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# The Enhanced Plan for Features, Events, and Processes (FEPs) at Yucca Mountain

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# The Enhanced Plan for Features, Events, and Processes (FEPs) at Yucca Mountain

**TDR-WIS-PA-000005 REV 00**

**March 2002**

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## ACRONYMS

| | |
|---|---|
| AECL | Atomic Energy of Canada, Ltd. |
| AMR | Analysis Model Report |
| AP | Administrative Procedure |
| CFR | Code of Federal Regulations |
| CRWMS | Civilian Radioactive Waste Management System |
| DE | disruptive events |
| DOE | U.S. Department of Energy |
| EBS | engineered barrier system |
| EDZ | excavation-disturbed zone |
| EFEP | external feature, event, and process |
| EP | event and process |
| EPA | U.S. Environmental Protection Agency |
| FEP | feature, event, and process |
| FR | Federal Register |
| HLW | high-level waste |
| HMIP | Her Majesty's Inspectorate of Pollution |
| IAEA | International Atomic Energy Agency |
| ICN | Interim Change Notice |
| IRSR | Issue Resolution Status Report |
| KTI | Key Technical Issue |
| LA | License Application |
| M&O | Management and Operating (Contractor) |
| MDD | Master Directed Diagram |
| NAGRA | National Cooperative for the Disposal of Radioactive Waste (Nationale Genossenschaft Für die Lagerung Radioaktiver Abfalle) (Switzerland) |
| NEA | Nuclear Energy Agency |
| NFE | near-field environment |
| NRC | U.S. Nuclear Regulatory Commission |
| OECD | Organisation for Economic Co-operation and Development |

## ACRONYMS (Continued)

| | |
|---|---|
| PA | Performance Assessment |
| PAAG | Performance Assessment Advisory Group |
| PASS | Performance Assessment Strategy and Scope |
| PID | Process Influence Diagram |
| QA | Quality Assurance |
| QARD | Quality Assurance Requirements and Description |
| REV | Revision |
| RES | Rock Engineering System |
| RMEI | reasonably maximally exposed individual |
| SME | subject matter expert |
| SSE | Site Suitability Evaluation |
| SZ | saturated zone |
| TH | thermal-hydrology |
| THC | thermal-hydro-chemical |
| THM | thermal-hydro-mechanical |
| TSPA | Total System Performance Assessment |
| TSPAI | Total System Performance Assessment and Integration |
| TSPA-SR | Total System Performance Assessment for Site Recommendation |
| UZ | unsaturated zone |
| WF | waste form |
| WIPP | Waste Isolation Pilot Plant |
| WP | waste package |
| YMP | Yucca Mountain Project |
| YMRP | Yucca Mountain Review Plan |

# 1. INTRODUCTION

A performance assessment is required to demonstrate compliance with the post-closure performance objectives for the Yucca Mountain Project (YMP), as stated in 10 CFR Part 63.113 (66 FR 55732, p. 55807). A performance assessment is defined in 10 CFR 63.2 (66 FR 55732, p. 55794) as an analysis that: (1) identifies the features, events, and processes (FEPs) that might affect the potential geologic repository; (2) examines the effects of those FEPs upon the performance of the potential geologic repository; and (3) estimates the expected dose incurred by a specified reasonably maximally exposed individual as a result of releases caused by significant FEPs. The performance assessment must also provide the technical basis for inclusion or exclusion of specific FEPs in the performance assessment as stated in 10 CFR 63.114 (66 FR 55732, p. 55807).

An initial approach for FEP development, in support of the Total System Performance Assessment for the Site Recommendation (TSPA-SR) (CRWMS M&O 2000e), was documented in Freeze et al. (2001). The development of a comprehensive list of FEPs potentially relevant to the post-closure performance of the potential Yucca Mountain repository is an ongoing, iterative process based on site-specific information, design, and regulations. Although comprehensiveness of the FEPs list cannot be proven with absolute certainty, confidence can be gained through a combination of formal and systematic reviews (both top-down and bottom-up), audits, and comparisons with other FEP lists and through the application of more than one classification scheme. To support TSPA-SR, DOE used a multi-step approach for demonstrating comprehensiveness of the initial list of FEPs. Input was obtained from other international radioactive waste disposal programs as compiled by the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD) to establish a general list of FEPs. The list was subsequently refined to include YMP-specific FEPs that account for the uniqueness of the design and setting (unsaturated fractured tuff). FEPs were then categorized to assess potential interactions and to establish the framework for scenario development and assessment.

The level of detail of each individual FEP was determined to be the lowest level that would support model development activities. Although the level of detail between FEPs varies, the level of detail is considered appropriate to demonstrate the safety case.

Once established, the FEPs were distributed to subject matter experts (SMEs) within the YMP organization to review the categorization of FEPs and develop screening arguments and supporting documentation. FEPs were screened by probability, consequence, or regulatory exclusion. Subsequent internal and external reviews (e.g., audits, workshops) of the YMP FEP list were conducted to identify omissions. The resulting FEPs and analyses were documented in FEP Analysis Model Reports (AMRs) for completeness and to provide the basis for what was considered and why it was considered in the TSPA-SR analyses. The relevant information in these FEP AMRs was subsequently transferred to the YMP FEP Database to provide a navigational tool for reviewing the FEPs and FEP analyses.

Subsequent to the completion of the YMP FEP Database to support TSPA-SR, additional internal and external reviews were performed (see Section 3.1). During these FEP reviews, specific enhancements to the TSPA-SR FEP approach were identified.

The purpose of this letter report is to document an Enhanced FEP Plan that will: (a) address the regulatory requirements of 10 CFR 63; (b) identify and, where possible, implement the specific enhancements identified in the FEP reviews, specifically Key Technical Issue (KTI) Agreement TSPAI 2.05; and (c) support the License Application (LA).

As required by AP-2.21Q, *Quality Determinations and Planning for Scientific, Engineering, and Regulatory Compliance Activities*, this work activity was evaluated for application to the Quality Assurance (QA) program, and the activity evaluation (BSC 2002) determined that the development of this letter report is not subject to the QA program.

The Enhanced FEP Plan is developed to respond to KTI Agreement TSPAI 2.05. The Plan communicates an approach that will be used by the Performance Assessment (PA) Project. The Plan is not an Office of Civilian Radioactive Waste Management (OCRWM) plan used to communicate long-range programmatic strategies, therefore AP-5.1Q, *Plan and Procedure Preparation, Review, and Approval*, does not apply.

## 2. FEP ANALYSIS AND SCENARIO DEVELOPMENT IN OTHER RADIOACTIVE WASTE DISPOSAL PROGRAMS

For underground disposal of radioactive waste, post-closure performance assessment is an iterative process that includes scenario development, model development, and consequence analysis. It is generally accepted (NEA 1992, pp. 11-14, 22; NEA 1999a, p. 11; NEA 1999b, p. 8) that FEP analysis – the process of identifying, classifying, and screening potentially relevant FEPs – is a key activity supporting scenario development.

The early history of FEP analysis is summarized in NEA (1999a, pp. 16-17). Early generic lists of disruptive FEPs were documented in IAEA (1983), Merrett and Gillespie (1983), NAGRA (1985), and Cranwell et al. (1990). All of these lists, summarized in Table 2-1, introduce categories for natural, human-induced, and waste and repository induced FEPs.

Table 2-1. New FEP List Development Prior to 1989

| ID | Country/ Organization | Structure | Comments | Source | Reference |
|---|---|---|---|---|---|
| 0.1 | International IAEA | 57 FEPs (Natural processes and events, Human activities, Waste and repository effects) | Suggested checklist of phenomena similar to Burkholder (1980) and Koplik et al. (1982) | New | IAEA 1983 |
| 0.2 | USA NRC | 27 FEPs (Natural, Human-induced, Waste- and repository-induced) | Potentially disruptive events and processes | New | Cranwell et al. 1990 (initially published in 1982) |
| 0.3 | Canada AECL | (disruptive actions of man, vault-related, natural phenomena) | Initial FEPs for Canadian Nuclear Fuel Waste Management Program | New | Merrett and Gillespie 1983 |
| 0.4 | Switzerland NAGRA | 44 FEPs (natural, human induced, waste and repository-induced) | Relevant processes and events for Project Gewahr | New | NAGRA 1985 |

In the late 1980s and early 1990s, new FEP development continued with project specific (rather than generic) lists developed in several different countries (see Table 2-2). Continuing FEP analysis in the mid-1990s focused on the completeness of the FEP lists. Many of these efforts (see Tables 2-3 and 2-4) derived from the original studies listed in Tables 2-1 and 2-2 and are part of chronological "development chains."

Table 2-2. New FEP List Development, 1989–1992

| ID | Country/ Organization | Structure | Comments | Source | Reference |
|---|---|---|---|---|---|
| 1.1 | Sweden SKI/SKB | 157 FEPs (waste, canister, buffer/backfill, EDZ/near-field, disruptive events-repository and far-field, far-field, surface) | Categorized as either Process System FEPs or External "Kept" FEPs | New | Andersson et al. 1989 |
| 1.2 | International NEA | 149 FEPs (Natural, Human, Waste and Repository) | Derives from Hodgkinson and Sumerling (1989) | New | NEA 1992 |
| 1.3 | UK HMIP | 305 FEPs (Near-Field, Far-Field, Biosphere, Short-Circuit Pathways Related to Human Activities) | FEPs for Dry Run 3 hypothetical low- and intermediate-level waste repository at Harwell site | New | Thorne 1992 |

Table 2-3. Continuing FEP List Development, 1993–1994

| ID | Country/ Organization | Structure | Comments | Source | Reference |
|---|---|---|---|---|---|
| 2.1 | Sweden SKI | >1200 FEPs (Waste, Canister, Buffer/Backfill, Repository/Near-Field, Far-Field, Biosphere, Geology/ Climate, Human Influences) | Initial FEP list combined early lists from Tables 2-1 and 2-2. Initial list categorized and then irrelevant, vague or incomprehensible FEPs removed. Complete consolidated list includes groupings in Appendix 6 (Process System FEPs and EFEPs) and Appendix 4 (Screened Out FEPs). | 0.1, 0.2, 0.3, 0.4, 1.1, 1.2, 1.3 | Stenhouse et al. 1993 |
| 2.2 | Canada AECL | 281 FEPs (vault, geosphere, biosphere) | FEPs added to some of the initial lists. Categorized under Central scenarios or Alternative scenarios (open borehole, human intrusion) | New 0.1, 0.3, 0.4, 1.1, 1.2 | Goodwin et al. 1994 |
| 2.3 | UK HMIP | 79 FEPs (Near-Field, Far-Field, Climatology, Biosphere, Short-Circuit Pathways) | FEPs from Dry Run 3 analysis, restructured and consolidated (especially biosphere) for relevance to Sellafield site | 1.3 | Miller and Chapman 1993 |

Table 2-4. Continuing FEP List Development, 1994–1996

| ID | Country/ Organization | Structure | Comments | Source | Reference |
|---|---|---|---|---|---|
| 3.1 | Sweden SKI | 161 FEPs (no categories listed) | SKI/SKB list audited against Stenhouse list. FEPs lumped into 10 categories as a part of either Process System (reference case, central scenarios) or Supplementary Scenarios | 1.1, 2.1 | Chapman et al. 1995 |
| 3.2 | Switzerland NAGRA | 245 FEPs (radionuclides, waste, canister, buffer/ backfill, repository and EDZ, rock-low permeability, rock-faults, rock-high permeability, bio-sphere, geologic EPs, climatic EPs, human activities) | New FEPs identified then audited against earlier lists. Categorized under Reference Scenario and Alternative Scenarios (for disruptive events). | New 0.2, 1.1, 1.2, 1.3, 2.2 | NAGRA 1994 |
| 3.3 | USA DOE | 246 FEPs (Natural, Waste and Repository, Human, Assessment Basis) | WIPP specific FEPs (e.g., seals) added to Stenhouse final list. FEPs then consolidated and reorganized under either Undisturbed performance or Disturbed performance (i.e., human intrusion) | New 2.1 | DOE 1996 |

The chronological development chains produced the following "end of chain" lists:

2.2 – Canada/AECL (Goodwin et al. 1994)
2.3 – U.K./HMIP (Miller and Chapman 1993)
3.1 – Sweden/SKI (Chapman et al. 1995)
3.2 – Switzerland/NAGRA (NAGRA 1994)
3.3 – U.S./DOE (DOE 1996).

New FEP list development should use these 5 lists as an initial basis.

The final report of the NEA Performance Assessment Advisory Group (PAAG) (NEA 1992) provides a summary of scenario methods and their application up to about 1990. The report of the NEA Working Group on the development of an International FEP Database (NEA 1999a) provides a follow-up summary of work up to about 1997. These methods provide details about the different approaches to FEP analysis and scenario development.

In most countries, FEP analysis follows steps 1 through 3 (FEP identification, classification, and screening) of the method outlined in Cranwell et al. (1990). Issues associated with these 3 steps, based on lessons learned from some of the FEP analysis efforts described above, are discussed in Section 2.1. For scenario development, Steps 4 and 5 (scenario construction and screening) of the method outlined in Cranwell et al. (1990) have often provided a basis, but several alternatives have also been explored. Methods and lessons learned associated with scenario development are

described in Section 2.2. Alternate FEP analysis approaches that are part of specific scenario development methods are also discussed in Section 2.2. Finally, general observations from other programs regarding comprehensiveness, level of detail, and transparency and traceability are summarized in Section 2.3.

## 2.1 FEP ANALYSIS METHODS

FEP analysis includes 3 steps: identification, classification, and screening. Lessons learned from other FEP analysis efforts (see Tables 2-1 through 2-4) are summarized in the following subsections.

### 2.1.1 FEP Identification

A general observation, based on the cumulative results from several other FEP development efforts, is:

> "To generate a sufficiently extensive list, this process must be free of limitations and draw on the...experience of a wide range of people. At the same time the list must be comprehensive, traceable, and well documented; this requires the process to have a basic structure" (NEA 1992, p. 22).

Input is needed from each part of the safety assessment process and from all relevant disciplines. A variety of methods should be used to formulate an initial list (NEA 1992, p. 23). Some common FEP identification methods include (NEA 1999a, pp. 26-27):

- Development from existing detailed lists of FEPs – requires a good classification scheme to sort the FEPs
- Brainstorming by groups of relevant experts – time consuming and likely to lead to an incomplete list
- Top-down elicitation, starting from comprehensive classification schemes – difficult to begin and develop in detail
- Hybrid procedure - reclassify an existing list; refine/extend the classification scheme and refine FEP names; audit against other lists to identify omissions.

The TSPA-SR FEPs approach (Freeze et al. 2001, Section 2) primarily incorporated the first two methods, with a partial application of the last two methods. The Enhanced FEP Plan (see Section 3.2) will make more complete use of the last two bullets to support the demonstration of comprehensiveness.

### 2.1.2 FEP Classification

The primary objectives of classification are to (a) uncover missing FEPs and interactions, and (b) provide a framework for organizing scenario development and assessment. Some general observations from other FEP classification efforts include the following:

"By classifying features, events, and processes under different schemes, information on additional phenomena and interaction can be gained. ...Classification schemes that examine the system from different viewpoints should be used" (NEA 1992, p. 26).

"...it is useful to have a structure or categories so that the completeness (of categories and within categories) can be assessed, and equivalent levels of detail guided, e.g., similar numbers of FEPs might be found in each category" (NEA 1999a, p. 27).

FEP lists are usually classified either on cause, field of effect, or a combination of the two (NEA 1999a, p. 28). Example classification schemes include (NEA 1992, pp. 26–28):

Cause - Natural (celestial, surface, subsurface); Human-Induced (intrusion, hydrological stress); Repository and Waste Induced

Physical Field of Effect and Causative Factors – Waste; Canister; Backfill; Repository/Near-Field; Far-Field (multiple pathways); Biosphere; Geologic Processes and Events; Climatic Processes and Events; Near Surface and Human Activities (from NEA 1999a, p. 28)

Location – Near-Field; Far-Field; Biosphere (also consider interfaces)

Scientific Discipline – (e.g., biology, chemistry, physics, geology)

Radionuclide Transfer Agent - Groundwater (soluble, colloidal); Gas (radioactive, aerosol); Natural (erosion, tectonics, diapirism, environmental change); Living Organism (people, animals, plants)

Radionuclide Mobilization - Release; Transport (migration pathways); Exposure (transfer from biosphere receptors to people, i.e., inhalation)

Layered – Interactions between FEPs tend to occur within each layer and in the inward direction, but not in the outward direction. Layers (from outside in) are: assessment basis, external factors (geologic, climatic, human, other – issues, processes and events originating outside the disposal system but acting upon it), system environment factors (engineered system, geosphere, biosphere –surface/human behavior), radionuclide factors (characteristics, release/migration, exposure) (from NEA 1999a, pp. 28–30)

Time Scales – (e.g., 0–100 yrs, 100–10,000 yrs, 10,000 – 1E6 yrs, >1E6 yrs).

The TSPA-SR FEPs classification (Freeze et al. 2001, Section 3) derived from an NEA classification scheme (NEA 1999a, pp. 28–34). It was general in nature and was based on a combination of the schemes listed above. The Enhanced FEP Plan (see Section 3.2) will introduce a new classification that is based on YMP specific fields of effect and causative factors. This approach will improve traceability by relating FEPs directly to specific YMP "categories" rather than to generic international groupings.

### 2.1.3 FEP Screening

The screening process is site-, system-, and regulation-specific. FEPs are considered one by one and are checked for interactions. FEPs can be screened by regulation, probability, bounding consequence, or physical reasonableness (e.g., "phenomena which are clearly not applicable to the specific repository or site can be eliminated from consideration") (NEA 1992, p. 29).

The TSPA-SR FEP screening process (Freeze et al. 2001, Section 4) evaluated FEPs relative to screening criteria outlined in draft regulations. Screening discussions were subject to general guidelines regarding content. The Enhanced FEP Plan will use the following criteria from 10 CFR 63 (66 FR 55732, pp. 55797, 55807):

> **10 CFR 63.21(c)(1)** The Safety Analysis Report must include a description of the Yucca Mountain Site, with appropriate attention to those features, events, and processes of the site that might affect design of the geologic repository operations area and performance of the geologic repository. The description of the site must include information regarding features, events, and processes outside of the site to the extent the information is relevant and material to safety or performance of the geologic repository. The information referred to in this paragraph must include:
> (i) The location of the geologic repository operations area with respect to the boundary of the site;
> (ii) Information regarding the geology, hydrology, and geochemistry of the site, including geomechanical properties and conditions of the host rock;
> (iii) Information regarding surface water hydrology, climatology, and meteorology of the site; and
> (iv) Information regarding the location of the reasonably maximally exposed individual, and regarding local human behaviors and characteristics, as needed to support selection of conceptual models and parameters used for the reference biosphere and reasonably maximally exposed individual.
>
> **10 CFR 63.21(c)(9)** The Safety Analysis Report must include an assessment to determine the degree to which those features, events, and processes of the site that are expected to materially affect compliance with 10 CFR 63.113—whether beneficial or potentially adverse to performance of the geologic repository—have been characterized, and the extent to which they affect waste isolation.
>
> **10 CFR 63.114(d)** Consider only events that have at least one chance in 10,000 of occurring over 10,000 years.
>
> **10 CFR 63.114(e)** Provide the technical basis for either inclusion or exclusion of specific features, events and processes in the performance assessment. Specific features, events, and processes must be evaluated in detail if the magnitude and time of the resulting radiological exposures to the reasonably maximally exposed individual, or radionuclide releases to the accessible environment, would be significantly changed by their omission.

**10 CFR 63.114(f)** Provide the technical basis for either inclusion or exclusion of degradation, deterioration, or alteration processes of engineered barriers in the performance assessment, including those processes that would adversely affect the performance of natural barriers. Degradation, deterioration, or alteration processes of engineered barriers must be evaluated in detail if the magnitude and time of the resulting radiological exposures to the reasonably maximally exposed individual, or radionuclide releases to the accessible environment, would be significantly changed by their omission.

Explicit guidelines for content will be outlined (see Section 3.2 and Appendix A) to ensure that the technical basis for inclusion (including traceable references to TSPA models) or exclusion is appropriately documented.

## 2.2 SCENARIO DEVELOPMENT METHODS

Scenario development includes 2 steps: scenario construction and scenario identification. These two steps are beyond the scope of the Enhanced FEP Plan. However, the following review of alternate scenario development methods provides some insight into alternate FEP analysis approaches and the associated lessons learned from other programs.

Some general observations from other FEP scenario development efforts include:

- A scenario is a "broad brush description of the characteristics and sequencing" of "one possible set of events and processes" (NEA 1992, p. 11).
- Scenario development is "the identification, broad description, and selection of alternative futures relevant to a reliable assessment of the radioactive waste repository safety" (NEA 1992, p. 11).
- Scenario formation forms a link between the list of FEPs and the modeling and consequence calculations. Therefore, scenario formation is influenced by the types of models and calculation tools available (NEA 1992, p. 52).
- "Most studies indicate clearly the usefulness of defining a central or base case scenario" (NEA 1992, p. 52).

Specific methods are presented in NEA (1992, Sections 5 and 6) and are summarized in the following subsections. The TSPA-SR FEPs approach was basically a systematic bottom-up approach (Section 2.2.3) with some top-down checks and balances. The Enhanced FEP Plan (see Section 3.2) will introduce some additional systematic top-down methods to further demonstrate comprehensiveness. Note that for all scenario development approaches only the screened-in (i.e., included) FEPs are considered.

### 2.2.1 Judgemental Methods

Judgemental methods are essentially brainstorming sessions involving technical experts. They are less than systematic approaches with minimal documentation of screening rationales. They are useful for studies with limited resources that do not require full comprehensiveness or traceability (NEA 1992, p. 35). They can be useful for formulating initial FEP lists, which can

then be checked against more systematic methods, but they do not provide the level of comprehensiveness required for YMP.

### 2.2.2 Event Tree/Logic Diagram Approach

Event trees (also referred to as fault trees or logic diagrams) are used to illustrate the set of combinations of basic events (FEPs) that can cause system failure. They can be useful when combined with systematic methods, but by themselves they tend to produce an unmanageable number of event combinations (NEA 1992, pp. 34, 35, and 38). They are primarily used as a means to organize scenario development and to complement judgemental methods. They can also be useful for examining certain subsets of the system such as was done for the TSPA-SR EBS FEPs (CRWMS M&O 2000b). However, they are not as useful for system components where failure modes are typically long-term and continuous rather than abrupt (i.e., in the geosphere).

### 2.2.3 Systematic Bottom-Up

Systematic bottom-up approaches are processes to combine large numbers of screened-in FEPs together to form a limited number of scenarios. Systematic bottom-up approaches are good for comprehensiveness. Specific examples are summarized in Table 2-5.

Table 2-5. Systematic Bottom-Up Scenario Development Approaches

| Organization | Basic Steps | Relevant FEP List from Tables 2-1 through 2-4 | References |
|---|---|---|---|
| Sandia | 1. Construct a base case (radionuclide release and transport with no disruptive phenomena).<br>2. Combine retained disruptive FEPs in an event tree (many scenarios).<br>3. Screen scenarios to a manageable number. | 0.2 | Cranwell et al. 1990<br><br>NEA 1992, pp. 39–41 |
| Joint SKI/SKB | 1. Construct a Process System (the organized assembly of all FEPs required to describe barrier performance and radionuclide-behavior that can be predicted with at least some degree of determinism).<br>2. Combine remaining FEPs (referred to as: primary cause, major external events, scenario generating) into scenarios.<br>3. Apply a top-down approach to reduce the number of scenarios and couplings. The Process System was simplified to 3 barriers (canister, near-field, far-field) each having 3 states (ordinary, less efficient, short circuit) for 27 combinations.<br>4. Apply scenario generating FEPs to the 27 combinations, where appropriate. | 1.1 | Andersson et al. 1989<br><br>NEA 1992, pp. 42-44, 48 |
| AECL | 1. Construct a central scenario (FEPs that are expected to be always important, or to occur frequently or to be capable of proceeding to a significant degree over the time scale of the assessment).<br>2. Group residual FEPs in all possible combinations to form alternative scenarios, which act in combination with the central scenario.<br>3. Reduce the number of residual FEPs and alternative scenarios through additional screening and grouping. | 2.2 | Goodwin et al. 1994<br><br>NEA 1992, pp. 44–45 |

All of the systematic bottom-up approaches described in Table 2-5 are similar. Nominal FEPs are combined into a base-case (reference/central) scenario and remaining FEPs are grouped and screened to form a manageable number of disruptive scenarios which act upon the base case scenario.

### 2.2.4 Systematic Top-Down

In systematic top-down approaches, end point consequences or states are postulated and then the mechanisms by which these states may be reached are considered. They adopt certain characteristics of event tree analysis, but systematically limit the number of FEP combinations.

Top-down approaches do not always ensure comprehensiveness unless they are truly systematic. Table 2-6 summarizes specific examples.

Table 2-6. Systematic Top-Down Scenario Development Approaches

| Organization | Basic Steps | Relevant FEP List from Tables 2-1 through 2-4 | References |
|---|---|---|---|
| UK DOE | 1. Identify target event (risk) and main factors (release from vault, transmission through geosphere, uptake in biosphere) considered to affect the outcome of the target event.<br>2. Define alternative states (3) of each barrier (main factor) and their probabilities.<br>3. Evaluate probabilistic consequence based on each of the 27 combinations. | None | Dalrymple et al. 1986<br><br>NEA 1992, pp. 47–48 |
| UK Nirex | 1. Define scenario elements (groups of FEPs based on cause or field of effect) and develop an influence diagram to show dependencies.<br>2. Define a comprehensive set of states for each scenario element.<br>3. Perform influence screening to eliminate or "fix" those that do not affect the state of another downstream element.<br>4. Select scenarios from the remaining multi-state elements. | None | Billington et al. 1989<br><br>NEA 1992, pp. 48–51 |
| SKI | 1. Construct a Process Influence Diagram (PID) to represent the Process System. PID is built top-down.<br>2. Map nominal FEPs to the PID to create the Reference Case and Central Scenarios.<br>3. Create and screen Supplementary Scenarios by lumping remaining FEPs (EFEPs). | 3.1 | Chapman et al. 1995, pp. 39–61 |
| SKB | 1. A structured Rock Engineering System (RES) matrix is used to assist is identifying and checking comprehensiveness of FEPs.<br>2. The RES matrix starts small with broad terms and is then expanded. The RES matrix helps to identify scenarios. | None | Hudson 1992<br><br>Eng et al. 1994 |
| UK Nirex | 1. Develop a structured Master Directed Diagram (MDD) to organize FEPs starting at PA "endpoints" (i.e., risk) and moving into more detail where necessary.<br>2. Define FEPs in the MDD as scenario defining FEPs or scenario FEPs.<br>3. Build a base scenario from some of the scenario defining FEPs.<br>4. Group the remaining scenario defining FEPs into variant scenarios.<br>5. Use weight-risk diagrams and subsume lesser risk scenarios to retain a few important scenarios.<br>6. Put FEPs in any one scenario into an Influence Matrix diagram to show interactions. | None | Kelly and Billington 1997<br><br>NEA 1999b, pp. 21-24 |

The last two approaches in Table 2-6, the SKB RES method and the UK Nirex MDD method, both contain steps where FEPs are put into a matrix to help identify interactions and check comprehensiveness. This matrix approach has been adopted for the Enhanced FEP Plan (see Section 3.2).

## 2.3 FEP EVALUATION CRITERIA

This section includes lessons learned from other programs regarding comprehensiveness, level of detail, transparency, and traceability.

### 2.3.1 Comprehensiveness

Some general observations about comprehensiveness from other FEP analysis efforts include:

> "Comprehensiveness can never be accomplished in one step, and will have to be judged against a record of continuous and open reviews, the most recent of these reviews having given evidence of no major findings. ...Comprehensiveness can only be sought and achieved in relation to a specific site, a specific type of waste, and a specific regulatory context." (NEA 1999b, p. 15)
>
> "Review by external experts is important for arguing comprehensiveness..." (NEA 1999b, p. 16).
>
> "It is impossible to demonstrate comprehensiveness or completeness, in the sense that it is impossible to exhaustively identify all possible FEPs and interactions within a complex and evolving system. It is possible, however, to list a range of broadly-defined FEPs that might be relevant to consider in safety assessments. This is the aim of the International FEP List: to be comprehensive in a broad sense rather than in a detailed sense." (NEA 1999a, pp. 24–25)
>
> "The [International FEP Database] classification scheme captures a range of radioactive waste disposal assessment projects within its scope. ...this will be an aid to achieving comprehensiveness of assessments..." (NEA 1999a, p. 43).
>
> "A formal audit process can give confidence in the comprehensiveness of considerations. The [FEP list] was audited against a combined list of over 1000 FEPs identified in other assessment and scenario development studies...no critical omissions were identified." (NAGRA 1994, pp. 112–13)
>
> "Confidence in the comprehensiveness of the list of factors is developed by organizing and ordering the information in many different ways." (Goodwin et al. 1994, p. 7)

For the Waste Isolation Pilot Plant (WIPP) project, confidence in the comprehensiveness and appropriateness of the FEP list was supported by (DOE 1996, SCR Attachment 1, p. 13):

- Nine lists from different countries used as a starting point
- List extended through review of WIPP project literature
- Formal presentations and reviews with stakeholders and regulator
- Formal documented reviews within the project
- Reduction of the list in documented manner
- Participation in the International FEP Database.

In summary, comprehensiveness of a FEP list cannot be proven with absolute certainty. However, confidence can be gained through a combination of formal and systematic reviews (both top-down and bottom-up), audits, and comparisons with other FEP lists and through the application of more than one classification scheme.

### 2.3.2 Level of Detail

Some general observations regarding the level of detail for FEPs, taken from other FEP analysis efforts include:

> "A list that is too general will not be useful. On the other hand, a list that [is too detailed] will tend to become incomplete as it becomes more difficult to be comprehensive at more detailed levels." (NEA 1999a, p. 25)
>
> "The Working Group thought that, as a guide, the International List should contain a total of about 100 FEPs, and not more than about 200 FEPs. The larger the list, the finer the classification of FEPs that can be achieved, but the list becomes harder to use. The list is designed to be short enough that a user can become generally familiar with it and will not inadvertently overlook a FEP on the list." (NEA 1999a, p. 25)
>
> "Consideration within a variant scenario does not necessarily imply explicit representation of a specific FEP, many FEPs have a similar impact on system performance. It may be possible to represent a number of FEPs by a single representative scenario-defining FEP." (Bailey et al. 1998, pp. 4.1-4.2)
>
> "The aim of the MDD is to provide a comprehensive set of FEPs. For each FEP on the MDD, the following question may be asked: 'Is it helpful for modeling purposes to include additional FEPs at the next level down, in order to represent this FEP?' If the answer is 'no', then the MDD can be considered comprehensive at that level. ...As the MDD is developed downwards, the FEPs become more specific. Eventually, there comes a point at which the level of detail of the FEPs is equivalent to that which has to be considered in a numerical model of the FEP. Development of these FEPs then ceases, as no additional benefit will be gained by decomposing to greater levels of detail. ...Therefore, the lowest level FEPs on the MDD should reflect an appropriate level of detail to enable model development to proceed. ...It should be noted that at the lowest levels, the MDD does not necessarily represent all FEP interactions as this would introduce unnecessary complexity. Instead, interactions between key FEPs were considered using a matrix diagram in the conceptual model development stage. ...It is sometimes found that certain high-level FEPs do not require decomposition, even though their level of detail is insufficient for mathematical model development. This might arise

when...further decomposition would only lead to FEPs that do not need to be considered (such as ...human intrusion...excluded on...Regulatory Guidance)." (Bailey et al. 1998, pp. 3.3-3.4)

"The objective of lumping is to reduce the number of FEPs that are to be combined into scenarios by grouping 'similar' FEPs together and only work with the groups...in practice, it is necessary to resort to lumping in order to reduce the number of FEPs such that the final number of formed scenarios is manageable." (Andersson et al. 1989, pp. 17-18)

"...it may not only be necessary to check that all FEPs have been processed in a logical and consistent way, but to also split up some of the FEPs into smaller ones before repeating the screening/lumping process..." (Andersson et al. 1989, p. 23).

"...the initial list will be a mixture of loosely defined factors at different levels of detail. Therefore, it is necessary to define the FEPs in more detail, to sort out inconsistencies and eliminate overlap...and to structure or categorise them in a way that facilitates systematic consideration..." (NEA 1992, p. 30).

In summary, the level of detail of a FEP list should be guided by grouping/lumping such that the final list contains on the order of a few hundred FEPs. The level of detail should also be guided by the complexity required for modeling or screening.

### 2.3.3 Transparency and Traceability

Transparency can be defined as follows: "a document (calculation, analysis, model, etc.) is sufficiently detailed as to purpose, method, assumptions, inputs, conclusions, references and units such that a person technically qualified in the subject can understand the document and ensure its adequacy without recourse to the originator" (DOE 2000). Traceability is "the ability to trace the history, application, or location of an item, data, or sample using recorded documentation" (DOE 2002).

Some general observations about transparency and traceability from other FEP analysis efforts include:

"...the choice of scenarios, conceptual models and their representation within numerical models must be underpinned by a clear, auditable rationale. ...A major objective of the FEP analysis is to provide the framework for this audit." (Bailey et al. 1998, p. 1.9)

"It is essential that a safety assessment be presented in a clear and accessible way such that the basis for decisions and assumptions can be readily understood. ...This calls for a structured, hierarchical presentation, in which the reader is guided through the levels of detail. ...The level of detail demanded by the modelling requirements should be that which is necessary and sufficient to demonstrate the safety case. ...An inappropriate level of detail merely adds to the complexity of the assessment with no corresponding gain in accuracy or clarity." (Bailey et al. 1998, p. 1.10)

> "The organization of FEPs in a Master Directed Diagram (MDD) with accompanying searchable databases with relevant information provides a well-structured, updateable description of the knowledge base for the disposal system from the point of view of post-closure safety. ...coupled with an adequate review process, this tool could allow the issue of comprehensiveness to be positively tackled." (NEA 1999b, p. 25)

In summary, transparency and traceability require clear, auditable documentation of the technical basis for inclusion (including traceable references to TSPA models) or exclusion of FEPs. Transparency and traceability are enhanced through the use of a database.

# 3. YMP APPROACH TO FEP ANALYSIS

The initial approach for FEP analysis (identification, classification, and screening) supporting TSPA-SR was documented in Freeze et al. (2001). Section 3.1 summarizes the comments from a series of internal and external reviews of the TSPA-SR FEPs. In response to these review comments, specific enhancements to the initial FEP analysis approach were identified. Section 3.2 describes these enhancements as part of the Enhanced FEP Plan, which will guide FEP analysis in support of the LA.

## 3.1 REVIEWS OF FEPS FOR SITE RECOMMENDATION

The following recent reviews have been conducted on the YMP TSPA-SR FEP process and FEP Database:

- NRC TSPAI IRSR Rev. 3 (NRC 2000) (Sept 2000)
- NRC TSPA QA Audit (May 2001)
- NRC/DOE FEPs Technical Exchange (May 2001)
- NRC/DOE TSPA Technical Exchange (Aug 2001)
- NEA/IAEA TSPA Peer Review (Nov 2001).

Recurring general observations and suggestions from these reviews are summarized in Table 3-1.

Table 3-1. Summary of Recurring Review Comments for TSPA-SR FEP Analysis

| ID | Comment |
|---|---|
| R01 | Improve documentation/traceability to ensure that primary FEPs are comprehensive and that they envelop all secondary FEPs. |
| R02 | Upgrade screening text (better traceability for included FEPs, components, and model issues). |
| R03 | Improve intuitiveness of navigation in database. |
| R04 | Use consistent level of detail (define criteria for FEPs, components, and modeling issues). |
| R05 | Review areas of importance (e.g., igneous, biosphere) and other "broad" FEPs to see whether additional detail (i.e., more primary FEPs) is warranted. |
| R06 | Justify the degree of consistency among FEPs. |
| R07 | Introduce a configuration management procedure/protocol for addressing new and changed FEPs in response to design changes and other new information. |
| R08 | Apply a systematic FEP identification approach similar to the approach for EBS (CRWMS M&O 2000b). |
| R09 | Evaluate the use of shared FEPs. |
| R10 | Reduce cases of partial include/excludes where possible. |
| R11 | Ensure complete treatment of coupling between FEPs. |

In addition, 7 KTI Agreements related to FEP analysis were identified during the NRC/DOE TSPA Technical Exchange in August 2001 (see Table 3-2). The Enhanced FEP Plan directly addresses the 13 items outlined in KTI Agreement TSPAI 2.05, with specific items identified as 2.05-1 through 2.05-13 in Table 3-2. The Plan also generally addresses the issues in the recurring review comments in Table 3-1 and, through its implementation, will address the other 6 KTI Agreements.

Table 3-2. Summary of KTI Agreements Related to FEP Analysis

| ID | Agreement |
|---|---|
| TSPAI 2.01 | Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 32, 41, 47, 50, 53, 58, 67, J-5, J-16, and J-18. DOE will clarify the screening arguments, as summarized in Attachment 2, for the highlighted FEPs. The clarifications will be provided in the referenced FEPs AMR and will be provided to the NRC in FY 2003. |
| TSPAI 2.02 | Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 3, 4, 11, 12, 19 (Parts 1, 2, and 6), 25, 26, 29, 34, 35, 36, 37, 38, 39, 42, 43, 44, 48, 49, 51, 54, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 78, 79, J-1, J-2, J-3, J-4, J-7, J-8, J-9, J-10, J-11, J-12, J-13, J-14, J-15, J-17, J-20, J-21, J-22, J-23, J-24, J-25, J-26, and J-27. DOE will provide the technical basis for the screening argument, as summarized in Attachment 2, for the highlighted FEPs. The technical basis will be provided in the referenced FEPs AMR and will be provided to the NRC in FY 2003. |
| TSPAI 2.03 | Add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. See Comment 19 (Part 7 and 8), 20, and J-6. DOE will add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. The FEPs will be added to the appropriate FEPs AMRs, and the AMRs will be provided to the NRC in FY 2003. |
| TSPAI 2.04 | Provide a clarification of the description of the primary FEP. See Comments 24, 31, and 33. DOE will clarify the description of the primary FEPs, as summarized in Attachment 2, for the highlighted FEPs. The clarifications will be provided in the referenced FEPs AMR and will be provided to the NRC in FY 2003. |
| TSPAI 2.05 | It is not clear to the NRC that the current list of FEPs (i.e., the list of FEPs documented in TDR-WIS-MD-000003, 00/01) is sufficiently comprehensive or exhibits the necessary attribute of being auditable (e.g., transparent and traceable). As discussed in the two TSPAI technical exchanges, there are unclear aspects of the approach that DOE plans to use to develop the necessary documentation of those features, events, and processes that they have considered. Accordingly, to provide additional confidence that the DOE will provide NRC with: (1) auditable documentation of what has been considered by the DOE, (2) the technical basis for excluding FEPs, and (3) an indication of the way in which included FEPs have been incorporated in the performance assessment; DOE will provide NRC with a detailed plan (the Enhanced FEP Plan) for comment. In the Enhanced FEP Plan, DOE will address the following items (listed separately as 2.05-1 through 2.05-13). DOE will provide the Enhanced Plan to NRC by March 2002. |
| 2.05-1 | The approach used to develop a pre-screening set of FEPs (i.e., the documentation of those things that DOE considered and which the DOE would use to provide support for a potential license application). |
| 2.05-2 | The guidance on the level-of-detail that DOE will use for redefining FEPs during the enhanced FEP process. |
| 2.05-3 | The form that the pre-screening list of FEPs will take (e.g., list, database, other descriptions). |
| 2.05-4 | The approach DOE would use for the ongoing evaluation of FEPs (e.g., how to address potentially new FEPs). |
| 2.05-5 | The approach that DOE would use to evaluate and update the existing scope and description of FEPs |
| 2.05-6 | The approach that DOE would use to improve the consistency in the level of detail among FEPs |
| 2.05-7 | How the DOE would evaluate the results of its efforts to update the existing scope and definition of FEPs |
| 2.05-8 | How the Enhanced FEP process would support assertions that the resulting set of FEPs will be sufficiently comprehensive (e.g., represents a wide range of both beneficial and potential adverse effects on performance) to reflect clearly what DOE has considered. |
| 2.05-9 | How DOE would indicate their disposition of included FEPs in the performance assessment. |
| 2.05-10 | The role and definition of the different hierarchical levels used to document the information (e.g., "components of FEPs" and "modeling issues"). |
| 2.05-11 | How the hierarchical levels used to document the information would be used within DOE's enhanced FEP process. |
| 2.05-12 | How the Enhanced FEP Plan would result in documentation that facilitates auditing (i.e., lead to a process that is transparent and traceable). |
| 2.05-13 | DOE's plans for using configuration management controls to identify FEP dependencies on ongoing work and design changes. |
| TSPAI 2.06 | Provide justification for the approach to: (1) the level of detail used to define FEPs; (2) the degree of consistency among FEPs; and (3) comprehensiveness of the set of FEPs initially considered (i.e., before screening).<br><br>DOE proposes to meet with NRC periodically to provide assessments of the DOE's progress, once it has initiated the Enhanced FEP process, and on changes to the approach documented in the Enhanced FEP Plan. During these progress meetings DOE agrees to provide a justification for their approach to: (1) the level of detail used to define FEPs; (2) the degree of consistency among FEPs; and (3) comprehensiveness of the pre-screening set of FEPs. |
| TSPAI 2.07 | Provide results of the implementation of the Enhanced FEP Plan (e.g., the revised FEP descriptions, screening arguments, the mapping of FEPs to TSPA keywords, and a searchable index of FEP components), in updates to the FEP AMR documents and the FEP Database. DOE agrees to provide the results of their implementation of the Enhanced FEP Plan (e.g., the revised FEP descriptions, screening arguments, improved database navigation through, for example, the mapping of FEPs to TSPA keywords, a searchable index of FEP components, etc.), information requested in updates to the FEP documents and the FEP Database (or other suitable documents) in FY 2003. |

## 3.2 ENHANCED FEP PLAN FOR LICENSE APPLICATION

The Enhanced FEP Plan for License Application will build on the FEP analysis performed in support of TSPA-SR (Freeze et al. 2001). The Enhanced FEP Plan addresses the specific issues identified in KTI Agreement TSPAI 2.05 (listed as 2.05-1 through 2.05-13 in Table 3-2). The Plan also addresses other FEP issues related to KTI Agreements (as listed in Table 3-2) and reviews (as listed in Table 3-1). General objectives of the Enhanced FEP Plan include:

- Satisfy and allow comparison to the specific regulatory requirements of 10 CFR 63 (see Section 2.1.3).
- Support the demonstration of comprehensiveness of YMP FEPs.
- Provide guidance for the screening of FEPs, including documentation of the mapping of included FEPs to TSPA model components.
- Develop a hierarchical structure that facilitates navigation within the database for reviewers and, where possible, parallels the structure used (a) in other regulatory-review related documents such as the NRC Yucca Mountain Review Plan (YMRP) (NRC 2002), or (b) to describe TSPA-LA.
- Provide a systematic process for identifying, evaluating, and controlling changes to the YMP FEPs.

The following sections outline the tasks that comprise the Enhanced FEP Plan. All of the issues identified in Tables 3-1 and 3-2 are addressed by one or more of the tasks. The Plan outlines a general philosophy for the tasks necessary to accomplish the above objectives and to satisfy the KTI Agreements. However, specific details of some of the issues cannot be prescribed until the Plan is implemented. These details of implementation are noted throughout the Plan.

The Plan will be implemented by the FEP Team, a group of individuals in the Performance Assessment Strategy and Scope (PASS) Subproject. The FEP Team is responsible for maintaining the YMP FEP list, ensuring consistent treatment and documentation of the FEPs used in TSPA-LA, and developing the YMP FEP Database. The FEP Team will be supported by a FEP AMR Lead and one or more SMEs from each of the subject areas (see Table 3-5 for a listing of FEP AMRs and associated subject areas). The FEP AMR Leads are responsible for ensuring that relevant FEPs are treated appropriately within their FEP AMRs. Note that the term AMR is used throughout this Plan for consistency. However, due to changes in the Quality Assurance Procedures, the FEP analyses previously documented in AMRs may be documented in accordance with AP-SIII.9Q, *Scientific Analyses*. SMEs are the personnel most knowledgeable about individual FEPs and are responsible for developing the explicit screening discussions for documentation in the FEP AMRs. A list of general responsibilities, by Task, is shown in Table 3-3. Guidelines for FEP screening content (within the FEP AMRs and the FEP Database) are provided in Appendix A.

Table 3-3. Responsibilities for FEP Team, FEP AMR Leads, and Subject Matter Experts

| Task | Task Description | FEP Team | FEP AMR Leads | SMEs |
|---|---|---|---|---|
| 1A | Revise the Hierarchical Classification Levels | X | | |
| 1B | Establish Level-of-Detail Criteria for Redefining FEPs | X | | |
| 1C | Revise the Existing FEP List | X | X | X |
| 2A | Configuration Management Controls for Identifying New FEPs | X | | |
| 2B | Ongoing Evaluation and Tracking of FEPs | X | X | X |
| 2C | Identify Role of FEP Database and FEP AMRs | X | X | X |
| 3 | Enhanced Documentation of Screening | | X | X |
| 4 | Database Programming | X | | |
| 5A | Evaluation of the Enhanced FEP Approach – Internal Review | X | | |
| 5B | Evaluation of the Enhanced FEP Approach – External Review | X | | |
| 6 | Final Deliverables – FEP AMRs<br>Final Deliverables – FEP Database Report<br>Final Deliverables – FEP Database | <br>X<br>X | X | |

### 3.2.1 Task 1 - Define Hierarchical Classification Levels and Level of Detail of FEPs

The process for classifying TSPA-SR FEPs is described in Section 3 of Freeze et al. (2001). The classification process was based on a hierarchical database-compatible structure developed by a multi-national FEPs working group, as described in Section 3.1 of Freeze et al. (2001). Each hierarchical level (Layers, Categories, and Headings) was subdivided into a number of topics. Most relevant to the YMP FEP process was the Heading level, at which the post-closure performance of the repository was categorized into 135 roughly equivalent topics. These Headings were selected by the multi-national FEPs experts to provide comprehensive coverage of potential FEPs for any high-level waste (HLW) repository system. Where possible, the Headings were selected to be mutually exclusive and have roughly equivalent levels of importance. However, because HLW repository systems are influenced by many coupled processes, and certain technical considerations carry higher levels of importance depending on design, not all Headings were mutually exclusive or had an equivalent level of importance.

The hierarchical classification process for TSPA-SR FEPs also included the identification of both primary and secondary FEPs. These FEPs included all FEPs from the "end of chain" lists noted in Section 2. A set of primary FEPs (a subset of the complete list of FEPs) was selected such that they encompassed all technical considerations relevant to the post-closure performance of the potential repository. The remaining FEPs, called secondary FEPs, were considered redundant or duplicative of the primary FEPs and were retained only for traceability of FEP origins to support the demonstration of comprehensiveness.

Task 1 of the Enhanced FEP Plan outlines changes to the hierarchical classification structure (for more consistency with YMP project literature) and outlines criteria for determining FEP level of detail. A key aspect of the new hierarchical structure and the new level-of-detail criteria is the elimination of secondary FEPs. As noted in Section 3.2, two of the objectives of the Enhanced FEP Plan are to support the demonstration of comprehensiveness and to develop a hierarchical structure that parallels the structure used in other YMP project literature. Consistency with other project literature will provide for more intuitive navigation within the database. A general approach for accomplishing these two objectives is presented below. Specific details (i.e., specific entries within each of the hierarchical levels) of the basis structure will be identified

during implementation of the Plan and will be conveyed to NRC during progress meetings in accordance with KTI Agreement TSPAI 2.06.

Task 1 is divided into the following three subtasks:

- Task 1A – Revise the Hierarchical Classification Levels
- Task 1B – Establish Level-of-Detail Criteria for Redefining FEPs
- Task 1C – Revise the Existing FEP List.

Each of these subtasks is described in the following sections.

### 3.2.1.1 Task 1A - Revise the Hierarchical Classification Levels

This task addresses the following KTI Agreement TSPAI 2.05 items and recurring review comments:

| ID | Issue |
|---|---|
| TSPAI 2.05-8 | How the Enhanced FEP process would support assertions that the resulting set of FEPs will be sufficiently comprehensive (e.g., represents a wide range of both beneficial and potential adverse effects on performance) to reflect clearly what DOE has considered. |
| TSPAI 2.05-10 | The role and definition of the different hierarchical levels used to document the information (e.g., "components of FEPs" and "modeling issues") |
| TSPAI 2.05-11 | How the hierarchical levels used to document the information would be used within DOE's enhanced FEP process |
| R01 | Improve documentation/traceability to ensure that primary FEPs are comprehensive and that they envelop all secondary FEPs. |
| R03 | Improve intuitiveness of navigation in database. |

The hierarchical classification levels will be used to define an organizational structure into which individual FEPs will be mapped. Changes to the individual FEPs are discussed under Task 1B (Section 3.2.1.2). The following steps outline a general approach for the FEP Team for revising the hierarchical classification levels to improve navigation and support the demonstration of comprehensiveness.

Step 1A-1: Define the role of the upper hierarchical levels

The uppermost hierarchical levels serve to broadly classify the individual FEPs based on the repository subsystems and subsystem components. The discussion below provides an example of how the different hierarchical levels would be used. Actual levels will derive from the basis structure selected during implementation of the Plan.

Hierarchical Level 1 represents the coarsest division of the repository issues, by repository system and subsystem. Regardless of which basis structure is selected, Level 1 will likely be comprised of:

- Engineered Subsystem
- Natural Subsystem (Geosphere)
- Biosphere (Accessible Environment/Reasonably Maximally Exposed Individual)
- Repository System-Level Issues.

Hierarchical Level 2 represents the subsystem components. Regardless of which basis structure is selected, Level 2 will likely include the list of potential engineered barriers:

- Drip Shield
- Backfill
- Waste Package
- Waste Form
- Buffer/Invert
- Drifts/Supports/Seals

and natural barriers:

- Unsaturated Zone
- Saturated Zone.

Because DOE has chosen to keep some design options flexible, Level 2 may contain subsystem components (e.g., backfill) which are not currently included in the repository design.

Step 1A-2: Define the role of the lower hierarchical levels

The lower hierarchical levels serve to classify the individual FEPs based on the processes or events that can act upon or in association with the subsystem components identified in Level 2. The discussion below provides an example of how the lower hierarchical levels would be used. Actual levels will derive from the basis structure selected during implementation of the Plan.

Hierarchical Level 3 represents the characteristics, functions, processes, and events that are associated with one or more subsystem components. Level 3 may also represent interactions and effects between processes, events, and subsystem components. The composition of Level 3 is dependent upon which YMP-specific basis structure is selected during implementation of the Plan. An example is given below based upon the outline in the TSPA-SR (CRWMS M&O 2000e) and Site Suitability Evaluation (SSE) (DOE 2002) documents.

In the example, Level 3A includes, for each component, nominal processes such as:

- Characteristics/performance/degradation of the component
- Flow of water in the component
- Transport of radionuclides in the component.

Level 3B includes, for each component, coupled processes such as:

- Thermal-hydrology (TH) effects on the component
- Thermal-hydro-chemical (THC) effects on the component
- Thermal-hydro-mechanical (THM) effects on the component.

Level 3C includes, for each component, disruptive events such as:

- Igneous activity
- Seismic activity
- Nuclear criticality
- Human intrusion
- Other.

Other possible outlines might follow the YMRP (NRC 2002, Section 4.2.1.3) or be aligned with TSPA model components. Regardless, Level 3 will include processes and events that act upon the subsystem components.

In some cases the Level 3 processes and events themselves may require another hierarchical level of classification (Hierarchical Level 4) for the most efficient classification of individual FEPs. For example, some possible sub-divisions of Level 3A nominal processes are:

Hierarchical Level 4A – Characteristic/Performance/Degradation Process Categories

- Mechanical
- Chemical
- Thermal
- Hydrologic
- Biological
- Microbial
- Radiological.

Hierarchical Level 4B – Nominal Flow Process Categories

- Liquid/Gas
- Fracture/Matrix.

Hierarchical Level 4C – Nominal Transport Process Categories

- Liquid
- Gas
- Solid
- Human
- Animal/Plant/Microbe.

A final decision on the use of Hierarchical Level 4 will be made during implementation of the Plan. It will likely be implemented only for categories where there are large numbers of FEPs and where further classification would aid navigation. The additional classification will aid in the demonstration of comprehensiveness (determining whether all relevant processes have been considered) and will aid in database navigation, especially where there are many interrelated FEPs and/or complex processes. However, where there are few FEPs under consideration, use of Level 4 may unnecessarily clutter the structure and hinder navigation. The decision on the use of Hierarchical Level 4 will also be influenced by the level-of-detail criteria discussed in Task 1B (Section 3.2.1.2).

Step 1A-3: Develop a FEP Matrix

Hierarchical levels 1-3 provide a structure for organizing individual FEPs. The potential interactions of the Level 3 processes and events on the Level 2 subsystem components will be illustrated in a FEP matrix (Table 3-4). The Level 1 subsystems and Level 2 components serve as the vertical axis for the matrix. The horizontal axis contains the Level 3 processes and events. During implementation, the specific Level 3 processes and events necessary for horizontal axis comprehensiveness will be evaluated. In particular, it may prove useful to move some disruptive events to the vertical axis and/or to group the horizontal axis processes and events by scenario classes (i.e., nominal, disruptive, human intrusion).

The matrix intersections represent "boxes" for which potential FEPs may exist. Where boxes are marked with an "X", one or more potential FEPs exist. As was noted under Step 1A-2, an additional hierarchical level (Level 4) may be required for some boxes. The final form of the FEP matrix will be determined during implementation of the Plan.

As is described in Task 1B (Section 3.2.1.2), all Primary FEPs will be mapped to at least one of the boxes in the FEP matrix. Some Primary FEPs may have links to multiple boxes. Within the database it will be possible to locate associated Primary FEPs at any overlying Hierarchical Level. For example, searches can be made for all Waste Package FEPs, all TH Coupled Process FEPs, all Seismic FEPs, etc.

The FEP matrix provides a top-down review of the comprehensiveness of the FEPs process. It complements the bottom-up approach to FEP identification employed for TSPA-SR. The consistency of this classification scheme with other project literature will enhance the transparency and traceability of the underlying FEPs and will aid in navigation within the database.

Table 3-4. Example FEP Matrix of Interactions between Components, Processes, and Events

| Hierarchical Levels 1-2: **Subsystems Subsystem Components** | Hierarchical Level 3A: **Nominal Processes** | | | Hierarchical Level 3B: **Coupled Processes** | | | Hierarchical Level 3C: **Disruptive Events** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Characteristics/Performance/Degradation | Flow | Transport | Thermal-Hydrology (TH) | Thermal-Hydro-Chemical (THC) | Thermal Hydro-Mechanical (THM) | Igneous | Seismic | Criticality | Human Intrusion | Other |
| ***ENGINEERED SUBSYSTEM*** | | | | | | | | | | | |
| **Drip Shield** | X | X | | X | X | X | X | X | X | X | X |
| **Backfill** | X | X | X | X | X | X | X | X | X | X | X |
| **Waste Package** | X | X | X | X | X | X | X | X | X | X | X |
| **Waste Form** | X | X | X | X | X | X | X | X | X | X | X |
| WF Inventory | X | | | | | | | | X | | |
| WF Cladding | X | X | X | X | X | X | X | X | | X | X |
| **Buffer/Invert** | X | X | X | X | X | X | X | X | X | X | X |
| **Drifts/Seals/Supports** | X | X | X | X | X | X | X | X | X | X | X |
| ***GEOSPHERE*** | | | | | | | | | | | |
| **Unsaturated Zone** | X | X | X | X | X | X | X | X | X | | X |
| Climate | X | | | | | | X | | | | X |
| Infiltration | X | X | | | | | X | X | | X | X |
| UZ Above Repository | X | X | | X | X | X | X | X | | X | X |
| Seepage at Repository | X | X | | X | X | X | X | X | | X | X |
| UZ Below Repository | X | X | X | X | X | X | X | X | X | X | X |
| **Saturated Zone** | X | X | X | X | X | X | X | X | X | X | X |
| ***BIOSPHERE*** | | | | | | | | | | | |
| **Biosphere** | X | | X | | | | X | X | | X | X |
| ***SYSTEM-LEVEL*** | | | | | | | | | | | |
| **Assessment Basis** | X | | | | | | | | | X | |
| Assumptions/Regulations/Models | X | | | | | | | | | X | |
| **Operations** | X | | | | | | | | | | |
| Design/Operation/Closure | X | | | | | | | | | | |

NOTE: X = Indicates that the Level 3 Process or Event may influence the Level 2 Subsystem Component.

### 3.2.1.2 Task 1B - Establish Level-of-Detail Criteria for Redefining FEPs

This task addresses the following KTI Agreement TSPAI 2.05 items and recurring review comments:

| ID | Issue |
|---|---|
| | |
| TSPAI 2.05-2 | The guidance on the level-of-detail that DOE will use for redefining FEPs during the enhanced FEP process |
| TSPAI 2.05-6 | The approach that DOE would use to improve the consistency in the level of detail among FEPs |
| TSPAI 2.05-9 | How DOE would indicate their disposition of included FEPs in the performance assessment |
| TSPAI 2.05-10 | The role and definition of the different hierarchical levels used to document the information (e.g., "components of FEPs" and "modeling issues") |
| R04 | Use consistent level of detail (define criteria for FEPs, components, and modeling issues). |
| R06 | Justify the degree of consistency among FEPs. |

The TSPA-SR FEP list contained 328 Primary FEPs (Freeze et al. 2001, Section 3.2). As a starting point for LA, each of these 328 Primary FEPs will be mapped to one or more boxes in the FEP matrix. This task outlines level-of-detail criteria to determine whether enhancements (clarification, combination, or subdivision) to the existing 328 Primary FEPs will be necessary during FEP mapping (Task 1C), ongoing evaluation of FEPs (Task 2), and documentation of FEP screening (Task 3).

There is no uniquely correct level of detail at which to define and/or aggregate Primary FEPs. However, bounding cases for level of detail can be defined. In the "too specific" case, Primary FEPs are narrowly defined, such that there are many independent FEPs, and it is impractical to develop specific screening decisions for each FEP. In the "too broad" case, primary FEPs are coarsely defined and it is difficult to isolate important issues for each FEP. Consequently, some important issues may get excluded. For TSPA-SR, YMP Primary FEPs were aggregated at the coarsest level at which technically sound screening decisions could be made, while still maintaining an adequate level of detail for the purposes of the analysis. The definition of adequate is not precise, but clearly falls between the bounding "too specific" and "too broad" cases. This aggregation process produced a greater number of Primary FEPs in the areas where more complex processes predominate. The TSPA-SR FEP list also contained secondary FEPs, which were redundant to or subsumed in the Primary FEPs.

For LA, YMP Primary FEPs will continue to be aggregated at the coarsest level at which technically sound screening decisions can be made, while still maintaining an "adequate" level of detail for the purposes of the analysis. Primary FEPs will be defined with the goal of having a single independent screening decision, consistent with the level of detail required for analysis. A Primary FEP may include several very specific issues, all of which are covered by the same "technically sound screening decision". For LA, these related issues are not FEPs, but rather will be identified as FEP Components. FEP Components will generally be used to replace the TSPA-SR Secondary FEPs and will provide a consistent and comprehensive summary of issues covered by a Primary FEP. FEP Components, where applicable, will be explicitly identified.

The level of detail for defining FEPs will be based on the following level-of-detail criteria, and also on the order in which these criteria will be applied.

Primary FEP:

- Is aggregated to the coarsest level at which a technically sound screening decision can be made.

  - The FEP may encompass a single feature, process or event, or a few closely related or coupled processes provided that the entire FEP can be addressed by a single specific screening discussion or model.

  - The FEP has a level of detail consistent with the detail required for analysis. There is no value in subdividing a FEP into multiple FEPs or very detailed FEP Components for screening, and then re-combining them into a coarser representation for modeling.

  - The FEP is aggregated to a level that produces a reasonable number (a few hundred) of FEPs to describe the system. If FEPs are too narrowly defined, the number of interrelated FEPs will increase, making it difficult for the database user to isolate discussions pertaining to a single issue.

  - The FEP encompasses all appropriate aspects of an issue such that screening based on low probability or low consequence is reasonable. If FEPs are too narrowly defined, then they may be excluded based on low probability or low consequence when they would otherwise be included.

- Has sufficient specificity such that a single screening argument addresses the components of the FEP.

  - The FEP has a level of detail no coarser than the Hierarchical Level 3 processes and events listed in Task 1A (Section 3.2.1.1).

  - The FEP has a level of detail that minimizes related issues having different screening decisions (e.g., minimize FEPs that have partial include/exclude components).

FEP Component:

- Is an explicit (finer) conceptual detail of a Primary FEP that does not influence screening. FEP Components are details covered by the existing technically sound screening decision of the Primary FEP, and their consequences are evaluated at the existing level of analysis of the Primary FEP.

  - The FEP Component is not treated individually as a Primary FEP because its consequence is included at a higher level in a less detailed Primary FEP.

  - The FEP Component may be a modeling issue. This type of FEP Component is applicable to specific details of the numerical modeling application.

- Is generally used to replace a secondary FEP, but will be more consistent and comprehensive as described in Step 1C-2 of Task 1C (Section 3.2.1.3).

As an example, a Primary FEP may be defined as Tectonic Activity. Examples of FEP Components would be folding, uplift, subsidence, and plate movement. FEP Components may also include modeling issues that are more specific than need be treated as independent FEPs. For example, a Primary FEP may be defined as Waste Package Corrosion. Examples of FEP Components that are modeling issues might be oxic, anoxic, uniform, and localized corrosion.

As the preceding discussion and definitions show, there are conflicting goals in defining an appropriate level of detail for FEPs. On the one hand, there is motivation to define FEPs coarsely, so as to minimize redundant screening arguments and produce a reasonable number of FEPs. On the other hand, there is motivation to define FEPs specifically so that important issues are explicitly screened. Recognizing that there is no uniquely correct level of detail at which to define and/or aggregate FEPs, the following priorities will be applied to the conflicting goals.

Priorities:

1. Coarseness - The over-riding definition of a FEP is that it is aggregated to the coarsest level at which a technically sound screening decision can be made. Therefore, existing FEPs that meet this definition will not be subdivided. The identification of FEP Components will ensure that users of the FEP Database can find relevant issues, even for coarsely aggregated FEPs. Attaining this goal will likely lead to a smaller number of FEPs with more FEP Components.

2. Specificity - FEPs should be defined specifically enough to ensure that important issues are explicitly treated as Primary FEPs. Attaining this goal will likely lead to a greater number of FEPs with fewer FEP Components.

While the level of detail will be bounded (and therefore generally consistent) at Hierarchical Level 3, the goals, definitions, and priorities outlined in this Task will likely result in an inconsistent level of detail at the Primary FEP level. To satisfy the coarseness priority, there will likely be more FEPs in areas where broad, technically sound screening decisions can be made. To satisfy the specificity priority, there will likely be more FEPs in areas where more complex processes predominate. To have a FEP level of detail consistent with the level of detail required for analysis, there will likely be more FEPs in areas where detailed analyses are required (e.g., important subsystems or subsystem components that are controlled by complex processes).

The step-by-step procedure for implementing the level-of-detail goals, definitions, and priorities is outlined in Step 1C-2 of Task 1C (Section 3.2.1.3). Following implementation of Task 1C, the resulting FEP list will be reviewed by the FEP Team. Where possible, significant inconsistencies in the level of detail of Primary FEPs will be reduced, within the framework of the definitions and priorities outlined in this Task. However, a consistent level of detail at the Primary FEP level is not anticipated nor is it considered necessary to demonstrate the safety case.

### 3.2.1.3 Task 1C - Revise the Existing FEP List

This task addresses the following KTI Agreement TSPAI 2.05 items and recurring review comments:

| ID | Issue |
|---|---|
| TSPAI 2.05-5 | The approach that DOE would use to evaluate and update the existing scope and description of FEPs |
| TSPAI 2.05-6 | The approach that DOE would use to improve the consistency in the level of detail among FEPs |
| R05 | Review areas of importance (e.g., igneous, biosphere) and other "broad" FEPs to see whether additional detail (i.e., more primary FEPs) is warranted. |
| R09 | Evaluate the use of shared FEPs. |
| R10 | Reduce cases of partial include/excludes where possible. |
| R11 | Ensure complete treatment of coupling between FEPs. |

The following steps are inter-related and will be performed concurrently.

Step 1C-1: Remap Primary FEPs to the new classification scheme outlined in Task 1A

Each Primary FEP will be assigned by the FEP Team to one or more boxes in the FEP matrix (Table 3-4). The initial TSPA-SR scheme will be retained for traceability to prior versions of the database.

Step 1C-2: Revise Primary FEPs to be consistent with the new hierarchical levels and level-of-detail criteria

This step, to be performed the FEP Team, FEP AMR Leads, and SMEs, will include the following:

- Revise FEP names and descriptions and add a FEP Components field to database. Secondary FEPs will be eliminated by moving secondary issues into either the FEP Descriptions or the FEP Components field. This includes ensuring that secondary FEP issues have been captured and examining the FEP Components for consistency and completeness. This step is performed in parallel with similar subtasks defined under Task 1B (Section 3.2.1.2). In accordance with Priority 1 of Task 1B, a secondary issue will only be converted into a new FEP if it is not covered by the existing independent screening decision and its consequences cannot be evaluated at the existing level of analysis. Otherwise, it will be considered a FEP Component.

- Evaluate shared FEPs and integrate information if necessary. While informal meetings were held to resolve any contradictory screening discussions for shared FEPs, the multiple screening discussions input to the database were not integrated. As a result, shared FEPs in TSPA-SR may contain duplicative screening information. Similarly, some SMEs modified the FEP Descriptions to ensure that all implications of the secondary FEPs were subsumed in the FEP Descriptions. Where these modified FEPs were shared FEPs, multiple FEP Descriptions were input to the database but not integrated.

- Review FEPs that are partially included and partially excluded, and subdivide where appropriate. This step is performed in parallel with similar subtasks defined under Task 1B (Section 3.2.1.2). Subdivision of a FEP will occur either upon recommendation by the FEP Team and corroboration by the appropriate FEP AMR Lead or SME, or, by request of the FEP AMR Lead. Subdivision of existing FEPs

from a coarse level of detail to a more specific level of detail is not required if the Primary FEP meets the criterion of being aggregated at the coarsest level at which a technically sound screening decision can be made.

- The Primary FEP list will be reviewed for consistency in level of detail. This will include a review of the treatment of coupling between FEPs. The FEP matrix outlined in Task 1A (Table 3-4) should be useful for this task. Modifications, either subdivision or aggregation of FEPs, will be made where significant inconsistencies with the definitions and priorities outlined in Task 1B (Section 3.2.1.2) are identified by the FEP Team, FEP AMR Leads, and/or the affected SMEs.

### 3.2.2 Task 2 - Ongoing Development of the FEP List

The process for developing the TSPA-SR FEP list is described in Freeze et al. (2001, Section 2). Significant changes to the FEP list may result from Task 1 (Section 3.2.1) above. Ongoing development to support LA is divided into the following subtasks:

- Task 2A – Configuration Management Controls for Identifying New FEPs
- Task 2B – Ongoing Evaluation and Tracking of FEPs
- Task 2C – Identify Role of FEP Database and AMRs.

Each of these subtasks is described in the following sections.

#### 3.2.2.1 Task 2A – Configuration Management Controls for Identifying New FEPs

This task addresses the following KTI Agreement TSPAI 2.05 items and recurring review comment:

| ID | Issue |
|---|---|
| TSPAI 2.05-1 | The approach used to develop a pre-screening set of FEPs (i.e., the documentation of those things that DOE considered and which the DOE would use to provide support for a potential license application) |
| TSPAI 2.05-13 | DOE's plans for using configuration management controls to identify FEP dependencies on ongoing work and design changes. |
| R07 | Introduce a configuration management procedure/protocol for addressing new and changed FEPs in response to design changes and other new information. |

Configuration management controls will be used to identify design changes and new information that may result in new FEPs or changes to existing FEPs and/or their screening. The FEP Team is currently working to formalize the processes necessary to ensure that FEPs are considered during analysis and design activities. The Project already has a formal and comprehensive review process, which can be used as the basis for this effort. Although various options would integrate the consideration of new or changed FEPs into the review process, the approach that is being taken at this time is to develop the necessary changes to (1) AP-2.14Q, *Review of Technical Products and Data*, to make the PASS Subproject Manager a mandatory reviewer for any design or analysis work which could impact FEPs; and (2) AP-3.12Q, *Design Calculations and Analyses*, such that a review is necessary if design calculations or analysis results could impact FEPs. The final approach for applying configuration management controls will be determined during implementation of the Plan.

### 3.2.2.2 Task 2B – Ongoing Evaluation and Tracking of FEPs

This task addresses the following KTI Agreement TSPAI 2.05 items and recurring review comments:

| ID | Issue |
|---|---|
| TSPAI 2.05-1 | The approach used to develop a pre-screening set of FEPs (i.e., the documentation of those things that DOE considered and which the DOE would use to provide support for a potential license application) |
| TSPAI 2.05-3 | The form that the pre-screening list of FEPs will take (e.g., list, database, other descriptions) |
| TSPAI 2.05-4 | The approach DOE would use for the ongoing evaluation of FEPs (e.g., how to address potentially new FEPs) |
| R07 | Introduce a configuration management procedure/protocol for addressing new and changed FEPs in response to design changes and other new information. |
| R08 | Apply a systematic FEP identification approach similar to the approach for EBS (REF). |

Implementation of this task will address KTI Agreement TSPAI 2.03.

The TSPA-SR FEP list (Freeze et al. 2001, Section 2) was derived from the "end of chain" international FEP analyses (see Section 2) augmented by YMP specific information and iterative reviews. The ongoing approach for evaluating and tracking FEPs is described by the two steps below.

Step 2B-1: Establish baseline FEP list for LA

- Update specific FEPs in FEP AMRs as identified in TSPAI 2.03 (see Table 3-2).
- Review Version 1.2 of the NEA International FEP Database (NEA 1999a) for any changes from the previous version that may signify the need for new FEPs.
- Review "empty" boxes in the FEP matrix to ensure completeness.
- Review "populated" boxes of the FEP matrix to see if additional detail is warranted in accordance with the level-of-detail criteria outlined in Task 1B.
- Review general event tree logic diagrams for nominal flow (Barr et al. 1995), tectonic processes (Barr et al. 1996), igneous activity (Barr et al. 1993), and criticality (CRWMS M&O 1997). These existing reports document a systematic identification of FEPs similar to the method employed in the EBS (CRWMS M&O 2000b).

Step 2B-2: Track new information

New information identified in Task 2A and Step 2B-1 will be evaluated to determine whether a new FEP is warranted. New FEPs and changes to existing FEPs could come from many sources: AP-2.14Q reviews, introduction of an alternative conceptual model, design changes, etc. Regardless of the source, all potential FEPs or changes to existing FEPs will be handled in the same way. (For clarity, the term "potential FEP" as used in the following process description refers to a potential new FEP or a change to an existing FEP.)

- The FEP Team will receive all potential FEPs. These potential FEPs will be entered in a log. The format the log will take and the medium on which it is maintained will be determined during implementation. All recording will be contemporaneous and the log will be suitable for transmittal to the Records Processing Center.

- The FEP Team will evaluate the potential FEP. If the Team can determine the final disposition, they will do so and process the potential FEP through to conclusion. If the FEP Team is unable to determine the final disposition, they will transmit the potential FEP to the appropriate FEP AMR Lead(s) for their review and disposition.

A potential FEP can have one of three possible dispositions:

- It is a new FEP. In this case, the new FEP will be added to the FEP list and included in the appropriate FEP AMR(s).

- It is a FEP Component. In this case, the new FEP Component will be added to the FEP list as a component of a FEP. During the normal review of the FEP AMR, reviewers will ensure that this component is included in the screening decision for the FEP to which it is attached.

- It is neither a new FEP nor a FEP Component. In this case, the documentation that justifies reaching that conclusion will be assembled and submitted to the Records Processing Center as part of the FEPs final deliverables (see Section 3.2.6).

The FEP Team will track the status of the potential FEP through to its final disposition. At the conclusion of the implementation period for this Plan, the log will be reviewed to ensure that all potential FEPs have been assigned a final disposition, that all FEPs or FEP Components are in the FEP list, and that potential FEPs that are not to be included have appropriate and adequate documentation. After the review is complete and resulting actions have been finished, the log will be made a part of the FEPs final deliverables.

#### 3.2.2.3 Task 2C – Identify Role of FEP Database and AMRs

This task addresses the following KTI Agreement TSPAI 2.05 item:

| ID | Issue |
|---|---|
| TSPAI 2.05-3 | The form that the pre-screening list of FEPs will take (e.g., list, database, other descriptions) |

The FEPs relevant to the YMP LA will be provided in the form of a list. The list will include all relevant Primary FEPs, FEP Components (see Sections 3.2.1.1 and 3.2.1.2), and screening discussions (see Section 3.2.3). The FEPs will be listed individually in FEP AMRs and will be listed collectively in the FEP Database. The FEP AMRs are the qualified source for the FEP screening discussions. The FEP Database provides additional navigational methods for viewing, grouping, and retrieving the FEPs.

### 3.2.3 Task 3 - Enhanced Documentation of Screening

This task addresses the following KTI Agreement TSPAI 2.05 items and recurring review comments:

| ID | Issue |
|---|---|
| TSPAI 2.05-5 | The approach that DOE would use to evaluate and update the existing scope and description of FEPs |
| TSPAI 2.05-9 | How DOE would indicate their disposition of included FEPs in the performance assessment |
| TSPAI 2.05-12 | How the Enhanced FEP Plan would result in documentation that facilitates auditing (i.e., lead to a process that is transparent and traceable) |
| R01 | Improve documentation/traceability to ensure that primary FEPs are comprehensive and that they envelop all secondary FEPs. |
| R02 | Upgrade screening text (better traceability for included FEPs, components, and model issues). |

Implementation of this task will address KTI Agreements TSPAI 2.01, 2.02, and 2.04.

The TSPA-SR screening criteria and guidelines are described in Freeze et al. (2001, Section 4). Additional enhancements will be made to the FEP Screening Arguments and TSPA Dispositions in the FEP AMRs (and subsequently in the database) to support LA. These enhancements will include:

- Revise FEPs in FEP AMRs as noted in KTI Agreements TSPAI 2.01, 2.02, and 2.04 (see Table 3-2).
- Document changes due to new and re-organized FEPs from Task 1 (Section 3.2.1) and Task 2 (Section 3.2.2).
- Review TSPA Dispositions to ensure that they include explicit references to the implementation of FEPs (and FEP Components) in TSPA.
- Review Screening Arguments to ensure that there is adequate basis for exclusion (see Section 2.1.3 for criteria).
- Review text to improve consistency with the screening content guidelines outlined in Appendix A.

### 3.2.4 Task 4 - Database Programming

This task addresses the following KTI Agreement TSPAI 2.05 item and recurring review comment:

| ID | Issue |
|---|---|
| TSPAI 2.05-3 | The form that the pre-screening list of FEPs will take (e.g., list, database, other descriptions) |
| R03 | Improve intuitiveness of navigation in database. |

The TSPA-SR FEP Database capabilities are described in Freeze et al. (2001, Section 5) and in the Software Package/User Guide (CRWMS M&O 2001f). To support LA, the following programming subtasks will be implemented by the FEP Team:

- General Upgrades and Improvements
- Improve Navigation
- Quality Assurance Issues.

Each of these subtasks is described in the following sections. During implementation, it may be necessary to modify these subtasks based on internal and external feedback regarding the effectiveness of the planned implementation.

#### 3.2.4.1 Task 4A - General Upgrades and Improvements

A number of enhancements are planned for the FEP Database software. The entire database will be converted to Microsoft Access® 2000 to take advantage of the features available in that version. The database will also be coded and packaged to run as a stand-alone program so the user will not be required to have Microsoft Access® 2000 installed to use the FEP Database. It is planned that there will be multiple interfaces available to the user, allowing the user more flexibility in determining how information is presented. The new hierarchical structure (see Section 3.2.1) will be added. During implementation, alternate graphical user interfaces will also be considered.

#### 3.2.4.2 Task 4B – Improve Navigation

During implementation, various methods will be considered to improve the ability of the user to navigate the FEP Database. Some navigation tools will be structured such that the user is presented with an ever-decreasing number of FEPs (e.g., going from Level 1 to Level 2 and downward to individual FEPs). Other tools and capabilities will be added to provide the user with greater search capabilities such as keyword searching or a search scheme based upon the Microsoft Help system.

#### 3.2.4.3 Task 4C – Quality Assurance Issues

The modifications to the FEP Database software will be accomplished in accordance with AP-SI.1Q, *Software Management* (appropriate revision). It is anticipated that these enhancements will be categorized as a Level 2 software modification and the requirements pertaining to Level 2 Software (AP-SI.1Q, Rev 3, ICN 3, Section 5.4) will be met. To better manage the configuration of the FEPs data and the FEPs software, the data (i.e., screening text taken from the FEP AMRs) and the code (i.e., the Visual Basic commands that control how the data is organized and presented) will be provided in two separate databases (they are currently both in the same database). This separation, which will be transparent to the user, will be accomplished using the Microsoft Access® 2000 "Database Splitter" feature.

### 3.2.5 Task 5 - Evaluation of the Enhanced FEP Approach

The TSPA-SR FEP approach was compared against NRC TSPAI IRSR (NRC 2000, Section 5.2.2) Acceptance Criteria as described in Section 6 of Freeze et al. (2001). Additional feedback on the approach was provided during reviews noted in Section 3.1. The evaluation of the implementation of the Enhanced FEP Plan will be based on the two subtasks, internal review and external feedback. Each of these subtasks is described in the following sections.

### 3.2.5.1 Task 5A – Internal Review

This task addresses the following KTI Agreement TSPAI 2.05 items:

| ID | Issue |
|---|---|
| TSPAI 2.05-7 | How the DOE would evaluate the results of its efforts to update the existing scope and definition of FEPs |
| TSPAI 2.05-8 | How the Enhanced FEP process would support assertions that the resulting set of FEPs will be sufficiently comprehensive (e.g., represents a wide range of both beneficial and potential adverse effects on performance) to reflect clearly what DOE has considered |
| TSPAI 2.05-12 | How the Enhanced FEP Plan would result in documentation that facilitates auditing (i.e., lead to a process that is transparent and traceable) |

Internal reviews of the implementation of the Enhanced FEP Plan will monitor progress of the various tasks against the schedule (see Section 3.2.6) and will make informal evaluations of the ability to meet the applicable Scenario Analysis Acceptance Criteria as outlined in the NRC YMRP (NRC 2002, pp. 4.2-8 through 4.2-16). Specific Acceptance Criteria in the current version of the YMRP include the following:

The Identification of an Initial List of FEPs is Adequate (YMRP, p. 4.2-8)

- The Safety Analysis Report contains a complete list of FEPs related to the geologic setting or the degradation, deterioration, or alteration of engineered barriers (including those processes that would affect the performance of natural barriers), that have the potential to influence repository performance.

- The FEP list is consistent with the site characterization data.

- The FEP list includes, but is not limited to, potentially disruptive events related to igneous activity (extrusive and intrusive); seismic shaking (high-frequency-low magnitude, and rare large-magnitude events); tectonic evolution (slip on existing faults and formation of new faults); climatic change (change to pluvial conditions); and criticality.

- Use, as appropriate, available generic lists of FEPs (e.g., NEA 1999a) as a reference to determine the completeness of the DOE list of FEPs (YMRP, p. 4.2-7).

Screening of the Initial List of FEPs is Appropriate (YMRP, p. 4.2-9)

- DOE has identified all FEPs related to either the geologic setting or to the degradation, deterioration, or alteration of engineered barriers (including those processes that would affect the performance of natural barriers) that have been excluded.

- DOE has provided justification and an adequate technical basis for each FEP excluded from the performance assessment. Acceptable justifications for excluding FEPs are:

- The FEP is specifically excluded by regulation;

- The probability of the FEP falls below the regulatory criterion;

- The omission of the FEP does not significantly change the magnitude and time of the resulting radiological exposures to the reasonably maximally exposed individual, or radionuclide releases to the accessible environment.

- Consider information from site and regional characterization, natural analog studies, and the repository design (YMRP, p. 4.2-7).

Events are Adequately Defined (YMRP, p. 4.2-14)

- Events or event classes are defined without ambiguity and used consistently in probability models, such that probabilities for each event or event class are estimated separately.

- Probabilities of intrusive and extrusive igneous events are calculated separately.

- Definitions of faulting and earthquakes are derived from the historical record, paleoseismic studies, or geological analyses.

- Criticality events are calculated separately by location (e.g., in-package, near-field, and far-field).

Probability Estimates for Future Events Are Supported by Appropriate Technical Bases (YMRP, p. 4.2-15)

- Probabilities for future natural events are based on past patterns of the natural events in the Yucca Mountain region, considering the likely future conditions and interactions of the natural and engineered repository system.

- Probability estimates have specifically included igneous events, faulting and seismic events, and criticality events.

  - Probability estimates for future igneous events are based on past patterns of igneous events in the Yucca Mountain region. This should include uncertainties about the distribution, timing, and characteristics of past igneous activity. Confirm that, at a minimum, documentation of past igneous activity, since about 12 million years ago, encompasses the area within about 50 kilometers (30 miles) of the proposed repository site. Give particular attention to the documentation of the locations, ages, volumes, geochemistry, and geologic settings of less than 6-million-year-old basaltic igneous features, such as cinder cones, lava flows, igneous dikes, and sills.

- Probability estimates for future faulting and seismic events are based on past patterns of these events in the Yucca Mountain region. Examine the adequacy and sufficiency of characterization and documentation of past faulting and seismicity in the Yucca Mountain region, since 2 million years ago. This should include characterization of uncertainties in the age, timing, magnitude (i.e., displacements), distribution, size, location, and style of faulting and seismicity. Evaluate whether interpretations of faulting and seismicity from surficial and underground mapping, interpretations of geophysical data, or analog investigations are internally consistent and geologically feasible, so reasonable projections can be made about the probability of future faulting and earthquake-induced ground vibrations at the site.

- Probability estimates for future criticality events are based on design characteristics and natural features of the proposed Yucca Mountain repository system. Confirm that the estimate of probability of criticality is determined using methodology based on DOE (1998).

Evaluations against these YMRP criteria will be made subjectively. Some additional general considerations are listed below, specific details are aspects of implementation of the Enhanced FEP Plan.

Scope and Definition (in support of TSPAI 2.05-7)

As noted in Section 2.3.2, the level of detail of a FEP list should be guided by grouping/lumping such that the final list contains on the order of a few hundred FEPs. The level of detail should also be guided by the complexity required for modeling or screening.

The updated YMP FEP list will have the following characteristics:

- Hierarchical Level 3 provides consistent "upper bound" for FEP scope (i.e., grouping/lumping based around subsystem components) (see Section 3.2.1.1)

- Criteria and priorities for FEP level of detail are provided (see Section 3.2.1.2)

Comprehensiveness (in support of TSPAI 2.05-8)

As noted in Section 2.3.1, the comprehensiveness of a FEP list cannot be proven with absolute certainty. However, confidence can be gained through a combination of formal and systematic reviews (both top-down and bottom-up), audits, and comparisons with other FEP lists and through the application of more than one classification scheme.

The updated YMP FEP list will have the following characteristics:

- Initial FEP list is based on both general international issues (from NEA FEP list) and site-specific issues, including the Site Characterization Plan (see Freeze et al. 2001, Section 2)

- FEP matrix explicitly identifies areas for FEP coverage (see Section 3.2.1.1)

- Application of both bottom-up (NEA list) and top-down (FEP matrix) classification schemes (see Section 3.2.1)

- Multiple reviews by subject matter experts and external reviewers. Fewer new potential FEPs identified during each successive review cycle (see Freeze et al. 2001, Section 2)

Transparency and Traceability (in support of TSPAI 2.05-12)

As noted in Section 2.3.3, transparency and traceability require clear, auditable documentation of the technical basis for inclusion (including traceable references to TSPA models) or exclusion of FEPs. The YMP FEP list will be entered into a database, which will enhance transparency and traceability.

The updated YMP FEP list will have the following characteristics:

- A user interface, based on the FEP matrix, which will provide multiple ways to find and group FEPs (see Section 3.2.4.2)

- Hyperlinks to FEP AMRs (see Freeze et al. 2001, Section 5.5)

- Documentation of FEP origins, classification, and screening processes for TSPA-SR FEPs is contained in Freeze et al. (2001)

- Documentation of the implementation of enhancements to hierarchical structure, criteria, FEP scope and FEP screening discussions will be contained in a FEP Database Report for LA (see Section 3.2.6)

- Guidance to FEP AMR Leads and SMEs (Appendix A) that they make reference to documentation of how included FEPs are treated in TSPA (see Section 3.2.3)

### 3.2.5.2 Task 5B – External Feedback

This task addresses the following KTI Agreement TSPAI 2.05 item:

| ID | Issue |
|---|---|
| TSPAI 2.05-7 | How the DOE would evaluate the results of its efforts to update the existing scope and definition of FEPs |

Implementation of this task will address KTI Agreement TSPAI 2.06.

The evaluation of the implementation of Enhanced FEP Plan will benefit from NRC feedback supplied at progress meetings as outlined in KTI Agreement TSPAI 2.06. Internal subjective evaluations of progress relative to the YMRP Acceptance Criteria (see Section 3.2.5.1) will be compared with NRC perceptions. In addition, we expect feedback regarding progress towards the 3 key items identified in KTI Agreement TSPAI 2.06:

- The level of detail used to define FEPs
- The degree of consistency among FEPs
- Comprehensiveness of the set of FEPs.

### 3.2.6 Task 6 –Submit Final Deliverables

Implementation of this task will address KTI Agreement TSPAI 2.07.

The implementation of the Enhanced FEP Plan will result in the following deliverables. Expected completion dates are shown in parentheses.

- Updated FEP AMRs (February–October 2003)
- FEP Database Report (October 2003)
- FEP Database (October 2003).

Updated FEP AMRs

The current list of FEP AMRs is shown in Table 3-5. These AMRs (or Scientific Analyses) will be updated by the FEP AMR Leads and SMEs, as needed, for consistency with the updated FEP list.

Table 3-5. FEP AMRs Contributing Screening Information to the TSPA-SR FEP Database

| Subject Area | FEP AMR Document Identifier | Reference |
|---|---|---|
| Unsaturated Zone Flow and Transport (UZ) | ANL-NBS-MD-000001 REV 01 | CRWMS M&O 2001e |
| Saturated Zone Flow and Transport (SZ) | ANL-NBS-MD-000002 REV 01 | CRWMS M&O 2001c |
| Biosphere (Bio) | ANL-MGR-MD-000011 REV 01 | CRWMS M&O 2001b |
| Disruptive Events (DE) | ANL-WIS-MD-000005 REV 00 ICN 01 | CRWMS M&O 2000c |
| Waste Package Degradation (WP) | ANL-EBS-PA-000002 REV 01 | CRWMS M&O 2001g |
| Waste Form Degradation (WF)<br>- Miscellaneous FEPs (WF Misc)<br>- Cladding FEPs (WF Clad)<br>- Colloid FEPs (WF Col) | <br>ANL-WIS-MD-000009 REV 00 ICN 01<br>ANL-WIS-MD-000008 REV 00 ICN 01<br>ANL-WIS-MD-000012 REV 00 ICN 01 | <br>CRWMS M&O 2001h<br>CRWMS M&O 2000a<br>CRWMS M&O 2001i |
| Near Field Environment (NFE) | ANL-NBS-MD-000004 REV 00 ICN 01 | CRWMS M&O 2001d |
| Engineered Barrier System Degradation, Flow, and Transport (EBS) | ANL-WIS-PA-000002 REV 01 | CRWMS M&O 2001a |
| System-Level and Criticality FEPs (Sys) | ANL-WIS-MD-000019 REV 00 | CRWMS M&O 2000d |

FEP Database Report

The FEP Database Report will be either a revision to Freeze et al. (2001) or a new, but similar, document developed by the FEP Team. It is expected to contain the following information about the development of the FEP list and the database:

- Origin and Development of the FEP List
- Hierarchical Classification Structure
- Level-of-Detail Guidance and Criteria
- Screening Guidance and Criteria
- Log of Disposition of Potential FEPs

FEP Database

The FEP Database will be prepared by the FEP Team and submitted in accordance in AP-SI.1Q. The FEP database provides navigational methods for viewing, grouping, and retrieving the FEPs, but the qualified source for the FEP screening discussions is the FEP AMRs.

## 3.3 ENHANCED FEP PLAN RESOLUTION OF KTI AGREEMENT TSPAI 2.05

The Enhanced FEP Plan described in Section 3.2 addresses the 13 specific items outlined in KTI Agreement TSPAI 2.05 (see Table 3-2). Table 3-6 summarizes how the Plan addresses each of the 13 items, with specific references to Plan sections. In addition, through implementation of the Plan, DOE expects to demonstrate conformance with the other 6 KTI Agreements listed in Table 3-2.

Table 3-6. Summary of Resolution of KTI Agreement TSPAI 2.05 Items

| | |
|---|---|
| **TSPA 2.05-1** | The approach used to develop a pre-screening set of FEPs (i.e., the documentation of those things that DOE has considered and which the DOE would use to provide support for a potential licensing application. |
| • The Enhanced FEP Plan (especially Tasks 1 and 2) describes the process that has been used to create the initial pre-screening set of FEPs. The updated pre-screening list will derive from the TSPA-SR FEP list (Freeze et al. 2001, Section 2).<br>• Configuration management controls will be applied during implementation of the Plan to identify potential new or changed FEPs resulting from design changes or new information (Task 2A, p. 29).<br>• New issues (potential FEPs) will be evaluated by the FEP Team and, if necessary, FEP AMR Leads. Potential FEPs will be dispositioned as FEPs, FEP Components, or be documented in an issue log (Task 2B, pp. 30-31). | |
| **TSPAI 2.05-2** | The guidance on the level-of-detail that DOE will use for redefining FEPs during the enhanced FEP process. |
| • The Enhanced FEP Plan presents a generalized set of criteria for determining whether existing FEPs and new issues will be classified as FEPs or FEP Components (Task 1B, p. 26). | |
| **TSPAI 2.05-3** | The form that the pre-screening list of FEPs will take (e.g., list, database, other descriptions). |
| • FEPs relevant to the YMP LA will be provided in the form of a list. FEPs will also be listed individually in the FEP AMRs and collectively in the FEP Database (Task 2C, p. 31).<br>• New issues (potential FEPs) raised during the implementation phase need not take any specific form as long as the information is recorded as it is received and the documentation is adequate for inclusion in the FEPs final deliverables (Task 2B, p. 31).<br>• Enhancements are planned to make it easier to navigate and locate FEPs within the FEP Database (Task 4, p. 33). | |

Table 3-6. Summary of Resolution of KTI Agreement TSPAI 2.05 Items (Continued)

| | |
|---|---|
| **TSPAI 2.05-4** | The approach DOE would use for the ongoing evaluation of FEPs (e.g., how to address potentially new FEPs). |
| • The Enhanced FEP Plan describes a process where an issue is received, evaluated by the FEP Team, the FEP AMR Leads if necessary, and eventually classified as a FEP, a FEP Component, or neither. Those issues that are determined to be neither FEPs nor FEP Components will be documented in an issue log and included as part of the FEPs final deliverables (Task 2B, pp. 30-31). | |
| **TSPAI 2.05-5** | The approach that DOE would use to evaluate and update the existing scope and description of FEPs. |
| • The Enhanced FEP Plan defines a process for remapping FEPs to a new classification scheme and for revising FEPs to be consistent with the defined level-of-detail criteria (Task 1C, pp. 28-29).<br>• The FEP Screening Arguments and TSPA Dispositions will be enhanced to improve consistency with screening content guidelines in Appendix A and as noted in other KTI agreements (Task 3, p. 32). | |
| **TSPAI 2.05-6** | The approach that DOE would use to improve the consistency in the level of detail among FEPs. |
| • The Enhanced FEP Plan presents criteria for determining the appropriate level of detail amongst FEPs. The Plan also identifies a bounding, generally consistent level of detail (Hierarchical Level 3) and describes conflicting goals that will result in inconsistencies in the level of detail (Task 1B, pp. 26-27).<br>• The Plan presents a step-by-step procedure for applying level-of-detail criteria to the FEP list (Task 1C, p. 28-29). | |
| **TSPAI 2.05-7** | How the DOE would evaluate the results of its efforts to update the existing scope and definition of FEPs. |
| • The Enhanced FEP Plan describes a process that will be used to evaluate the updated YMP FEP list against the YMRP Acceptance Criteria (Task 5A, pp. 34-36).<br>• DOE anticipates that feedback from the NRC during progress meetings (as per TSPAI 2.06) will also be used to determine the acceptability of updated FEPs (Task 5B, pp. 37-38). | |
| **TSPAI 2.05-8** | How the Enhanced FEP process would support assertions that the resulting set of FEPs will be sufficiently comprehensive (e.g., represents a wide range of both beneficial and potential adverse effects on performance) to reflect clearly what DOE has considered. |
| • The YMRP Acceptance Criteria will be used to evaluate the comprehensiveness of the FEP list (Task 5A, pp. 34-36).<br>• The FEP list is based on both a comprehensive list of international issues (from the NEA FEP list) and YMP site-specific issues, including the Site Characterization Plan (Task 5A, p. 36)<br>• The FEP list has been subject to multiple organizational structures and has been generated from both bottom-up (NEA list) and top-down (FEP matrix) classification schemes (Task 1A, pp. 20-22).<br>• The FEP matrix explicitly identifies areas for FEP coverage (Task 1A, p. 23)<br>• The FEP list has undergone multiple reviews by SMEs and external reviewers and fewer potential FEPs were identified during each successive review cycle (Task 5A, p. 37) | |
| **TSPAI 2.05-9** | How DOE would indicate their disposition of included FEPs in the performance assessment. |
| • The Enhanced FEP Plan describes a process for enhancing the documentation of FEPs and provides screening content guidelines in Appendix A which include ensuring that FEPs and FEP Components can be traced to their implementation in the TSPA (Task 3, p. 32).<br>• Where applicable, the implementation of both FEPs and FEP Components in TSPA will be documented (Task 1B, pp. 26-27). | |

Table 3-6. Summary of KTI Agreement TSPAI 2.05 Items (Continued)

| | |
|---|---|
| **TSPAI 2.05-10** | The role and definition of the different hierarchical levels used to document this information (e.g., "components of FEPs" and "modeling issues"). |
| • The Enhanced FEP Plan describes the role and definition of revised hierarchical classification levels (Task 1A, pp. 20-23).<br>• The Enhanced FEP Plan presents a generalized set of criteria for determining whether existing FEPs and new issues will be classified as FEPs or FEP Components (Task 1B, p. 26). | |
| **TSPAI 2.05-11** | How the hierarchical levels used to document the information would be used within DOE's enhanced FEP process. |
| • The Enhanced FEP Plan provides a detailed explanation of how the hierarchical levels would be applied (Task 1A, pp. 20-23). | |
| **TSPAI 2.05-12** | How the Enhanced FEP Plan would result in documentation that facilitates auditing (i.e., lead to a process that is transparent and traceable). |
| • The YMRP Acceptance Criteria will be used to evaluate the transparency and traceability of the FEP list (Task 5A, pp. 34-36).<br>• The FEP list will be entered into a database. The database user interface will be based on a YMP specific structure for more intuitive navigation and will provide multiple ways to find and group FEPs (Task 5A, p. 37)<br>• The FEP Database will provide hyperlinks to the FEP AMRs (Task 5A, p. 37).<br>• Screening content guidance will be provided to FEP AMR Leads and SMEs to ensure that they make reference to documentation of how FEPs are included in TSPA (Task 3, p. 32). | |
| **TSPAI 2.05-13** | DOE's plans for using configuration management controls to identify FEP dependencies on ongoing work and design changes. |
| • Configuration management controls will be applied during implementation of the Plan to identify potential new or changed FEPs resulting from design changes or new information (Task 2A, p. 29). | |

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# APPENDIX A
# FEP SCREENING CONTENT GUIDELINES

These guidelines for FEP screening content will be considered by the FEP AMR Leads and SMEs in the planning and implementation of FEP AMRs. Information for each of the following fields must be included in FEP AMRs.

**YMP Primary FEP Description** – Must be relevant to YMP and must encompass a single feature, event or process or a few closely related or coupled processes. Where necessary, the Description should also include the FEP Components.

**FEP Components** – Identifies explicit (finer) conceptual or modeling details of the primary FEP. Where applicable, these details should be listed in keyword form. Where necessary, FEP Component descriptions will be included in the YMP Primary FEP Description.

**Screening Decision and Regulatory Basis** – Must state whether the FEP is included or excluded from the TSPA. For excluded FEPs, the exclusion criteria (regulation, low probability, low consequence) must be explicitly identified. Regulatory exclusions should only be used in areas such as biosphere where the required characteristics of the biosphere and reasonably maximally exposed individual (RMEI) are clearly specified in the regulations. For partially included or partially excluded FEPs, the FEP Components that are included and excluded must be identified.

**Screening Argument** - For excluded FEPs this is the main screening discussion. A summary of the technical basis for exclusion must be presented, and the summary must address all FEP Components. Low probability exclusions must include an explicit comparison of the probability of occurrence to the regulatory criteria ($<10^{-4}$ in 10,000 years). The probability must be quantified where possible, although non-quantitative low-probability arguments are acceptable for "not credible" FEPs. Low consequence exclusions must include an explicit statement, consistent with the regulatory criteria (see Section 2.1.3), that "the magnitude and time of the resulting radiological exposures to the reasonably maximally exposed individual, or radionuclide releases to the accessible environment" would not be "significantly changed" by the omission of the FEP. The basis for this statement must be explained. The change in exposure or release must be quantified where possible, and the interpretation of "significant change" must be described (it may be different for each FEP). It is acceptable to quantify the change in an intermediate performance measure (e.g., radionuclide mass release to the saturated zone). However, in that case, the qualitative link to change in exposure or release must be explicitly stated. Regulatory exclusions must identify a specific regulation and clearly state the rationale for the exclusion. Regulatory exclusions should only be used in areas such as biosphere where the required characteristics of the biosphere and RMEI are clearly specified in the regulations.

**TSPA Disposition** - For included FEPs this is the main screening discussion. A summary discussion of the treatment of the FEP in the TSPA must be presented. A reference to an AMR describing a model and/or model abstraction is desirable. In some cases, a FEP may affect multiple facets of the project, may be relevant to more than one FEP AMR subject area, or may not fit neatly within the FEP AMR structure. In these cases, rather than create multiple separate FEPs, these shared FEPs will be assigned to more than one FEP AMR.