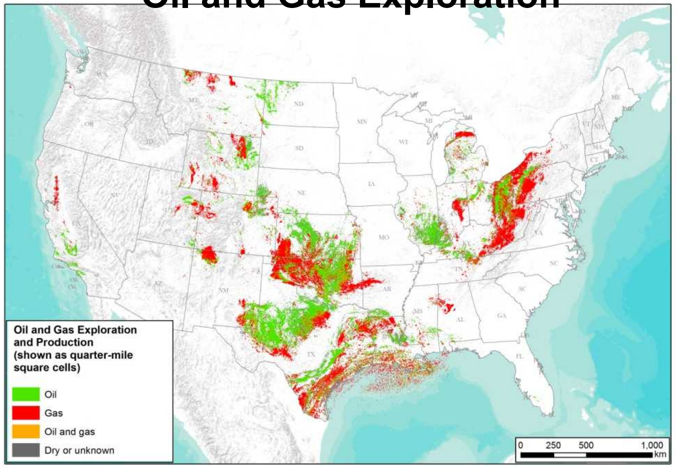
Siting Considerations – Technical Factors (cont.)

- **Topographic relief and hydraulic gradient**
  - Hydraulic gradients in the deep subsurface are generally related to regional variations in topography and can lead to the potential for upward flow in regional discharge areas. However, deep groundwater can be isolated and stagnant in some hydrogeologic settings, in spite of topographic effects.
- **Geochemical environment**
  - High salinity and geochemically-reducing conditions tend to reduce radionuclide mobility
- **Geothermal gradient**
  - High heat flux can lead to upward hydraulic gradients and is also related to the potential for geothermal drilling
- **Natural resources potential**
  - Petroleum and mineral resources exploration and/or production could lead to human intrusion into the deep borehole and/or impact the release of radionuclides to the overlying sediments.

Geothermal Map – Heat Flow



Oil and Gas Exploration



Siting Considerations – Logistical Factors

- **Availability of drilling contractors and support services**
  - Capability for drilling a large-diameter hole to approximately 5,000 m depth
- **Regulations and permitting**
  - Legal and regulatory requirements should be achievable (the regulatory environment is different in different states and for Federal versus private land)
  - Existing regulations for post-closure safety in mined geologic repositories (e.g., 10 CFR 60 and 40 CFR 191) would need to be updated to be applicable to deep borehole disposal
- **Site area**
  - Should be sufficient for drilling, construction, surface facilities (e.g., waste handling), and downhole operations
- **Site access**
  - Reasonable access to roadways and/or railways for transportation of waste and other materials (waste transportation costs could vary considerably depending on the disposal site location relative to waste storage or nuclear power plant locations)

Siting Considerations – Sociopolitical Factors

- **Proximity to population centers**
- **Opinion (e.g., support or opposition) of state and local entities and other stakeholders towards nuclear facilities**
- **Willingness to host**