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Salt Disposal R&D: Big Picture

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Roadmap Meeting

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Salt as a Disposal Medium

- **Salt's benefits as a medium for disposal:**
  - Impermeable to flow in far field ($\leq 10^{-20}\ \mathrm{m}^2$)
  - High thermal conductivity ($\sim 5\ \frac{\mathrm{W}}{\mathrm{m \cdot K}}$)
  - Relatively dry (<1% porosity; <5% total H_2O)
  - Biologically simple
  - Creep closure and healing of excavations/fractures
  - Easily mined via continuous miner
  - Granular salt reconsolidates back to intact salt
- **No release to far field without human intrusion**
  - WIPP Performance Assessment
  - Long time scales/Large length scales
  - Shaft seals only pathway out of repository

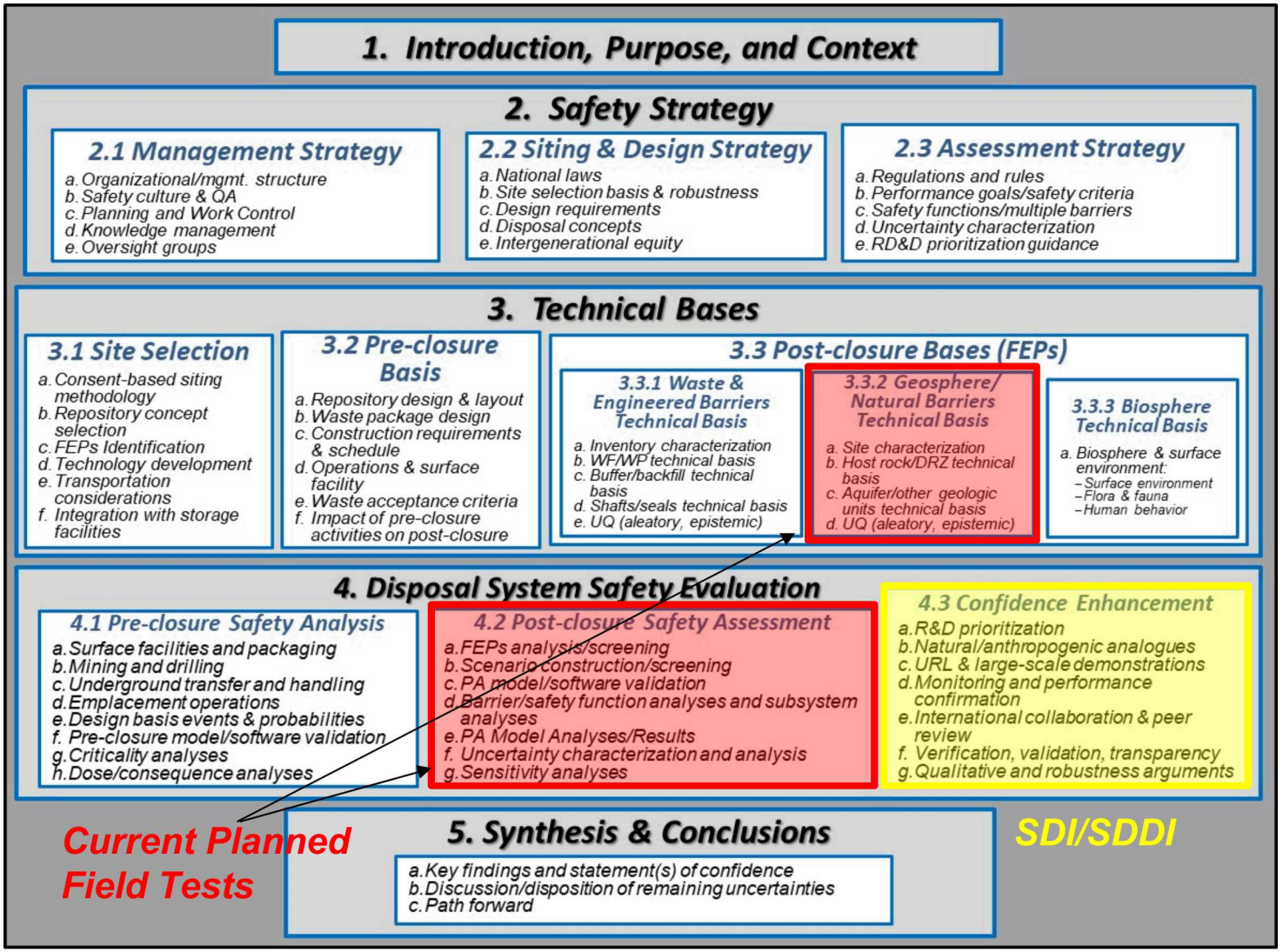
Salt as a Disposal Medium

- **In short term/near field salt is more complex**
  - Salt is very soluble in water
  - Brine very corrosive to common waste package materials
  - Water exists in 3 significant forms
    - *Fluid inclusions migrate under T gradient*
    - *Hydrous minerals dehydrate at elevated T*
  - Hypersaline brines have complex geochemistry
    - *Requires Pitzer model or similar*
  - Complex geomechanical behavior
    - *Cannot support differential stress (openings creep closed during operations – WIPP requires significant maintenance)*
    - *Constitutive models are complex and still under research*
    - *Laboratory/field behavior notably different (creep at low τ)*
  - Granular salt reconsolidation:
    - *Reconsoldiation path very tress, T & water content sensitive.*
  - HMC aspects of intact salt are quite T -sensitive

Salt as a Disposal Medium

- **Salt's long-term PA benefits vs. short-term complications**
  - Long-term benefits generally seen as more important
- **WIPP Performance Assessment**
  - Non-heat generating waste
  - Conservative regarding waste package corrosion (took no credit)
  - Granular salt reconsolidation only considered in shaft seal (no backfill around waste)
  - Human intrusion brine source overwhelms local brine source
- **Study short-term "complications" and "deviations"**
  - Importance to Safety Case?
    - *Initial conditions to long-term performance assessment?*
  - Importance to Confidence Enhancement?
  - Importance to Pre-Closure Safety?

Salt R&D in Safety Case



Salt R&D Gaps: 2012 UFD Roadmap

- **2012 UFD Roadmap Document**
  - Five of top 6 high-priority FEPs (Appendix B) are on Salt [score]
    1. *2.2.01.01 – Evolution of Clay/Shale EDZ [8.00]*
    2. *2.2.08.01 – Flow through salt host rock [7.73]*
    3. *2.2.08.02 – Flow through other geologic units near salt repository [7.73]*
    4. *2.2.08.06 – Flow through the salt EDZ [7.73]*
    5. *2.2.08.04 – Effect of repository excavation on flow in salt host rock [7.10]*
    6. *2.2.08.07 – Mineralogic dehydration of salt [6.49]*
- **These FEPs rated "High: information essential to decisions"**
  - Site Selection
  - Site Characterization
  - Site Suitability

Salt State of the Art: 2012 UFD Roadmap

- **2012 UFD Roadmap Document: "State of the Art" for key FEPs**
  - Need to understand ***fracturing and healing*** in clays and salt.
  - ***Water migration in salt is a unique process that needs to be better understood***. Need to understand thermal and pressure gradients and gas generation and migration.
  - Need to know the ***evolution of the characteristics of the EDZ*** under the thermal-mechanical and wetting changes (clay and salt).
  - Need to understand the ***coupled evolution of near-field host rock*** (EDZ) and backfill.
  - Considerable work has been done for WIPP and European programs.
  - European programs starting multi-year projects investigating thermal-mechanical and moisture effects in the EDZ.
  - This issue includes ***other disturbances (e.g., ventilation) beyond just excavation effects***.
- **2012 UFD Roadmap "take-away message" regarding Salt**
  - Brine migration (+ventilation dry-out) needs to be better understood
  - THMC Evolution of EDZ is complex, but important
  - Significant existing international field testing database exists

Salt R&D Priorities

- **Salt R&D is focused on field test**
  - Shakedown heater test in existing boreholes (now)
  - Heater test in new built-for-purpose boreholes (later FY19)
  - Larger scale follow-on demonstrations
- **Salt R&D Modeling/Lab Efforts Support field test**
  - Numerical modeling to design and interpret results of field test
    - *LANL (FEHM) & LBL (TOUGH-FLAC)*
  - Laboratory testing to analyze brine/gas/solid samples collected during field test
    - *SNL (solids and liquids) & LANL (liquids and gases)*

Integration with GDSA/PA & Safety Case

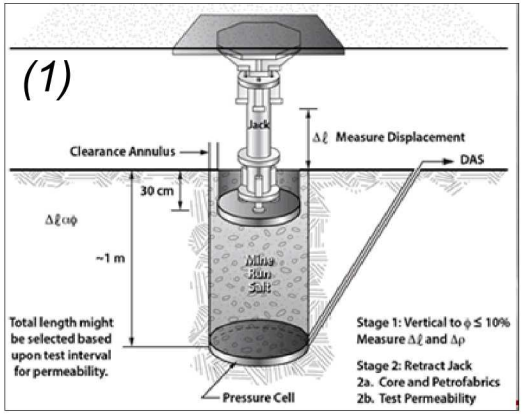
- **Developments for GDSA are lower priority in Salt R&D (FY18)**
  - Numerical modeling to design/interpret tests takes priority
- **GDSA and PA potential contribution areas for Salt**
  - Pitzer model needed to do "full chemistry" in salt (using EQ3/6 now)
  - Other chemistry → fluid flow coupling effects with brine
    - *FEHM implements some of these now (e.g., vapor-pressure lowering)*
    - *Implementing analogous features in PFLOTRAN is possible*
  - EDZ development and evolution is especially important in salt
    - *TOUGH-FLAC implements these now*
    - *Moving features from TOUGH-FLAC to PFLOTRAN is difficult / requires "response surface" for PA*

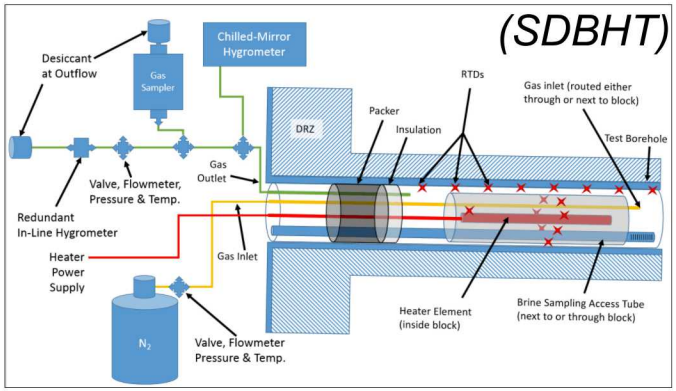
Recent Salt Field Test History

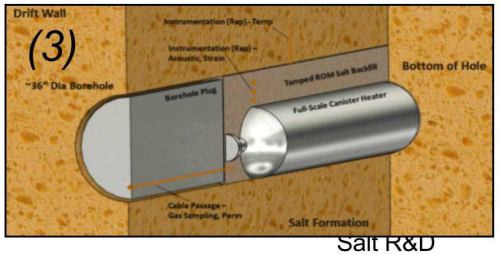
- **DOE-EM planned Disposal Demonstrations planned at WIPP**
  - DOE-Environmental Management (DOE-EM) Carlsbad Field Office runs WIPP
  - Salt Disposal Investigations (SDI) – 2011 (hot alcove-style disposal demo)
  - Salt Defense Disposal Investigations (SDDI) – 2013 (cooler in-drift disposal demo)
- **DOE-NE Salt R&D Albuquerque Workshop (March 27, 2013)**
  - SNL, LANL, LBNL, DOE: salt field experiments consistent w/ UFD roadmap
- **DOE-EM work on SDI/SDDI stopped (Feb 7, 2014)**
- **DOE-NE Small-scale (phased) testing approach at WIPP**
  - 2014 DOE-NE ramps down generic modeling and laboratory work on salt
  - 2014-2016: morphed from drift-scale demonstration to borehole-scale test
  - Small-scale borehole heater test designed in FY17 (SNL/LANL/LBNL)
  - Small-scale borehole heater test implementation beginning ***June 2018***

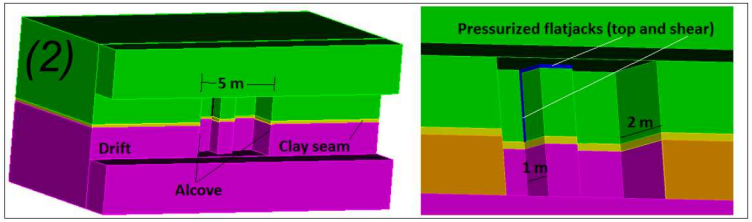
Salt Disposal R&D Five-Year Plan

- **Small-Diameter Borehole Heater Test (SDBHT)**
  - FY17-18 test plan / late FY18 begin execution
  - Isothermal test & 120 °C test in existing holes
  - Re-design for follow-on heated tests
- **Other Possible Tests in "Out Years"**
  - Further SDBHT configurations
  - Intermediate-scale testing
    1. *Large-scale granular salt reconsolidation*
    2. *Shear testing (being done at WIPP)*
    3. *Single-canister thermal test*
- **Laboratory/Modeling Investigations**
  - Only those supporting field investigations









Salt Host Rock Integration Pyramid