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FEP Catalog for HLW/SNF Disposal in Salt

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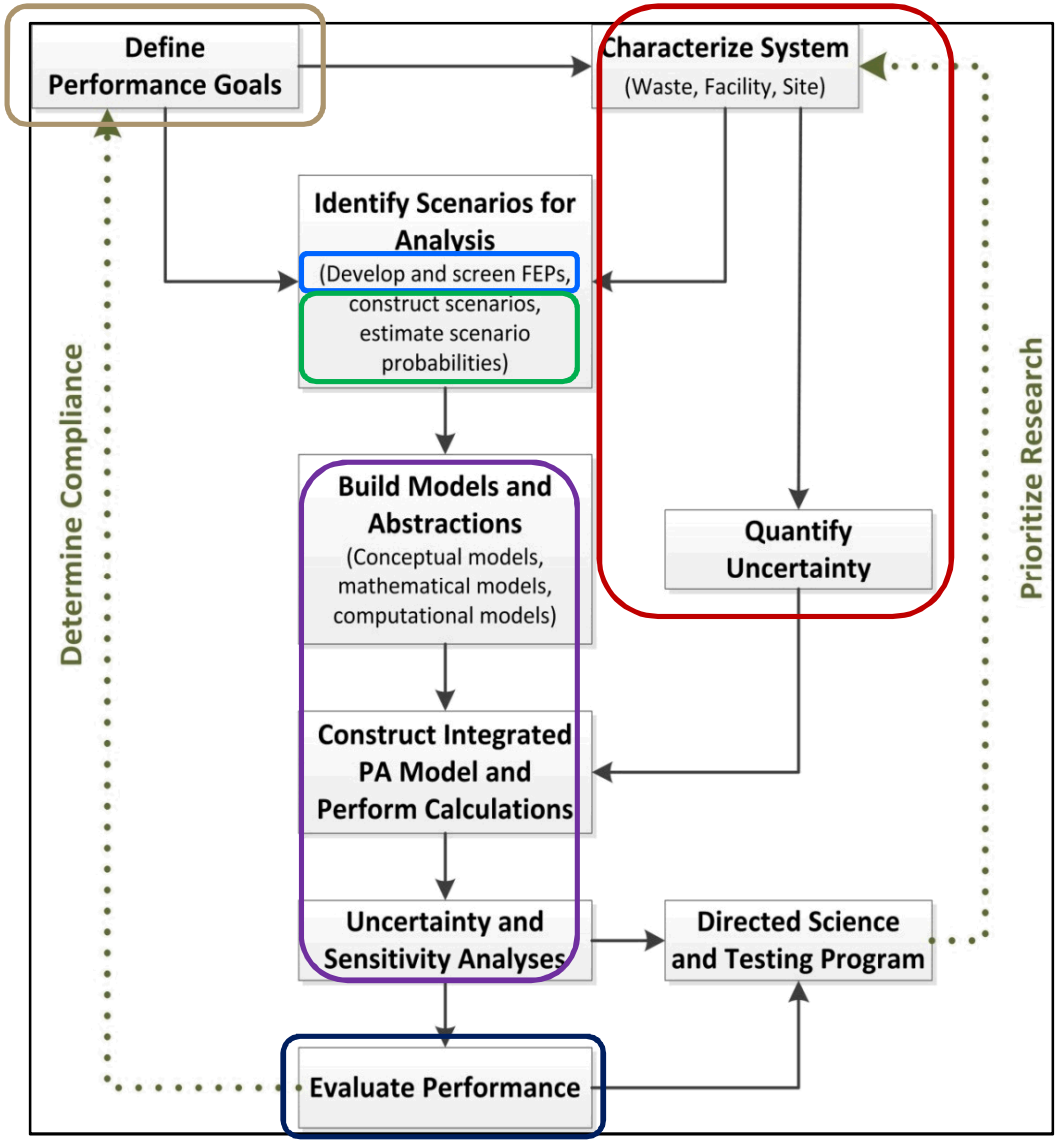
Outline

- Safety Assessment Methodology
- What are Features, Events and Processes
- Identification of FEPs for the Catalog
- Refinement of Generic FEPs for HLW/SNF Disposal in Salt
- Initial FEPs Screening for HLW/SNF Disposal in Salt
- Future FEPs Screening Activities for HLW/SNF Disposal in Salt

Safety Assessment Methodology

- Formal structure to guide iterative quantitative post-closure assessments
  - Application Objectives
  - Site Characterization
  - **FEP Analysis**
  - Scenario Development
  - PA Model Implementation
  - Assessment Results

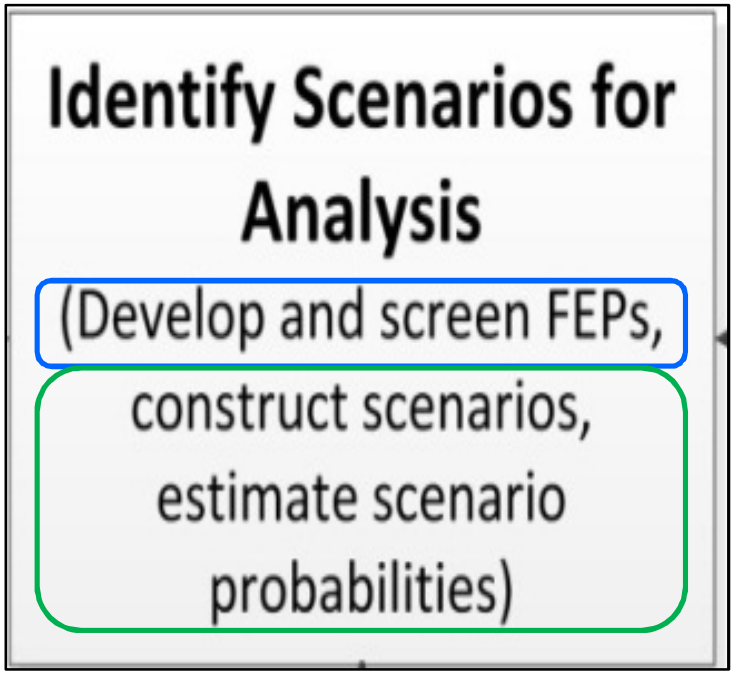


Features, Events, and Processes

- Feature(s)
  - An *object, structure, or condition* that has a potential to affect repository system performance (NRC 2003, Section 3)
- Event(s)
  - A natural or human-caused *phenomenon* that has a potential to affect repository system performance and that occurs during an interval that is short compared to the period of performance (NRC 2003, Section 3)
- Process(es)
  - A natural or human-caused *phenomenon* that has a potential to affect repository system performance and that occurs during all or a significant part of the period of performance (NRC 2003, Section 3)
- A "FEP" generally encompasses a single phenomenon
  - Typically a FEP is a *process* or *event* acting upon a *feature*

Development of a FEPs Catalog

- Formal FEP Analysis for PA consists of the systematic implementation of:
  - FEP Identification
  - FEP Screening
- FEP Analysis is performed iteratively with Scenario Development and PA Model Implementation
- References – FEP Analysis
  - NEA International FEP Database - (NEA 1999a, 2006)
  - US OCRWM - BSC (2005), SNL (2008)
  - US UFD - Freeze et al. (2010, 2011), Freeze and Swift (2010)



Identification of FEPs

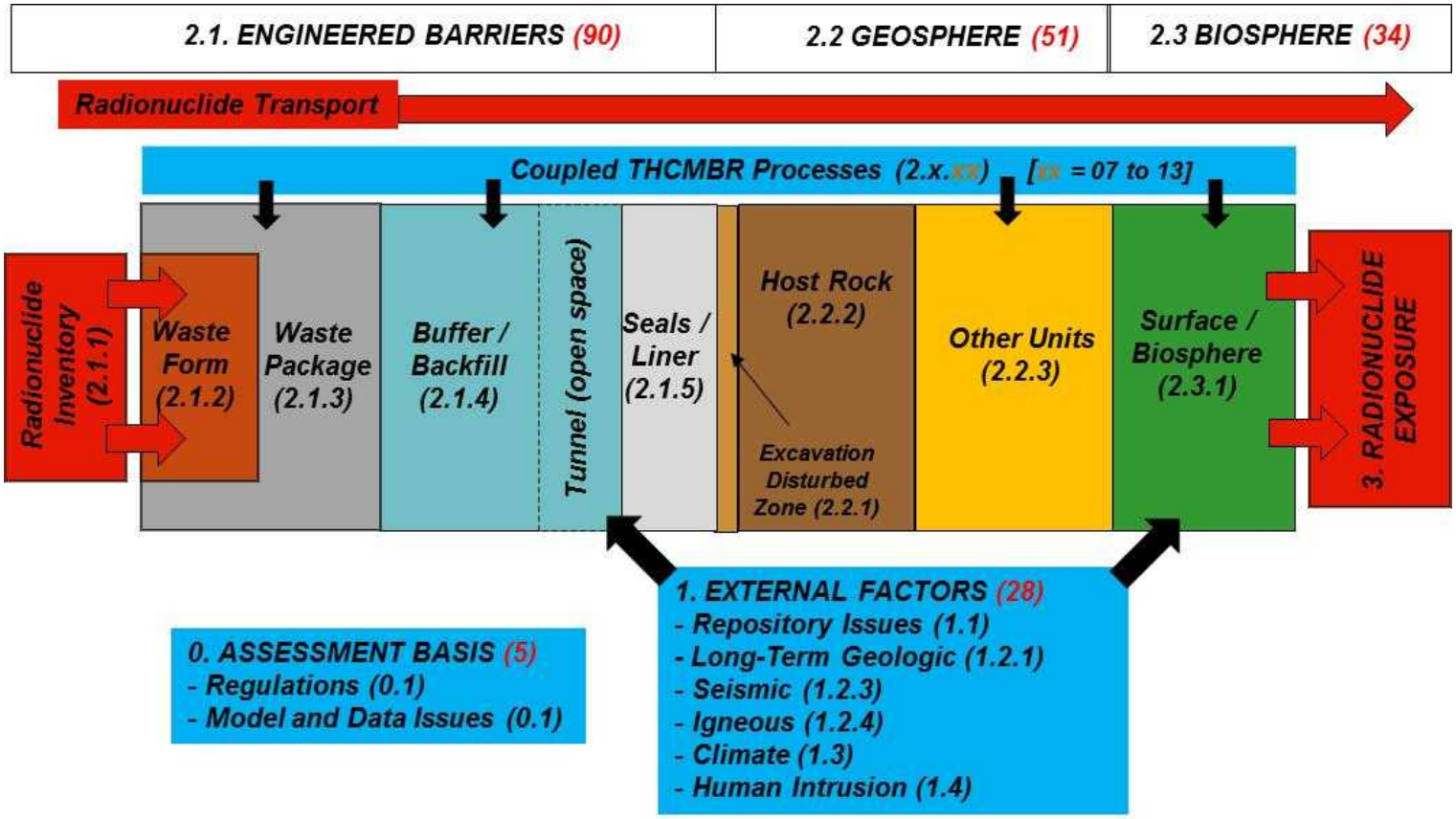
- NEA FEP Database is the basis for many FEP lists
  - comprehensive NEA FEP list (NEA 1999, 2006) contains ~2000 FEPs from 10 international programs in 6 countries
- Yucca Mountain Project (YMP) list = 374 FEPs
  - ~400 site- and design-specific phenomena considered in addition to ~2000 NEA FEPs (SNL 2008)
  - NEA list contains many duplicate or redundant FEPs – e.g., same FEP listed in each of the 10 programs
  - Categorization identified additional NEA FEPs that could be combined
- Preliminary UFD FEP list = 208 FEPs
  - Site- and design-specific YMP FEP list provides initial basis for generic UFD FEP list applicable to a range of disposal options
  - Focus on generic details results in smaller number of broader FEPs (Freeze et al. 2010, 2011)

Development of a FEPs Catalog for HLW/SNF Disposal in Salt

- Reviewed UFD generic FEPs list
  - Applicable to four different media
  - Used NEA hierarchical numbering system
- Modified the "Associated Processes" where Needed
  - more salt-specific for some FEPs
  - Cross-checked to WIPP FEPs catalogue
- Made Some Assumptions *(for initial salt FEPs screening)*:
  - Some early waste package failures are assumed to occur
  - The outer corrosion barrier of the waste package remains structurally intact and acts as a barrier to flow during the period up to the peak thermal pulse. However, the outer corrosion barrier is not a long-term hydrologic barrier after the peak thermal pulse
  - A "reference" salt design/site was developed *(for initial salt FEPs screening)*:

Reviewed UFD Generic FEPs List

- NEA hierarchical numbering system used to categorize 208 UFD FEPs by physical domains and features, THCMBR processes, and external factors/events



Preliminary UFD FEPs - Example Listing for 1 of the 208 FEPs

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Broad description of FEP provided in the "Description" column

Additional FEP detail provided in the "Associated Processes" column

Traceability and comprehensiveness provided by the "Related FEP Number" and "Domain" columns

Screening Decision is dependent on Disposal Option

UFD FEP Number	Description	Associated Processes	Related FEP Number	Domain	Disposal Options	Screening Decision
2.1.08.06	Alteration and Evolution of EBS Flow Pathways	- Drift collapse - Degradation/consolidation of EBS components - Plugging of flow pathways - Formation of corrosion products - Water ponding [see also Evolution of Flow Pathways in WPs in 2.1.03.08, Evolution of Backfill in 2.1.04.01, Drift Collapse in 2.1.07.02, and Mechanical Degradation of EBS in 2.1.07.10]	2.1.08.12.0A 2.1.08.15.0A 2.1.03.10.0A 2.1.03.11.0A 2.1.09.02.0A	EBS (FLOW)		

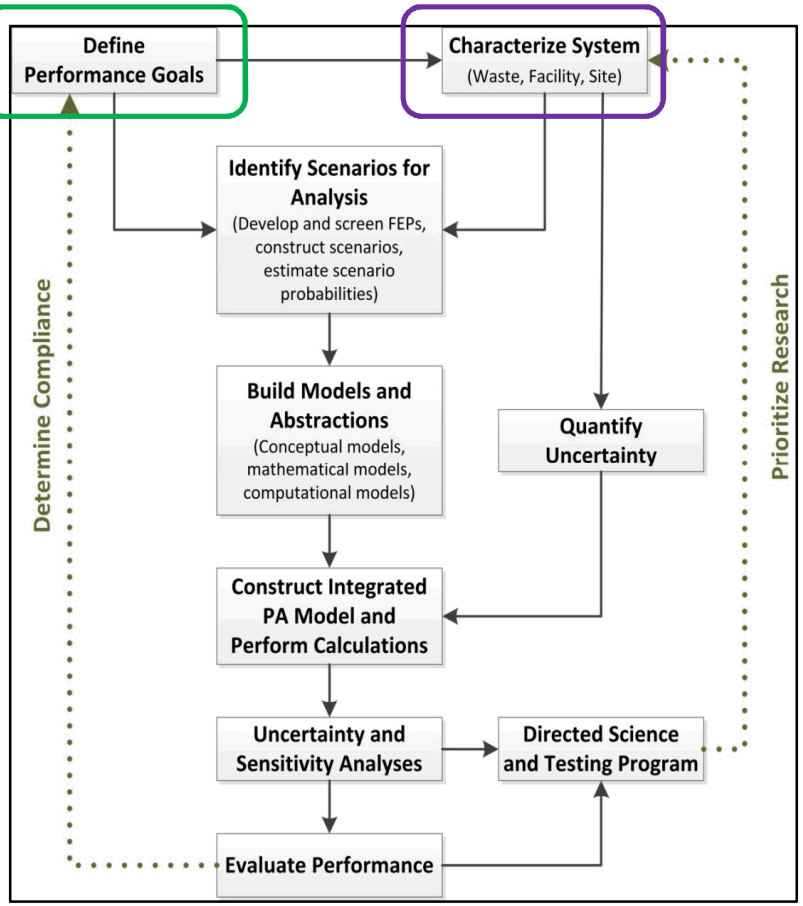
UFD Generic FEPs Modified to be Salt-Specific

UFD FEP Number	Description	Associated Processes	Related FEP Number	Domain	Disposal Options	Screening Decision
2.1.07.03	Mechanical Effects of Backfill	- Protection of other EBS components from rockfall / drift collapse	2.1.04.04.0A	EBS	- Mined crystalline - Mined shale/clay - Mined salt - Deep borehole crystalline	

UFD FEP Number	Description	Associated Processes	Related FEP Number	Domain	Disposal Options	Screening Decision
2.1.07.03	Mechanical Effects of Backfill	- Crushed salt backfill should consolidate during room closure process - Static and dynamic loading on EBS structures - Restricts displacement of EBS components during ground motion and fault displacement - Protection of ~~other~~ EBS components from rockfall / drift collapse caused by ground motion and fault displacement	2.1.04.04.0A	EBS	- Mined salt	Included for quasi-static creep closure; Site Specific – direct fault displacement from a seismic event is highly site specific Excluded on low probability for seismic ground motion. The encapsulation process for a backfilled room should be completed by 500 years after closure of the repository, providing little time for major (low frequency) seismic ground motion to modify backfill. Excluded on low probability/low consequence from a volcanic event. The encapsulation process for a backfilled room should be completed by 500 years after closure of the repository, providing little time for major (low frequency) volcanic events to modify backfill.

Salt Disposal Reference Case

- Bedded salt
- Crushed salt backfill will be emplaced
- Minimal ground support in emplacement drifts
- Use existing regulations (40 CFR 191) modified to include the risk-informed approach of 40 CFR 197:
  - 10,000-year screening of most FEPs, except 1,000,000 years for certain events, such as climate change (40 CFR 197)
  - Dose-based (40 CFR 197)
  - Waste recoverable for 300 years (40 CFR 191)



FEP Screening for any Repository

- FEPs may be screened out (excluded from the PA model) by evaluation against the following screening criteria:
  - Low probability - probability of occurrence during the time period of concern is less than an established (regulatory) threshold
  - Low consequence - effect (quantitative or qualitative) on a specified performance measure (e.g., dose, subsystem measure) is not measureable/observable/significant during the time period of concern
  - Regulation - inconsistent or incompatible with the regulations
- Each FEP should be evaluated against the screening criteria
  - Screening criteria can be considered in any order
  - Screening need not be quantitative, but should have a technical basis
    - may be more qualitative and inclusive during early iterations
- If a FEP cannot be excluded, then it must be included
  - Err on side of inclusion – there is no downside to including a non-important FEP in a PA Model, other than computational / implementation cost

FEP Screening Categories for a Generic Salt Repository

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Categories are not necessarily mutually exclusive:

- Included. A FEP that is almost certain to be screened in to the generic salt disposal system models, independent of the type of salt site (bedded salt versus domal salt) or specific site characteristics. An example of an included FEP is FEP 2.2.08.02, Advective Flow, in the geosphere.
- Excluded – A FEP that is almost certain to be screened out of the generic salt disposal system models, independent of the specific salt site. An example of an excluded FEP is FEP 1.5.01.01, Meteorite Impact.
- Site-Specific – A FEP that requires a substantial amount of detailed information for a specific site. An example is FEP 1.4.02.01, Human Intrusion, which requires knowledge of the potential for mining and resource extraction activities to develop a detailed screening argument.
- Design-Specific – A FEP that requires detailed information for a specific repository design. Examples would be galvanic effects between dissimilar metals in a waste package, such as FEPs 2.1.09.09, Chemical Effects at EBS Component Interfaces, and FEP 2.1.09.11, Electrochemical Effects in EBS, which require knowledge of waste package design and EBS materials to formulate a screening argument.
- Evaluate – All other FEPs are candidates for screening calculations with the generic salt disposal system models. Some of these models may involve coupled processes, with the results providing guidance on which phenomena must be included in a salt disposal system model for the final licensing case

Initial FEPs Screening for Generic Salt Repository (cont.)

Table A-1. Features, Events, and Processes (FEPs) Potentially Relevant to Disposal of UNF and HLW at a Generic Salt Site, based on Freeze et al. (2011). [Changes for a generic salt site are identified by a **reddish brown typeface**.]

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.0.00.00	2. DISPOSAL SYSTEM FACTORS				
2.1.00.00	1. WASTES AND ENGINEERED FEATURES				
2.1.11.00	1.11. THERMAL PROCESSES				
2.1.11.08	Thermal-Mechanical Effects on Backfill	- Mechanical loads from room closure due to salt creep - Consolidation of backfill - Alteration - Cracking - Thermal expansion / stress - Movement of WP due to the negative buoyance	**Included** for the effects of quasi-static creep closure of the host rock and the resulting mechanical loading on and consolidation of crushed salt backfill.	W20 Salt Creep Incl. W31 Differing Thermal Expansion of Repository Components Excl. W35 Mechanical Effects of Backfill Excl.	Partially
2.1.11.10	Thermal Effects on Flow in EBS	- Altered influx/seepage - Altered saturation / relative humidity (dry-out, resaturation) - Condensation	**Evaluate** **Likely Included** to capture dryout and rewetting of the EBS	N28 Thermal Effects on Groundwater Flow Excl. W29 Thermal Effects on Material Properties Excl.	No
2.1.11.12	Thermally-Driven Buoyant Flow / Heat Pipes in EBS	- Vapor flow	**Evaluate** **Likely Excluded** after consolidation of crushed salt	N28 Thermal Effects on Groundwater Flow Excl. W43 Convection Excl. W89 Transport of Radioactive Gases Excl.	No
2.1.11.13	Thermal Effects on Chemistry and Microbial Activity in EBS		**Evaluate** **Evaluate** temperature dependence of solubility limits; **Excluded** for thermal effects on microbial activity because there is no organic material in the inventory.	W45 Effects of Temperature on Microbial Gas Generation Incl.	No

Future Steps with FEPs Catalog

- Two primary issues are important for a FEPs Catalog: comprehensiveness and level of detail
- Comprehensiveness
  - Has already been addressed when modifying the UFD Generic FEPs list for a generic salt repository
  - Will need to be re-examined when a specific site and design are chosen
- Level of detail
  - No unique discretization, but must define FEPs broadly enough to produce a manageable number of FEPs (a few hundred), yet specific enough to provide the complexity required for screening and/or modeling
  - Initial screening of generic salt FEPs revealed issues:
    - A number of FEPs should be split into two or more FEPs because they are too broad in scope. For example, FEP 1.1.02.03, Thermal-Hydrologic Effects from Preclosure Operations, had both “include” and “exclude” aspects
    - FEPs sometimes seem to duplicate the same scope. For example, FEP 1.1.03.01, Climate Change, and FEP 1.1.04.01, Human Influences on Climate

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