National Level Site Evaluation: Considerations, Processes and Criteria: US Case Studies

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Features, Events, and Processes (FEPs) for Nuclear Waste Repository Systems

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Outline

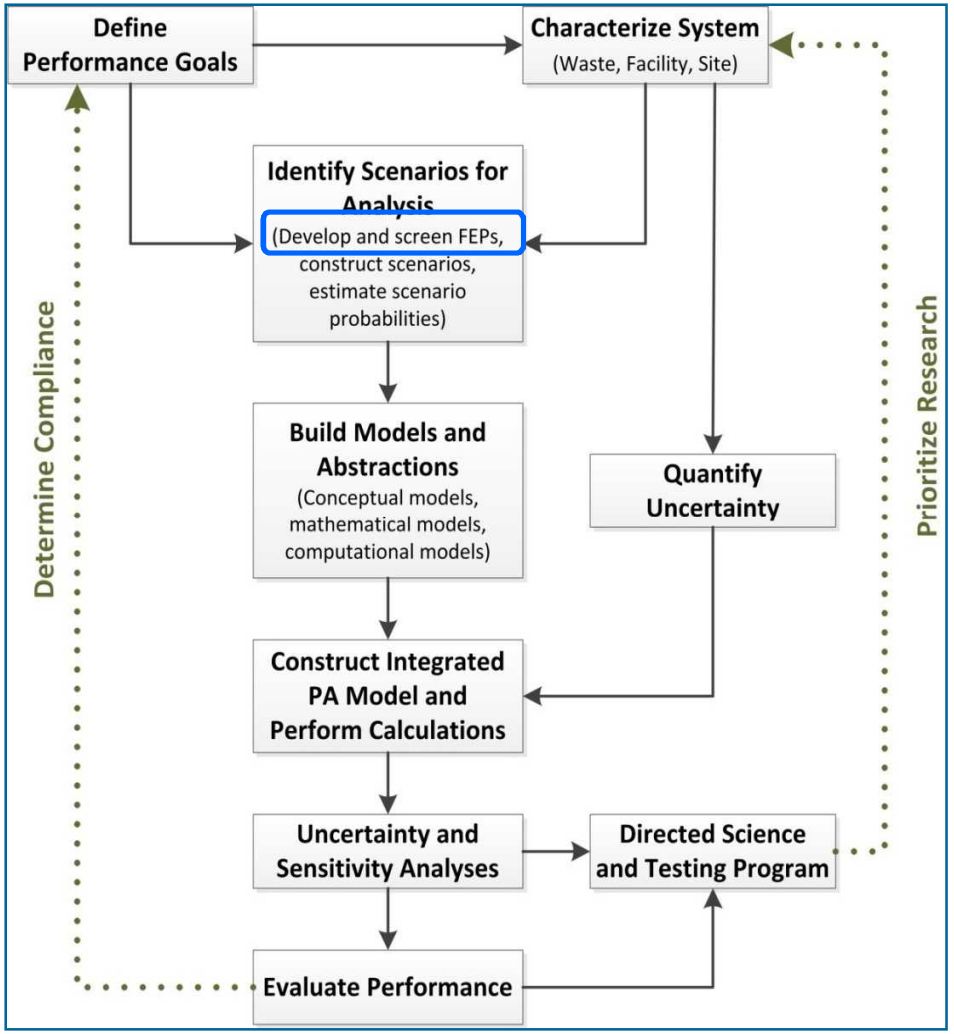
- FEP Overview
- FEP Analysis – Considerations
  - FEP Identification
  - FEP Screening
- FEP Analysis – Demonstration
  - U.S. DOE Used Fuel Disposition Campaign (UFDC)

FEP Overview – What are FEPs?

- Feature
  - An *object, structure, or condition* that has a potential to affect repository system performance
- Event
  - 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
- Process
  - 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
- A "FEP" generally encompasses a single phenomenon
  - Typically a FEP is a *process* or *event* acting upon or within a *feature*

FEP Overview – What is FEP Analysis?

- Formal FEP Analysis is part of the PA Methodology, and includes:
  - FEP Identification
  - FEP Screening
- FEP Analysis feeds:
  - Scenario Development
    - Undisturbed / Disturbed
  - PA Model Development and Implementation
- FEP Analysis is performed iteratively within the PA Methodology



FEP Overview – What is FEP Analysis?

- Formal FEP Analysis satisfies two objectives:
  - FEP Identification supports the comprehensiveness of the FEP List
    - *Have we thought of everything?*
    - Must develop a FEP list that can be demonstrated to cover the entire range of potentially relevant phenomena at a sufficient level of detail
  - FEP Screening supports the completeness of the PA Model
    - *Are all important phenomena represented in the PA Model?*
    - Must identify FEPs that individually, or in combination with one or more other FEPs, may have a measureable / observable / significant effect on long-term repository system performance

FEP Analysis - Identification

- Approaches
  - Bottom Up
    - BOPSAT - Bunch of people sitting around a table (brainstorming)
    - Development from existing lists
  - Top Down
    - Add detail to an organized categorization scheme – e.g., by location, by time/duration of occurrence, by causative factor (geology, climate, repository, human, etc.), by scientific discipline (THCM), by transport mode, …
  - Hybrid
    - Combination of bottom up and top down – e.g., re-categorize a list, refine/extend a list, audit a list for comprehensiveness
- It is most common to start with an existing FEP list and then augment it with site- and design-specific considerations

FEP Analysis - Identification

- Considerations
  - Comprehensiveness cannot be proven with absolute certainty. However, confidence can be gained through a combination of:
    - Formal and systematic reviews (bottom-up and top-down), audits, and comparisons with other FEP lists
    - Application of more than one categorization scheme
  - There is no uniquely correct level of detail at which to define or aggregate or lump FEPs. However, the level of detail in a FEP list should be:
    - Broad enough to produce a systematically categorized, manageable number of FEPs (i.e., a few hundred)
    - Specific enough to provide the complexity required for screening and/or modeling
    - Appropriate for the purpose/phase of the analysis (i.e., broader in early iterations with simple PA models, more detailed in later iterations with complex PA models)

FEP Analysis - Screening

- Approach - General
  - From the comprehensive FEP list, screening criteria are used to identify a subset of important FEPs to be included in the PA Model that define the range of possible future states (i.e., scenarios) of the repository system
  - Screening decisions (i.e., include or exclude) are:
    - Site-, design-, and regulation-specific
    - Dependent on the period of concern (e.g., 10,000 yrs vs. 1,000,000 yrs)
    - Dependent on the purpose/phase of the analysis (i.e., more inclusive in early iterations)

FEP Analysis - Screening

- Approach - Screening Criteria
  - Low Probability
    - Probability of occurrence during the time period of concern is less than an established (regulated) 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
      - A FEP may have a significant effect on subsystem performance (e.g., increased sorption of actinides) but minimal effect on system performance measure (e.g., dose dominated by non-sorbing ^{129}I)
  - Regulation
    - Inconsistent or incompatible with the regulations
  - Reasonableness
    - Not relevant or applicable to the specific repository design or site (variant of low probability or consequence)

FEP Analysis - Screening

- Considerations
  - Each FEP should be evaluated against the screening criteria
    - Screening criteria can be considered in any order
    - Screening need not be quantitative (more qualitative in early iterations)
    - Screening should consider interactions between FEPs
      - Avoid Risk Dilution - ensure that FEP level of detail is appropriate and does not minimize importance and/or consequence of interactions
    - Screening should consider both beneficial and adverse effects
      - Define a realistic case rather than a worst case
  - If a FEP cannot be excluded, then it must be included/retained
    - Err on the side of inclusion – there is no downside to including a non-important FEP in a PA Model, other than computational / implementation cost

FEP Analysis - Screening

- Considerations (cont.)
  - FEP screening decisions should have a documented technical basis (quantitative or qualitative)
  - Included FEPs
    - Describe how the FEP is included – e.g., explicitly modeled, by parameter assignment
    - Describe the appropriateness/completeness of the inclusion
  - Excluded FEPs
    - Provide a defensible technical rationale for exclusion – preferably quantitative, but can be qualitative

FEP Analysis – Iteration

- Early iterations
  - FEP level of detail may be broad
  - FEP screening may be more qualitative and inclusive, and based on generic information
    - Informal screening – model and/or code selection defines included FEPs
- Later iterations
  - FEP list may be more refined to reflect
    - Missing FEPs and/or interactions
    - Increased level of detail in important areas
  - FEP screening may be revisited to reflect
    - Repository-specific information
    - New information and/or model results

FEP Identification – Demonstration

- DOE-NE Used Fuel Disposition Campaign (UFDC)
  - Generic FEP list applicable to a range of deep geologic repository options (clay, salt, granite, deep borehole)
  - Informed by FEP Analysis supporting 2008 Yucca Mountain License Application (BSC 2005, SNL 2008)

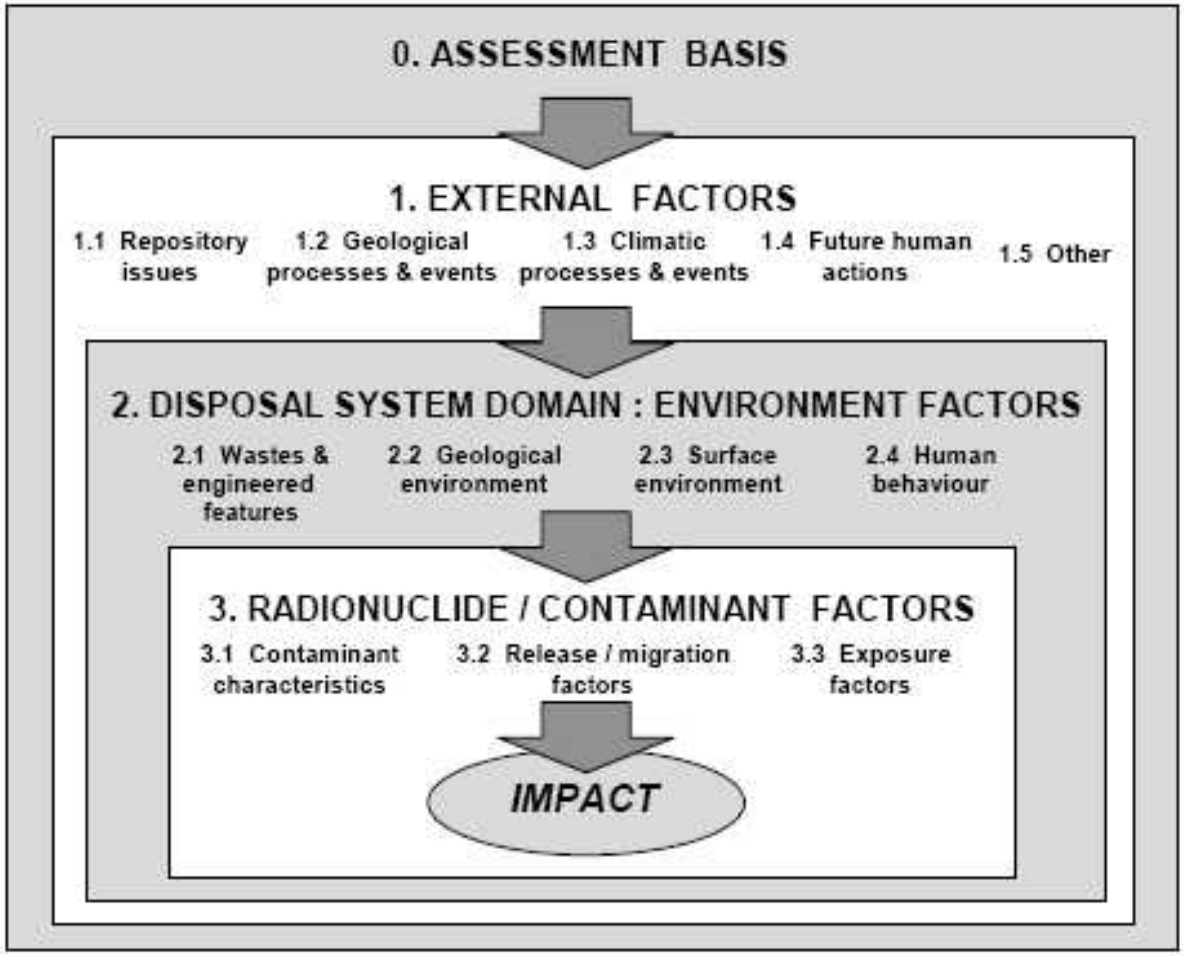
- NEA FEP list is the basis for UFDC FEP list
  - NEA FEP list from International FEP Database (NEA 2006) contains ~2000 FEPs from 10 international programs in 6 countries
  - Comprehensive because the 10 international programs cover a range of repository options

FEP Identification – Demonstration

- NEA FEPs (~2000) were categorized and consolidated
  - Many duplicate or redundant FEPs – e.g., same FEP listed in each of the 10 programs
  - Many site-specific FEPs were generalized and consolidated – e.g., common transport processes through various site-specific geologic features
  - Categorization identified related FEPs that could be combined
- Preliminary UFDC list = 208 FEPs (Freeze et al. 2011)
  - Initial development (first iteration) of generic details results in a small number of broad FEPs

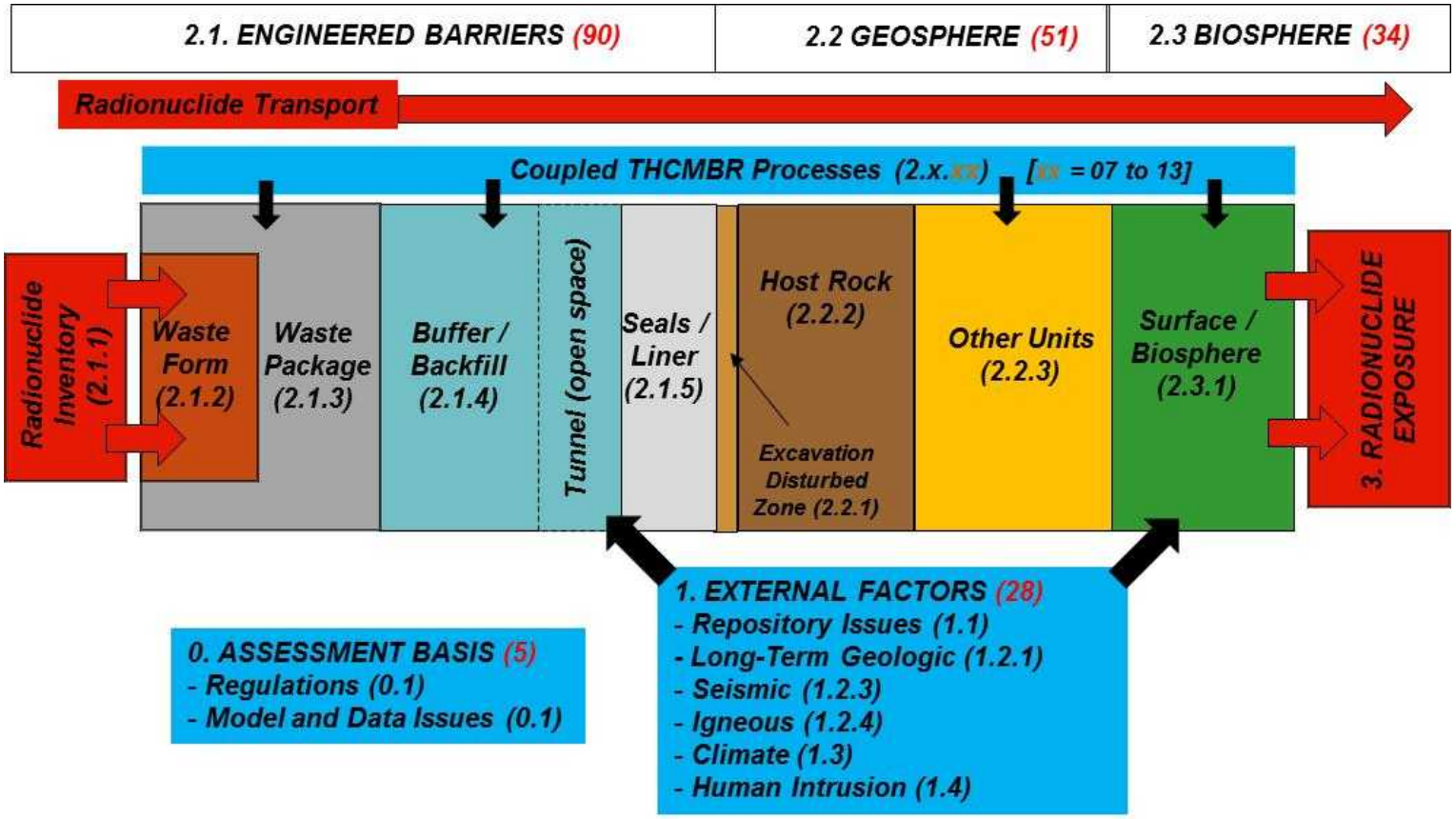
FEP Identification – Demonstration

- NEA FEP categorization scheme is the basis for UFDC categorization



FEP Identification – Demonstration

- NEA hierarchical numbering scheme used to categorize 208 UFDC FEPs by generic features, THCMBR processes, and external factors/events



FEP Identification – Demonstration

- Example of FEP information for 1 of the 208 UFDC FEPs

Broad description of FEP provided in the "Description" column

Additional FEP detail provided in the "Associated Processes" column

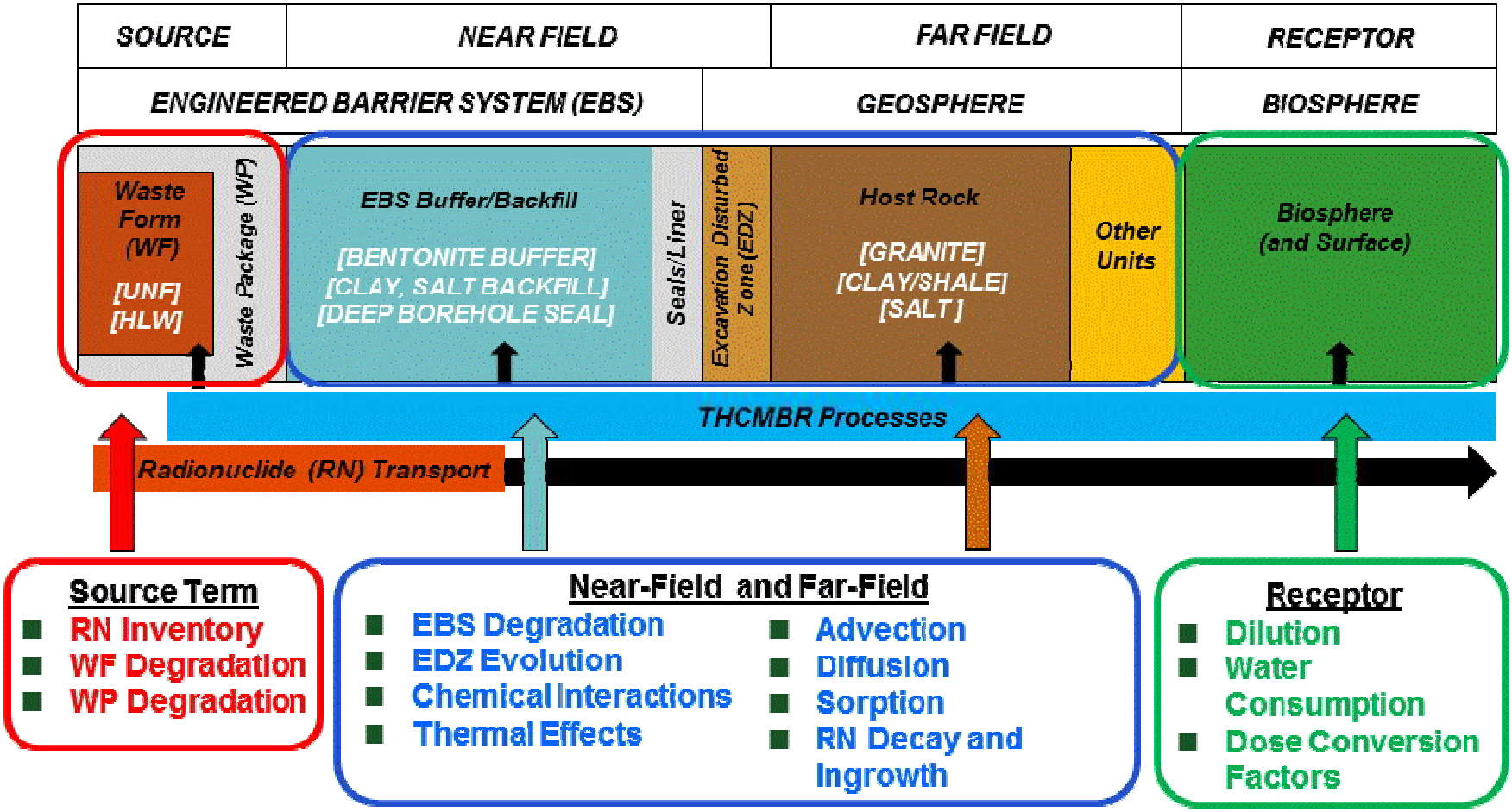
Traceability and comprehensiveness provided by the "Related FEP Number" and "Domain" columns

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)		

FEP Screening – Demonstration

- Schematic of important generic undisturbed scenario phenomena



Summary

- Formal FEP Identification supports comprehensiveness
  - provides objective evidence that all potentially relevant FEPs have been considered
- Formal FEP Screening supports completeness
  - provides a structure to ensure that all important FEPs are appropriately represented (included) in the PA model
- The NEA International FEP Database and other references listed herein provide a useful starting point to develop a FEP list
- The FEP list, FEP screening decisions, and the PA Model all evolve as part of an integrated and iterative process

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