Summary of NWTRB Deep Borehole Disposal Workshop

Presented to:
Interagency Steering Committee on Performance and Risk Assessment

Presented By:
Bret Leslie, Ph.D., Senior Professional Staff

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The views presented in this talk do not represent those of the U.S. Nuclear Waste Technical Review Board, an independent Federal agency, charged with evaluating the technical and scientific validity of the U.S. Department of Energy's efforts to implement the Nuclear Waste Policy Act

Deep Borehole Disposal Workshop

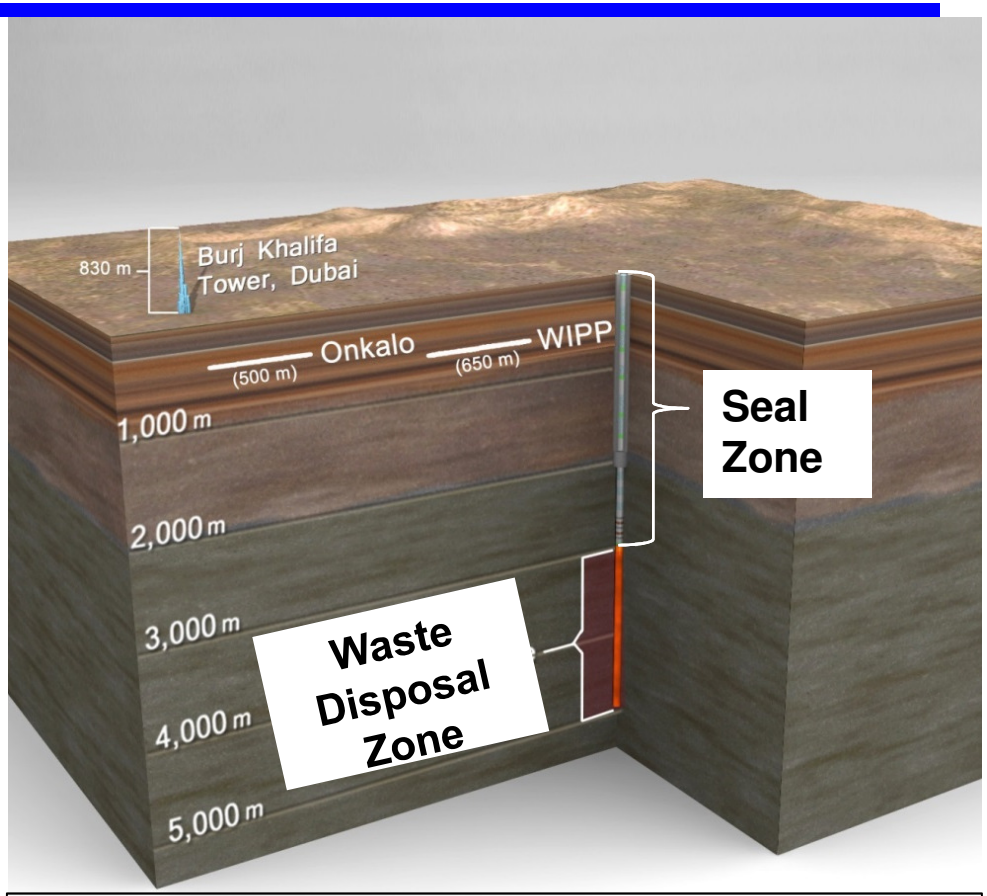
- What
  - International Technical Workshop on Deep Borehole Disposal of Radioactive Waste
- When and where
  - October 20-21, 2015 in Washington DC
- Materials available for review at http://www.nwtrb.gov/meetings/meetings.html
  - Agenda and workshop presentations
  - Transcripts and indexed webcast
  - Six supporting presentations from a NWTRB briefing by Sandia National Laboratories (SNL) staff that covered the technical topics presented by DOE and SNL during morning of October 20th

Workshop Topics

- DOE's
  - Strategy for Management and Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste
  - Deep Borehole Disposal Research Program
  - Deep Borehole Field Test: Site Characterization and Design Requirements
- International Perspective on Deep Borehole Disposal
- Panel discussions
  - Experience in Deep Drilling in Crystalline Rocks; Emplacement Mode; Borehole Seals; Hydrogeology and Geochemistry at Depth: Anticipated Conditions and Characterizing the Conditions (2 panels); Multiple Barriers: Waste Forms and Canister Materials; and Efficacy of Deep Borehole Disposal and Risk Analysis
- U.S. Environmental Protection Agency (EPA) Perspectives on Deep Borehole Disposal

DOE's Deep Borehole Disposal Concept

- 5,000 m deep borehole(s) in crystalline basement rock, well below fresh ground water resources
- Small DOE waste forms (e.g., cesium and strontium capsules)
- Sited using technical siting guidelines to avoid undesirable conditions (e.g., young meteoric water at depth)



Legend: The depths of the Waste Isolation Pilot Plant and the Finnish geologic repository and the height of the Dubai tower are provided for scale only

(After Gunter 2015)

Some Key Observations From Panelists

- Summary panel session with key observations from a representative of each panel
  - Observations based on all information in the workshop
- Experience in deep drilling
  - Plan for the unforeseen: develop drilling, completion and sealing plan based upon real downhole conditions
  - Integrated approach is needed for drilling/completion in relation to rest of project
  - Field Test site needs detailed 3-D site characterization, combining surface-based and downhole methods
  - Many questions remain about seal design and implementation
  - Long-term downhole monitoring is needed

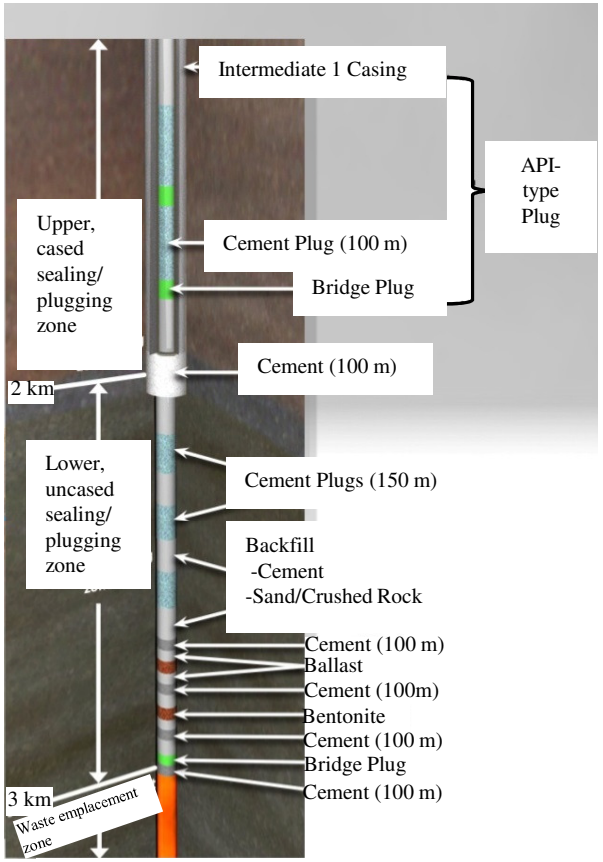
Some Key Observations From Panelists

- Emplacement Mode
  - Place design, operational, and science objectives on an equal footing
  - Simulate all aspects of deep borehole disposal implementation as if it were using radioactive wastes
  - Emphasize engineering controls, not administrative controls
  - Consider measures to mitigate risks during emplacement
  - Develop an organizational structure to establish and demonstrate a culture of safety
  - Develop strategy to integrate conventional borehole operations and remote handling of highly radioactive materials
  - Plan for contingencies
    - Include provisions to recover from minor and major events remotely

All key observations are at http://www.nwtrb.gov/meetings/2015/oct/panelists.pdf

Some Key Observations From Panelists

- Borehole seals
  - Upper zone: Fill borehole with compacted solid material. Use cementing techniques including squeezing and verify cement seals outside of casing.
  - Detailed seal development and testing programs are recommended.
    - Long-term testing; accelerated testing methods?
  - Modelling.
    - For assessment of long-term performance.
  - Detailed assessment of the sealing environment is required



(After Gunter 2015)

Some Key Observations From Panelists

- Hydrogeology at Depth: Anticipated Conditions and Characterizing the Conditions
  - Measurement of permeability and formation pressures may prove to be very difficult within the disposal zone due to borehole quality, heterogeneity and very low permeability
  - Adequate assessment of heterogeneity at a proposed disposal site should include multiple characterization boreholes and contiguous measurements within the disposal zone
  - Emplacement strategies, monitoring and safety assessment will need to be adaptive to deal with hydrogeologic heterogeneity
  - Long groundwater residence times (millions of years) inferred from environmental tracers in pore fluids (noble gases, isotopes, etc.) do not preclude the potential for active flow through interconnected permeable pathways from disposal depths to the near surface.

Some Key Observations From Panelists

- Geochemistry at Depth: Anticipated Conditions and Characterizing the Conditions
  - Careful, coordinated planning (e.g. geophysics, hydrogeology, geochemistry, microbiology) needed for sampling, analyses & modeling
  - Introduce multiple tracers during drilling & emplacement of waste
  - Need multiple boreholes for characterization & monitoring
  - Need borehole tests that are more realistic for storage of radioactive waste (e.g. heater + tracer); what do you need to make it a successful & translatable “proof of concept” project?
  - Gases will be present & could be a safety/storage concern in repository or near-surface environment (e.g. metal embrittlement, explosions)

All key observations are at http://www.nwtrb.gov/meetings/2015/oct/panelists.pdf

Some Key Observations From Panelists

- Multiple Barriers: Waste Forms and Canister Materials
  - The deep borehole disposal concept is intended to be multi-barrier but with primary reliance on the geological barrier
  - More systematic consideration of multi-barriers should be carried out at an early stage
  - Ideally, we need a good understanding of the geochemical environment to achieve this – but we recognize considerable uncertainties
  - This could be mitigated by more robust waste packages and assigning appropriate credit to performance
  - Conceptual safety challenge in assuming initial repository state involves dissolution of radio cesium / strontium in solution rather than being retained as a solid
  - The seal / liner / rock disturbed zone is a likely pathway for radionuclide migration – conceptually this is thought to be within engineering capability, but remains to be demonstrated

All key observations are at http://www.nwtrb.gov/meetings/2015/oct/panelists.pdf

Some Key Observations From Panelists

- Efficacy of Deep Borehole Disposal and Risk Analysis
  - Advantages – disadvantages?
    - Claimed passive safety
    - No full site characterization or safety assessment yet performed
  - Calculated doses mean little without developed concept and site
  - Expected uncertainties:
    - Operational risks likely to dominate
    - Post-closure risks may pop up when you have a better understanding of scenarios
  - Effect of high temperatures: Depends on waste form and needs consideration
  - Lack of international experience: No benchmark available

All key observations are at http://www.nwtrb.gov/meetings/2015/oct/panelists.pdf

EPA Perspectives on Deep Borehole Disposal

- Described applicability of Nuclear Waste Policy Act (NWPA) and its standards (40 CFR 191) to boreholes
  - Boreholes used for disposal are a “repository” as defined by NWPA
  - 40 CFR 191 applies, as written, to deep borehole disposal
- Some questions raised by boreholes
  - What is the accessible environment for purposes of determining compliance?
  - What constitutes the disposal system for a deep borehole?
  - How should we treat one borehole vs multiple boreholes?
  - How should intrusion be considered? Is it necessary? How to discern the probability of an intrusion?
  - Can you adequately characterize the disposal system at depth?
  - What engineered barrier would be needed?
  - How can DOE ensure that the waste could be retrieved? When?

Questions?