AN AUDIT OF THE U.S. DEPARTMENT OF ENERGY TREATMENT OF FEATURES, EVENTS, AND PROCESSES AT YUCCA MOUNTAIN, NEVADA, WITH EMPHASIS ON THE EVOLUTION OF THE NEAR-FIELD ENVIRONMENT

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ABSTRACT

The draft U.S. Department of Energy (DOE) database of features, events, and processes (FEPs) for performance assessment scenario development for the proposed high-level nuclear waste repository at Yucca Mountain, Nevada, has been assessed with respect to (i) the Nuclear Regulatory Commission (NRC) Evolution of the Near-Field Environment (ENFE) key technical issue (KTI) and (ii) NRC acceptance criteria regarding scenario development. Relevant database entries have been identified and categorized according to relevance to ENFE subissues. The goal of the evaluation is to provide guidance to NRC/CNWRA staff involved in issue resolution and review plan development activities, and to assess DOE's scenario development process. ENFE-related entries composed 35 percent of the 1,786 database entries and 50 percent of the 310 primary entries. Deficiencies in the exclusion of FEPs have been identified, typically due to an inadequate technical basis. Four ENFE-relevant FEPs that were not in the database, but may be important to repository performance, have been identified. Conclusions on DOE's scenario development process and the FEP database related to structure, transparency, and usability, have been enumerated. Two key findings are that the combination of secondary entries into primary entries—a key component of the FEPs classification process—is problematic, and the database may not permit ready assessment of DOE's approach to interactions and couplings among FEPs. Findings and recommendations for DOE to consider center on how their scenario development process and FEP database address transparency, traceability, comprehensiveness, and screening. Guidance is also provided to NRC/CNWRA staff in the ENFE and Total System Performance Assessment and Integration KTIs on issue resolution activities and the development of review methods for the Yucca Mountain Review Plan.

CONTENTS

CONTENTS (cont'd)

FIGURES

TABLES

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QUALITY OF DATA, ANALYSES, AND CODE DEVELOPMENT

This report was prepared in accordance with the quality assurance requirements described in the CNWRA Quality Assurance Manual.

DATA: No original CNWRA-generated data are included in this report. Sources of non-CNWRA data cited should be consulted for determining levels of quality assurance.

ANALYSES AND CODES: Microsoft Excel 97 and Microsoft Access 97 computer codes were used for analyses contained in this report. These are commercial computer codes and are not controlled under the CNWRA Technical Operating Procedure-018 (Development and Control of Scientific and Engineering Software).

1 INTRODUCTION

1.1 OBJECTIVES

As part of its scenario development process for the Total System Performance Assessment for the Site Recommendation (TSPA-SR) for the proposed repository for high-level nuclear waste at Yucca Mountain, Nevada, the U.S. Department of Energy (DOE) is developing a database of features, events, and processes (FEPs) that may affect repository performance (U.S. Department of Energy, 1999a; Swift et al., 1999). The purpose of the database is to house the entire set of FEPs considered for inclusion in DOE total system performance assessments (TSPAs) for both the site recommendation and potential license application. The database includes descriptions, technical justifications for inclusion or exclusion into the TSPA, and disposition of FEPs in the TSPA. Completion and release of the database is intended to aid in DOE's effort to attain transparency and traceability in the licensing process and the technical arguments underlining the safety case (Swift et al., 1999). In order to obtain early feedback on their scenario development process, DOE provided the database in a preliminary form as Revision 00b (U.S. Department of Energy, 1999a) to the Nuclear Regulatory Commission (NRC).

As part of the ongoing issue resolution activities in the evolution of the near-field environment (ENFE) key technical issue (KTI), NRC recently concluded that the DOE's FEPs analysis and NRC review of the analysis will provide the best near-term opportunity to further resolution of subissues within the ENFE KTI (Nuclear Regulatory Commission, 1999a). At that time, NRC also noted that one potential area of concern arising from DOE/NRC interactions was that coupled thermal-hydrological-chemical (THC) processes discussed in the ENFE Issue Resolution Status Report (IRSR) were not specifically included within the DOE FEP database. NRC promised to review the DOE FEPs screening analysis to evaluate its completeness and determine whether an adequate technical basis has been provided for those FEPs associated with coupled THC processes that were screened out of the DOE performance assessment (Nuclear Regulatory Commission, 1999a).

This report documents that review. The ENFE KTI is chiefly concerned with the effects of combinations of evolving THC processes on performance of all components of the engineered barrier system (EBS) as well as on the surrounding environment affected by waste emplacement (Nuclear Regulatory Commission, 1999a). The objective of this analysis is three-fold. First, it will provide guidance to ENFE staff at NRC and the Center for Nuclear Waste Regulatory Analyses (CNWRA) on FY2000 activities related to FEPs analysis and issue resolution. Second, the report will provide feedback to DOE on their treatment of FEPs and the utility of the database. Although the FEP database is in preliminary form, an early assessment of the include/exclude status of FEPs and the supporting technical screening arguments therein will allow NRC to identify potential deficiencies in advance of DOE's final formulation for TSPA-SR. Finally, this analysis provides a test of existing NRC review methods for scenario development (Nuclear Regulatory Commission, 1998).

This analysis was guided primarily by the acceptance criteria and review methods for issue resolution presented in the ENFE IRSR (Nuclear Regulatory Commission, 1999a) and the Total System Performance Assessment and Integration (TSPAI) IRSR (Nuclear Regulatory Commission, 1998). The ENFE IRSR provides a comprehensive summary of those technical issues deemed important by NRC and discussion of ENFE-relevant FEPs. The TSPAI IRSR contains acceptance criteria and review methods to be applied to DOE's scenario development and model abstraction processes. Aspects of that review considered in this audit were (i) identification of an initial set of processes and events, (ii) classification of processes and events, and (iii) screening of processes and events (sections 4.4.1, 4.4.2, and 4.4.3 of Nuclear Regulatory Commission, 1998). This audit provided a means to apply and test those review methods, in order to further the goals (relevant to

those discussed in the previous paragraph) of providing feedback to DOE on the adequacy of their approach to meeting the acceptance criteria and to NRC/CNWRA on whether the review methods need to be revised. Because review methods will be incorporated into the NRC Yucca Mountain Review Plan, this audit may also provide valuable guidance to that document.

This report will contribute to the completion of other ENFE-related milestones for FY2000. Four intermediate milestones are planned for addressing resolution of ENFE subissues 1–4, concerning THC effects on seepage and flow, waste package and drip shield chemical environment, radionuclide release, and radionuclide transport (see section 2.3). The results of the present analysis—in particular, identification of excluded FEPs—will be used to audit the DOE's disposition of FEPs using the acceptance criteria in the ENFE IRSR (Nuclear Regulatory Commission, 1999a) as well as in the TSPAI IRSR (Nuclear Regulatory Commission, 1998). DOE analysis and model reports (AMRs) (U.S. Department of Energy, 1999b) that will be reviewed in this audit support process model reports (PMRs) relating to unsaturated zone flow and transport (AMR number U0170), near-field environment (N0080), waste package (W0055), waste form (F0050 and F0185), engineered barrier system (E0015 and E0110), and saturated zone flow and transport (S0075). The four aforementioned intermediate milestones will document the ENFE review of DOE's disposition of FEPs. The next revision of the ENFE IRSR—a major milestone—will document the complete analysis of FEPs relevant to the ENFE KTI.

This analysis consists of three components:

(i) Identification of FEPs technically relevant to the ENFE KTI and distribution of these FEPs among ENFE subissues;
(ii) Identification of apparent deficiencies in the database for both unsupported FEP exclusions and absence of relevant FEPs; and
(iii) Discussion of deficiencies in database structure, organization, and execution.

This report should not be construed as a complete review of the overall DOE TSPA scenario development process. Information on the process obtained from DOE at an Appendix 7 meeting (September 8, 1999) and subsequent teleconferences was included in the review.

1.2 THE DATABASE

The DOE scenario development process has been summarized in a recent publication (Swift et al., 1999) and at an Appendix 7 meeting on September 8, 1999. Figure 1-1 illustrates the proposed overall process (Swift et al., 1999). The first four steps shown—FEPs identification and classification, FEPs screening, scenario construction, and scenario screening—correspond (though not precisely) to steps outlined in the TSPAI IRSR section on scenario analysis (section 4.4 in Nuclear Regulatory Commission, 1998), while the final step on TSPA implementation addresses the same process outlined in the TSPAI IRSR section on model abstraction (section 4.3, Nuclear Regulatory Commission, 1998).

The first two steps in figure 1-1 reflect the FEPs analysis process addressed in this report. The proposed DOE FEPs screening process is shown in figure 1-2 (Swift et al., 1999). DOE's FEP database is

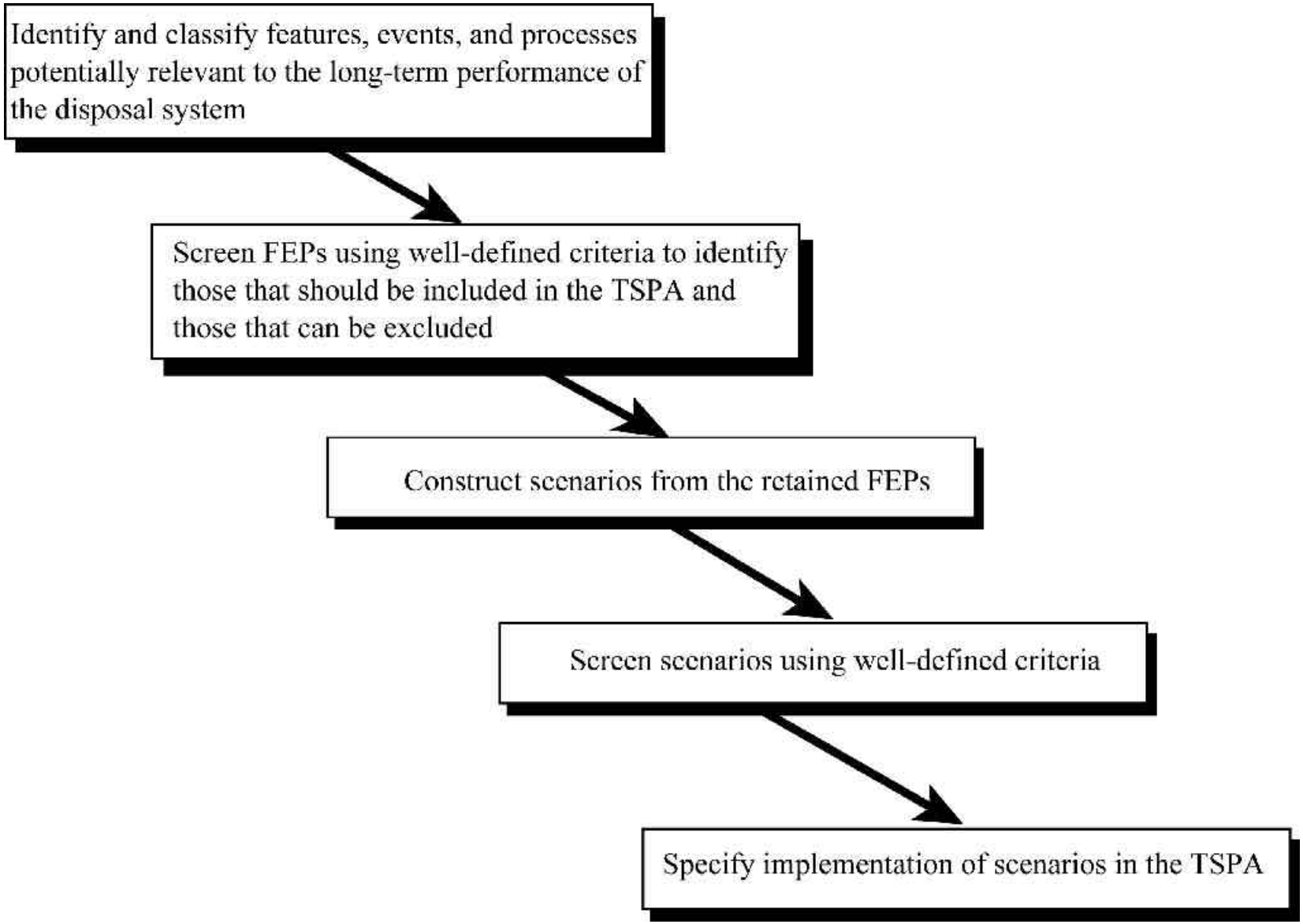

Figure 1-1. Proposed U.S. Department of Energy scenario development process, after Swift et al. (1999)

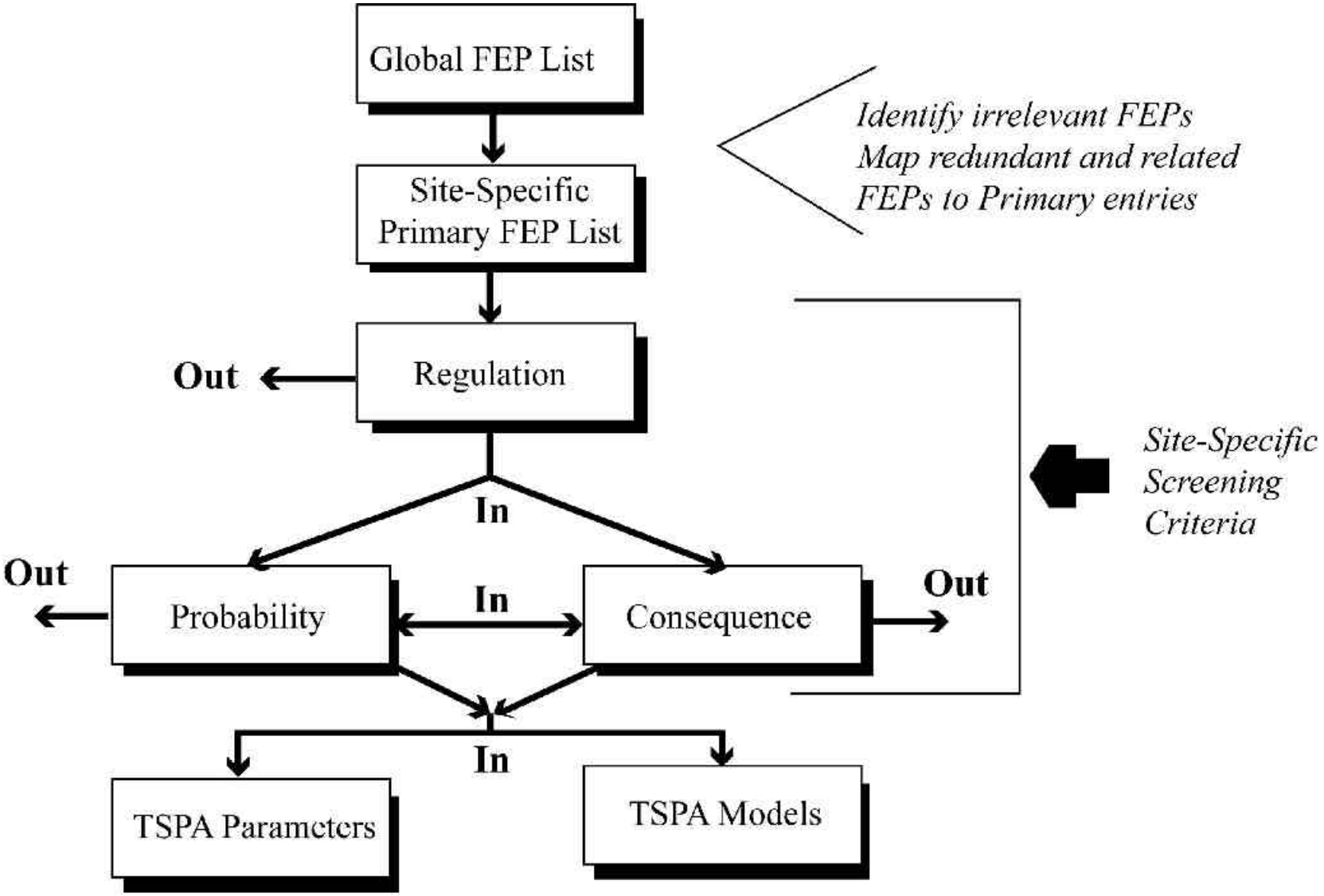

Figure 1-2. Illustration of proposed U.S. Department of Energy features, events, and processes screening methodology, after Swift et al. (1999)

based on the International FEPs Database issued by the Nuclear Energy Agency (NEA) of the European Commission's Organization for Economic Cooperation and Development (Nuclear Energy Agency, 1997); this is denoted in figure 1-2 as the "Global FEP List." The NEA database is a compilation of FEPs from seven nuclear waste disposal assessment efforts conducted in five nations and by the NEA. DOE started with the NEA database (Swift et al., 1999). Additional entries specific to Yucca Mountain were added to those in the NEA database. FEPs in the database (Revision 00b) were identified by a variety of methods, including expert judgment, informal elicitation, event tree analysis, stakeholder review, and regulatory stipulation (Swift et al., 1999). There is no specific technique that has been described as a preferred method of FEP identification in the DOE scenario development effort (Swift et al., 1999). Details on the processes for selecting the initial FEP list and the addition of FEPs will be presented in Chapter 2 of the TSPA-SR Methods and Assumptions document (Sandia National Laboratories, 1999). Additionally, the basis for DOE's conclusion that the database is comprehensive will be addressed in the TSPA-SR Methods and Assumptions document and will be provided with release of the Revision 00 database in 2000 (Sandia National Laboratories, 1999). It has been suggested that final demonstration of comprehensiveness would be achieved through iterative review and comment (Sandia National Laboratories, 1999).

Database entries were classified as primary or secondary (Swift et al., 1999), with the secondary entries categorized under the 311 primary entries. Secondary FEPs are those entries that are completely redundant (e.g., the NEA list contains as many entries for a FEP such as meteorite impact as there were participating programs) or FEPs that can be aggregated into a single primary FEP for the purposes of the TSPA (Swift et al, 1999). Combined with entries that categorize the primary FEPs, the database contains a total of 1,786 entries. The primary entries—numbers which end in ".00"—are intended to combine information from secondary entries so that the primary entries stand alone as FEPs to be screened (second box in figure 1-2).

Screening of primary FEPs is based first on relevance to regulations, then on the basis of probability and consequence (third and fourth levels of figure 1-2). Finally, TSPA disposition of retained FEPs is defined (bottom of figure 1-2). Each primary entry is intended to have its own screening argument and TSPA disposition description. In fact, details of individual FEPs and their screening arguments are commonly contained in the secondary entries; this is likely due to the preliminary nature of the database. Further comments on these aspects of the database are discussed in section 3.4.

DOE provided summaries of their preliminary screening results, as presented in Revision 00b of the database, at the September 8, 1999, Appendix 7 meeting (presentation by P. Swift). Of the 1,786 total entries

- 796 were classified as "Include"
- 834 were classified as "Exclude"
- 18 were classified as both, meaning that some aspects of the FEP were included and some were excluded
- 138 were undecided (denoted by a blank field or question mark)

Because final screening of FEPs will be performed at the primary level, preliminary screening of the 310 primary entries is more relevant:

- 167 were classified as "Include"
- 123 were classified as "Exclude"
- 13 were classified as both
- 7 were undecided

As noted in section 1.1, the currently available version of the DOE FEP database (provided in Microsoft Access format) is preliminary. The majority of screening arguments—a key focus of this analysis—is to be

revised by June 2000. In addition, it is possible that even the classification of FEPs as included or excluded in the current version of the database will be revised. DOE screening decisions, screening arguments, TSPA disposition statements, and references in the final version of the database will be linked to FEP AMRs for each of the PMRs that describe model abstraction (presentation by G. Freeze, Appendix 7 meeting, September 8, 1999). The observations and assessments of the screening arguments will therefore need to be revisited as the FEP AMRs are released. Review of other AMRs will address many of the issues raised here [review of the FEP AMRs is expected to be incorporated into the several KTI IRSRs (see also section 2.3)]. For these reasons, and because of the broad scope of the present review, detailed technical analyses supported by the literature are not included in this report.

1.3 CONTRIBUTION TO NUCLEAR REGULATORY COMMISSION GOALS AND STREAMLINING

Regarding FEPs, proposed rule 10 CFR Part 63, Disposal of High-Level Radioactive Wastes in a Proposed Geological Repository at Yucca Mountain, Nevada, specifies in section 63.114 that DOE shall

- "Consider alternative conceptual models of features and processes that are consistent with available data and current scientific understanding, and evaluate the effects that alternative conceptual models have on the performance of the geologic repository."

- "Consider only events that have at least one chance in 10,000 of occurring over 10,000 years."

- "Provide the technical basis for either inclusion or exclusion of specific features, events, and processes of the geologic setting in the performance assessment. Specific features, events, and processes of the geologic setting must be evaluated in detail if the magnitude and time of the resulting expected annual dose would be significantly changed by their omission."

- "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 expected annual dose would be significantly changed by their omission."

The preceding discussion shows that the FEP database partially documents DOE's effort to meet these requirements. The present audit therefore serves to further the overarching NRC goal of ensuring protection of public health and safety. Should a license application be submitted, an active NRC role in reviewing DOE's scenario development process could serve to enhance the public's confidence in the NRC. A subsidiary NRC goal is to streamline the regulatory process through efficiency, effectiveness, and realism. This audit furthers the streamlining goal in several ways. Efficiency is served in that this audit will (i) provide feedback to DOE early in their scenario development process for TSPA-SR and a potential TSPA-LA, (ii) help guide NRC/CNWRA multidisciplinary activities in the direction of those issues requiring timely resolution, and (iii) probe the effectiveness of review methods. The audit was preceded by an Appendix 7 meeting and two conference calls that facilitated NRC/CNWRA familiarization with the database and provided a forum for provision of draft comments on the database to DOE. The audit provides a framework for subsequent tracking of database completion and revision together with implementation of the DOE scenario analysis in future pre-licensing documents.

2 APPROACH TO THE ANALYSIS

As discussed in section 1.1, this analysis is focused on (i) identifying and categorizing ENFE-relevant FEPs, (ii) ensuring ENFE-relevant FEPs that the NRC considers potentially important to performance are not excluded from abstraction in DOE's TSPA-SR and TSPA-LA without an adequate technical basis, and (iii) reviewing critically the database structure and organization. The approaches to the first two areas of focus are described in this chapter. Assessment of database structure and organization followed naturally from the evaluation.

2.1 APPROACH TO IDENTIFYING ENTRIES RELEVANT TO THE EVOLUTION OF THE NEAR-FIELD ENVIRONMENT KEY TECHNICAL ISSUE

The approach to identification of ENFE-relevant database entries consisted of two activities. First, inspection of all 311 primary entries produced a list of those deemed relevant based on categorization and a cursory examination of the FEP name and description. Second, this list, when compared with the list of entries resulting from the analysis of excluded entries described in section 2.2, provided a cross-check of the results of the initial inspection. The sets of entries resulting from these two analyses were then inspected in tandem to ensure relevance of entries to the ENFE KTI and completeness of coverage. Criteria for relevance to the ENFE KTI included

- Processes involve THC, thermal-chemical, or hydrologic-chemical coupling. Entries describing only thermal-mechanical or thermal-hydrologic couplings were generally omitted.

- Features or processes potentially directly affect coupled THC processes or are affected by them. For example, waste package and waste form degradation processes were generally included because they can affect both chemical and hydrologic conditions in the EBS. Likewise, because fractures are central to models of thermal-chemical alteration of host tuff, entries pertaining to near-field fractures were included.

- Features are located in, or processes take place in, the near field as defined in the ENFE IRSR. The portion of the site where changes in the physical and chemical properties, resulting from the construction of the underground facility or from the heat generated by the emplaced radioactive waste, significantly affect performance of the repository is defined as the near field (Nuclear Regulatory Commission, 1999a)

- FEPs describing criticality within the waste package were not considered. These FEPs have been assigned to the Container Life and Source Term KTI.

In practice, it was found that these criteria could only be applied through inspection of the FEP name, descriptions, and screening argument; the name alone was potentially misleading. For example, the presence of terms such as far-field and saturated zone did not ensure ENFE irrelevance. Secondary entries identified by the filters (described in section 2.2) and the secondary entries to the primary entries identified in the initial inspection were assessed for ENFE relevance. Relevance of a primary entry did not ensure that all the corresponding secondary entries were ENFE-relevant. Conversely, some secondary entries were deemed relevant while their corresponding primary entry was not (comments on DOE's roll-up of secondary entries into primary FEPs are included in section 3.4). In general, inspection of secondary entries was more cursory than for primary entries. This contrast in emphasis is justified by DOE's planned reliance on primary entries in the final database.

In constructing the list, decisions regarding ENFE relevance were biased in favor of inclusion. It is preferable to have to dismiss an entry in the future rather than to overlook an entry that may be relevant.

2.2 METHODS TO EVALUATE DATABASE DEFICIENCIES

Proposed regulation 10 CFR Part 63 states in sections 63.114(e) and 63.114(f) that the DOE performance assessment shall

> Provide the technical basis for either inclusion or exclusion of specific features, events, and processes of the geologic setting in the performance assessment. Specific features, events, and processes of the geologic setting must be evaluated in detail if the magnitude and time of the resulting expected annual dose would be significantly changed by their omission.
>
> 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 expected annual dose would be significantly changed by their omission.

Therefore, the grouping of secondary entries into primary entries and screening decisions and arguments in the FEP database received close scrutiny.

Two types of FEP deficiencies were assessed (i) insufficiently supported DOE classification of a FEP as excluded and (ii) omission of a FEP from the database. Identification of FEPs in the first category was achieved by recognition of excluded FEPs and assessment of their screening arguments. The steps followed in this assessment are depicted in figure 2-1. Numerous text filters were applied to identify relevant primary and secondary entries (Appendix 1). Filter search terms were formulated by reviewing the ENFE IRSR (Nuclear Regulatory Commission, 1999a)—in particular, subissue descriptions and acceptance criteria—for terms relevant to the KTI focus on the effects of coupled THC processes on repository performance. These filters were applied with an "OR" Boolean operator to the following fields in the database: FEP Name, Yucca Mountain Project Primary FEP Description, Originator FEP Description (i.e., description from the NEA database source), and Screening Argument. The resulting subset of entries for a given filter was saved as a Microsoft Excel spreadsheet, which was sorted so that excluded entries could be isolated. In practice, the "Include/Exclude" field in the database was in some cases empty, populated by an explanation that screening is not applicable (e.g., for categorical entries), populated by a statement of inclusion of some aspects of the entry and exclusion of others, or populated by one or more question marks presumably indicating inconclusiveness. Those entries with no entry in this field, an "include/exclude" statement, or a question mark after the screening were retained along with the excluded entries for analysis. In general, in this report all entries falling in these categories are referred to as "excluded."

The excluded entries were then looked up in the database (Revision 00b). After study, a given entry was classified as either clearly irrelevant (either to ENFE or Yucca Mountain in general; for example, FEPs

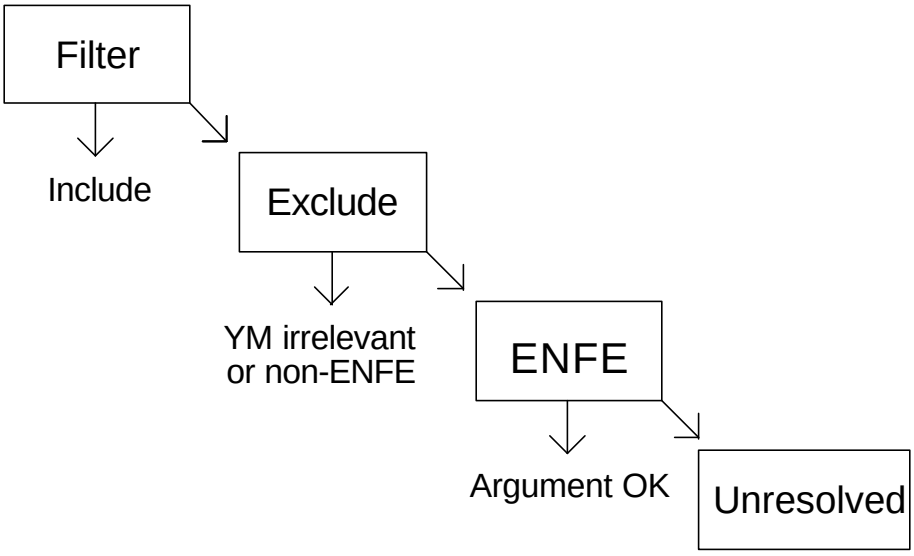

Figure 2-1. Decision process used in analysis of excluded features, events and processes. Filter was constructed based on criteria in evolution of the near-field environment issue resolution status report (Nuclear Regulatory Commission, 1999a).

specific to bentonite and buffer were omitted from consideration), acceptably justified, or unresolved (figure 2-1). Those FEPs entries belonging to the latter classification comprise the key product of the analysis; "unresolved" in this context means that the author either rejected the argument or was not able to accept or reject the argument due to its deficiencies. Again, construction of this list was biased in favor of inclusion. Even a FEP generally agreed to be easily dismissed could be considered "unresolved" if the screening argument was insufficient.

Appendix 1 shows the search terms used in the filters, the number of entries resulting from the filter, the number of these classified as excluded, the number of the excluded entries that are ENFE-relevant, and the number of excluded entries deemed unresolved in the initial analysis. Each of the columns in this table are therefore subsets of the previous column. Note that some of the filters are subsets of others (e.g., "colloid" and "colloid AND chemi" in appendix 1). A number of the "unresolved" entries counted in this table were later reclassified as resolved, and given entries may appear for more than one filter. This table is provided merely as an indication of the prevalence of ENFE-relevant terms in the database.

For those secondary entries deemed unresolved, the corresponding primary entry was studied for inclusion of the technical substance of the secondary entry. This step resulted in one of three actions. If the primary entry covered the substance of the secondary entry (as was DOE's intention) and was screened as "included," the secondary entry was dropped from the list of unresolved entries. If the primary entry covered the substance of the secondary and was "excluded," the secondary entry was dropped from the list of

unresolved entries, but the primary entry was itself assessed. Finally, if the primary entry did not satisfactorily cover the substance of the secondary entry, the latter was retained in the list of unresolved entries.

To ensure completeness of this analysis of excluded entries, the list of all ENFE-relevant entries (section 2.1) was inspected for excluded entries missed in the filter analysis. In addition, recognition was made of included entries that covered the substance of excluded entries elsewhere in the database.

This process may have missed a particular class of omission in the DOE FEP database: those FEPs that are deemed relevant by the NRC, but do not appear at all in the database. Based on review of the ENFE IRSR, a number of single-term searches was performed on the entire database to address this potential deficiency. Iterative inspection of all ENFE-relevant entries was also performed to assess whether or not these FEPs were truly absent. This analysis did not pre-judge the importance to performance of the identified FEPs.

An aspect of database organization that also received close scrutiny was the grouping of secondary entries into primary entries. This grouping is critical because DOE plans to perform all screening at the primary level (section 1.2). At the September 8, 1999, Appendix 7 Meeting on FEPs, DOE specifically requested NRC feedback on this aspect of the database.

2.3 APPROACH TO SUBISSUE ASSIGNMENT

The ENFE IRSR (Nuclear Regulatory Commission, 1999a) identifies five subissues that address ENFE-related system attributes important to repository importance:

Subissue 1	The effects of coupled THC processes on seepage into the drift and flow in the unsaturated zone
Subissue 2	The effects of coupled THC processes on the waste package and drip shield chemical environment
Subissue 3	The effects of coupled THC processes on the chemical environment for radionuclide release
Subissue 4	The effects of coupled THC processes on radionuclide transport through engineered and natural barriers
Subissue 5	Coupled THC processes affecting potential nuclear criticality in the near field

Primary and secondary ENFE-relevant database entries were categorized according to the subissues based on inspection of entry content. (Again, inspection was more cursory for secondary than for primary entries.) It was possible for a given entry to be assigned to more than one subissue, so that there is considerable overlap in subissue lists. In general, these assignments were straightforward. Special note is made of the following considerations:

- Subissue 1 entries included those associated with flow beneath the repository
- Subissue 3 entries included those associated with transport within the drift
- Subissue 4 entries included those associated with transport both within the drift and in the affected area outside the drift
- Subissue 4 included Yucca Mountain-relevant THC effects on transport in the saturated zone
- Because criticality FEPs are linked to all ENFE processes, and DOE's criticality analysis will be performed separately from TSPA (U.S. Department of Energy, 1998a), only those entries specific to criticality were included in the subissue 5 list

In Revision 1 of the TSPAI IRSR (Nuclear Regulatory Commission, 1998) key elements of the

repository system that need to be appropriately abstracted into a TSPA were defined as key elements of system abstraction (KESA). The fourteen KESAs form the basis of NRC's review of DOE's model abstraction (Nuclear Regulatory Commission, 1998). In Revision 2 of the TSPAI IRSR (in preparation) the KESAs have been redefined as integrated subissues (ISIs). This is a change in name, not a substantive change in the focus of review. The integrated review of model abstraction performed under each ISI requires the input from one or more of the NRC KTIs. Each KTI may contribute to the review of one or more ISI.

The ISIs potentially relevant to ENFE, discussed in the ENFE IRSR (Nuclear Regulatory Commission, 1999a), are

- Degradation of engineered barriers
- Quantity and chemistry of water contacting the waste packages and waste forms
- Radionuclide release rates and solubility limits
- Spatial and temporal distribution of flow
- Flow paths in the unsaturated zone
- Radionuclide transport in the unsaturated zone
- Radionuclide transport in the saturated zone

Parsing of FEPs into ISIs will be documented in Revision 2 of the TSPAI IRSR (in preparation). Individual FEPs will then be assigned by ISI teams to the appropriate KTIs for reviews to be documented in IRSRs. Final integration of these staff FEPs assessments is anticipated to be documented in Revision 3 of the TSPAI IRSR.

3 ANALYSIS

3.1 ENTRIES RELEVANT TO THE EVOLUTION OF THE NEAR-FIELD ENVIRONMENT KEY TECHNICAL ISSUE

Table 3-1 lists all DOE FEP database entries relevant to the ENFE KTI. Because this KTI concerns coupled processes involving virtually all repository components, it is perhaps not surprising that this list has 626 entries constituting 35 percent of the database and exactly half of the 310 primary entries. As mentioned in section 2.1, FEPs on waste package and waste form degradation are included, as are those concerned with other chemical processes within and outside the drift in the affected area. In addition, entries covering operational issues (1.1.xx.xx.xx in table 3-1) were included if they could potentially affect the nature of THC processes. Other special considerations

- Specific igneous activity FEPs (1.2.04.02.00) were included because they address changes to rock properties which, in turn, directly affect THC processes.

- Entries concerned with repository features not recently under consideration for Yucca Mountain, such as bentonite (2.1.04.06.00) and buffer (various), were not included.

- An Enhanced Design Alternative II (EDA-II) design was not assumed. Therefore, entries were not omitted if concerned with recent Yucca Mountain designs that may be supplanted by the EDA-II design.

- An example of relevant secondary entries with a corresponding irrelevant primary entry is seen in the 2.2.07.15.xx entries in table 3-1. The description of the primary entry specifies the saturated zone, but secondary entries describe flow and transport processes not requiring the saturated zone.

3.2 DEFICIENCIES

3.3 Features, Events, and Processes Excluded with Insufficient Cause ("unresolved")

Table 3-2 lists the 58 database entries concluded to be unresolved using the process described in section 2.2. Under the FEP name is text explaining the rationale for considering that entry unresolved. These notes are self-explanatory, but notable features of this list include

- A common rationale for inclusion in this table is inadequacy of the screening argument. For example, screening arguments based on "low consequence" or "low probability" are not supported by a technical basis. This inadequacy should be rectified in the final version of the database.

- A number of entries concern construction and operational errors.

- Other common themes are gas generation and transport and cladding degradation.

- None of the criticality FEPs should be considered excluded because the criticality analysis has yet to be performed.

Table 3-1. All U.S. Department of Energy features, events, and processes database (Revision 00b) entries relevant to the evolution of the near-field environment key technical issue with relevance to specific subissues indicated. Entries in bold are primary entries or secondary entries for which the corresponding primary entry was not included in the table. An asterisk in the first column indicates that the item is in table 3-2.

Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
1.1.02.00.00*	**Excavation/construction**	**Exclude**	**X**	**X**		**X**	
1.1.02.00.01	Blasting and vibration	Exclude	X			X	
1.1.02.00.02	Geochemical alteration (excavation)	Exclude	X	X		X	
1.1.02.00.03	Groundwater chemistry (excavation)	Exclude		X		X	
1.1.02.00.04	Influx of oxidizing water	Exclude		X			
1.1.02.00.05	Influx of oxidizing water	Exclude		X			
1.1.02.01.00	**Site flooding (during construction and operation)**	**Exclude**		**X**			
1.1.02.01.01	Repository flooding during operation	Exclude		X			
1.1.02.02.00*	**Effects of preclosure ventilation**	**??**	**X**				
1.1.02.03.00*	**Undesirable materials left**	**Exclude**		**X**	**X**	**X**	
1.1.02.03.01	Decontamination materials left	Exclude		X	X	X	
1.1.02.03.02	Inadvertent inclusion of undesirable materials	Exclude		X	X	X	
1.1.03.01.00*	**Error in waste or backfill emplacement**	**Exclude**	**X**	**X**			
1.1.03.01.01	Inadequate backfill or compaction, voidage	Exclude	X	X			
1.1.03.01.03	Containers are placed too close together	Exclude	X	X			
1.1.07.00.00*	**Repository design**	**Include (exclude deviations from design)**	**X**	**X**	**X**	**X**	
1.1.07.00.01	Poorly designed repository	Exclude	X	X	X	X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
1.1.08.00.00*	**Quality control**	**Include (exclude defects and deviations)**	**X**	**X**	**X**	**X**	
1.1.08.00.01	Poorly constructed repository	Exclude	X	X	X	X	
1.1.08.00.02	Material defects	Exclude	X	X	X	X	
1.1.08.00.05	Quality control (glass waste manufacture)	Include	X	X	X	X	
1.1.08.00.06	Quality control (canister manufacture & sealing)	Include	X	X	X	X	
1.1.12.01.00*	**Accidents and unplanned events during operation**	**Exclude**	**X**	**X**	**X**	**X**	
1.1.12.01.01	Preclosure events	Exclude	X	X	X	X	
1.1.12.01.02	Sabotage and improper operation	Exclude	X	X	X	X	
1.1.12.01.03	Accidents during operation	Exclude	X	X	X	X	
1.1.12.01.05	Handling accidents	Exclude	X	X	X	X	
1.1.12.01.06	Oil or organic fluid spill	Exclude	X	X	X	X	
1.1.13.00.00	**Retrievability**	**Include**	**X**	**X**	**X**	**X**	
1.2.02.01.00	**Fractures**	**Include (existing, reactivated), Exclude (new, SZ)**	**X**			**X**	
1.2.02.01.01	Changes in fracture properties	Include (UZ), Exclude (SZ)	X			X	
1.2.02.01.02	Fracturing	Include	X			X	
1.2.04.02.00	**Igneous activity causes changes to rock**	**Include**	**X**	**X**		**X**	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
	properties						
1.2.04.02.01	Dike provides a permeable flow path	Exclude	X	X		X	
1.2.04.02.02	Dike provides a barrier to flow	Exclude	X	X		X	
1.2.04.02.03	Volcanic activity in the vicinity produces an impoundment	Exclude	X	X		X	
1.2.04.02.04	Igneous activity causes extreme changes to rock geochemical properties	Include	X	X		X	
1.2.04.02.07	Magmatic activity	Include	X	X		X	
1.2.06.00.00*	**Hydrothermal activity**	**Exclude**	**X**	**X**	**X**	**X**	
1.2.08.00.00	**Diagenesis**	**Exclude**	**X**			**X**	
1.2.08.00.01	Diagenesis	Exclude	X			X	
1.2.08.00.02	Diagenesis	Exclude	X			X	
1.2.08.00.03	Fracture infills	Exclude	X			X	
2.1.01.02.00	**Codisposal/colocation of waste**	**Include**	**X**		**X**		
2.1.01.02.01	Other waste	Include	X		X		
2.1.01.02.02	Codisposal of reactive wastes	Include	X		X		
2.1.01.02.03	Near storage of other waste	Include	X		X		
2.1.01.02.04	DOE SNF/HLW glass interactions	Include	X		X		
2.1.01.02.05	DOE SNF WP placement		X		X		

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.01.02.06	DOE SNF canister arrangement within WP		X		X		
2.1.01.02.07	DOE SNF colocation with HLW	Include	X		X		
2.1.01.02.08	DOE SNF geometry		X		X		
2.1.01.02.09	DOE SNF WP placement		X		X		
2.1.01.02.10	DOE SNF colocation with HLW (waste form degradation impact)	Include	X		X		
2.1.01.02.11	DOE SNF colocation with HLW (radionuclide mobilization impact)	Include	X		X		
2.1.01.02.12	DOE SNF colocation with HLW (cladding degradation impact)	Include	X		X		
2.1.01.03.00	**Heterogeneity of waste forms**	**Include**	**X**	**X**	**X**		
2.1.01.03.01	Damaged or deviating fuel	Include	X	X	X		
2.1.01.03.02	Heterogeneity of waste form	Include	X	X	X		
2.1.01.03.03	Deviant inventory flask	Include	X	X	X		
2.1.01.03.04	DOE SNF canister atmosphere	Include			X		
2.1.02.01.00	**DSNF degradation, alteration, and dissolution**	**Include**		**X**	**X**		
2.1.02.01.01	DOE SNF dissolution	Include		X	X		
2.1.02.01.02	Alteration/dissolution of DOE SNF	Include		X	X		

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.02.01.03	Oxidation of DOE SNF	Exclude		X	X		
2.1.02.01.04	Alteration/dissolution of Pu ceramic waste	Exclude		X	X		
2.1.02.02.00	**CSNF alteration, dissolution, and radionuclide release**	**Include**		**X**	**X**		
2.1.02.02.01	Source terms (expected)	Include		X	X		
2.1.02.02.02	Source terms (other) (in waste form)	Include		X	X		
2.1.02.02.03	Stability of UO_2 (in waste form)	Include		X	X		
2.1.02.02.04	Degradation of fuel elements	Include		X	X		
2.1.02.02.05	Corrosion of metal parts (in waste form)	Include		X	X		
2.1.02.02.06	Corrosion prior to wetting	Include		X	X		
2.1.02.02.07	Radionuclide release (diffusion) through failed cladding	Include			X		
2.1.02.02.08	Water turnover, steel vessel	Include		X	X		
2.1.02.02.09	Dissolution chemistry (in waste and EBS)	Include		X	X		
2.1.02.02.10	Release from fuel matrix (release/migration factors)	Include			X		
2.1.02.02.11	Release from metal parts	Include			X		
2.1.02.02.12	Total release from fuel elements	Include			X		
2.1.02.02.13	Dissolution of waste (release/migration factors)	Include			X		

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.02.02.14	Release of radionuclides from the failed canister	Include			X		
2.1.02.02.15	Transport and release of nuclides, failed canister	Include			X		
2.1.02.03.00	**Glass degradation, alteration, and dissolution**	**Include**		**X**	**X**		
2.1.02.03.01	Degradation and alteration of glass waste form	Include		X	X		
2.1.02.03.02	Phase separation (in waste form)	Exclude		X	X		
2.1.02.03.03	Congruent dissolution (in waste form)	Exclude		X	X		
2.1.02.03.04*	Rate of glass dissolution	Exclude		X	X		
2.1.02.03.05	Selective leaching (in waste form)	Exclude		X	X		
2.1.02.03.06	Coprecipitates/solid solutions (in waste form)	Exclude		X	X		
2.1.02.03.07	Precipitation of silicates /silica gel (in waste form)	Exclude		X	X		
2.1.02.03.08	Iron corrosion products	Exclude		X	X		
2.1.02.03.09*	Radionuclide release from glass	Exclude			X		
2.1.02.03.10	Composition of DHLW Glass			X	X		
2.1.02.04.00*	**Alpha recoil enhances dissolution**	**Exclude**			**X**		
2.1.02.04.01	Recoil of alpha-decay	Include			X		

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.02.05.00*	**Glass cracking and surface area**	**Exclude**			**X**		
2.1.02.05.01	Solute transport resistance (in waste form)	Exclude			X		
2.1.02.06.00	**Glass recrystallization**	**Exclude**			**X**		
2.1.02.07.00	**Gap and grain release of Cs, I**	**Include**			**X**		
2.1.02.07.01	Gap and grain release	Include			X		
2.1.02.07.03	I, Cs-migration to fuel surface	Exclude			X		
2.1.02.08.00*	**Pyrophoricity**	**Exclude**	**X**	**X**	**X**		
2.1.02.08.01	DOE SNF pyrophoricity	Exclude	X	X	X		
2.1.02.08.02	DOE SNF pyrophoric event (waste heat impact)	Exclude	X	X	X		
2.1.02.08.03	DOE SNF pyrophoric event (waste package degradation impact)	Exclude		X			
2.1.02.08.04	Acetylene generation from DSNF	Exclude		X	X		
2.1.02.08.05	DOE SNF pyrophoric event (waste form degradation impact)	Exclude			X		
2.1.02.08.06	DOE SNF pyrophoric event (cladding degradation impact)	Exclude		X	X		
2.1.02.09.00	**Void space (in glass container)**	**Exclude**			**X**		
2.1.02.13.00*	**General corrosion of cladding**	**Exclude**			**X**		
2.1.02.13.01	Cladding degradation mechanisms at YMP,				X		

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
	pre-pin failure						
2.1.02.13.02	Corrosion (of cladding)				X		
2.1.02.14.00*	**MIC of cladding**	**Exclude**			**X**		
2.1.02.15.00*	**Acid corrosion of cladding from radiolysis**	**Exclude (?)**			**X**		
2.1.02.16.00	**Localized corrosion (pitting) of cladding**	**Include**			**X**		
2.1.02.17.00	**Localized corrosion (crevice corrosion) of cladding**	**Include**			**X**		
2.1.02.18.00	**High dissolved silica content of waters enhances corrosion of cladding**	**Include**			**X**		
2.1.02.19.00*	**Creep rupture of cladding**	**Exclude**			**X**		
2.1.02.19.01	Thermal cracking (in waste and EBS)	Exclude			X		
2.1.02.20.00	**Pressurization from He production causes cladding failure**	**Exclude**			**X**		
2.1.02.21.00	**Stress corrosion cracking of cladding**	**Include**			**X**		
2.1.02.21.01	Inside out from fission products (iodine) (failure of cladding)	Exclude			X		
2.1.02.21.02	Outside in from salts or waste package chemicals (failure of cladding)	Include			X		
2.1.02.21.03	Stress-corrosion cracking of zircaloy cladding	Include			X		
2.1.02.22.00	**Hydride embrittlement of cladding**	**Include**			**X**		

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.02.22.01	Hydride embrittlement from zirconium corrosion (of cladding)	Exclude			X		
2.1.02.22.02	Hydride embrittlement from waste package corrosion & H_2 absorption (of cladding)	Include			X		
2.1.02.22.03	Hydride embrittlement from galvanic corrosion of waste package contacting cladding	Include			X		
2.1.02.22.04	Delayed hydride cracking (of cladding)	Include			X		
2.1.02.22.05	Hydride reorientation (of cladding)	Include			X		
2.1.02.22.06	Hydrogen axial migration (of cladding)	Include (?)			X		
2.1.02.22.07	Hydride embrittlement from fuel reaction (causes failure of cladding)	Include			X		
2.1.02.23.00	**Cladding unzipping**	**Include**			**X**		
2.1.02.23.01	Cladding degradation after initial cladding perforation	Include			X		
2.1.02.23.02	Dry oxidation of fuel (causes failure of cladding)	Exclude			X		
2.1.02.23.03	Wet oxidation of fuel (causes failure of cladding)	Include			X		
2.1.02.24.00	**Mechanical failure of cladding**	**Include**			**X**		
2.1.02.25.00	**DSNF cladding degradation**	**Include**			**X**		
2.1.02.25.01	DOE SNF cladding material	Include			X		

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.02.25.02	DOE SNF cladding condition	Include			X		
2.1.02.25.03	Internal canister/cladding corrosion due to DOE SNF	Exclude			X		
2.1.03.01.00	**Corrosion of waste containers**	**Include**		**X**			
2.1.03.01.01	Metallic corrosion	Include		X			
2.1.03.01.02	Corrosion on wetting (of waste container)	Include		X			
2.1.03.01.03	Oxic corrosion (of waste container)	Include		X			
2.1.03.01.04	Anoxic corrosion (of waste container)	Exclude		X			
2.1.03.01.05	Total corrosion rate (of waste container)	Include		X			
2.1.03.01.09	Corrosion (of waste container)	Include		X			
2.1.03.01.10	Uniform corrosion (of waste container)	Exclude		X			
2.1.03.02.00	**Stress corrosion cracking of waste containers**	**Include**		**X**			
2.1.03.02.01	Stress corrosion cracking (of waste container)	Include		X			
2.1.03.02.02	Stress corrosion cracking—dry-waste container	Exclude		X			
2.1.03.03.00	**Pitting of waste containers**	**Include**		**X**			
2.1.03.03.01	Localized corrosion (of waste container)	Include		X			
2.1.03.03.02	Pitting (of waste container)	Include		X			

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.03.03.03	Pitting corrosion develops on containers	Include		X			
2.1.03.04.00	**Hydride cracking of waste containers**	**Include**		**X**			
2.1.03.04.01	Embrittlement and cracking	Include		X			
2.1.03.05.00	**Microbially-mediated corrosion of waste container**	**Include**		**X**			
2.1.03.06.00	**Internal corrosion of waste container**	**Include**		**X**	**X**		
2.1.03.06.01	DOE SNF waste package internal corrosion	Include		X	X		
2.1.03.07.00	**Mechanical impact on waste container**	**Include**		**X**			
2.1.03.07.01	Other canister degradation processes	Include		X			
2.1.03.07.03	Failure of steel canister	Include		X			
2.1.03.07.04	Reduced mechanical strength	Include		X			
2.1.03.07.05	Container failure (mechanical)	Include		X			
2.1.03.07.06	Falling rock hits container, increased seepage occurs, speeds corrosion of container			X			
2.1.03.10.00	**Container healing**	**Include**		**X**			
2.1.03.10.01	Corrosion products (physical effects)	Exclude		X			
2.1.03.11.00	**Container form**	**Include**		**X**	**X**		
2.1.03.11.03	Canister thickness	Include		X	X		

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.03.11.04	Container material inventory	Include		X	X		
2.1.03.11.05	Container integrity	Include		X	X		
2.1.03.11.06	DOE SNF waste package design	Include		X	X		
2.1.03.11.07	DOE SNF canister design	Include		X	X		
2.1.03.11.08	DOE SNF waste package design	Include		X	X		
2.1.03.12.00	**Container failure (long-term)**	**Include**		**X**	**X**		
2.1.03.12.02	Long-term physical stability (in waste and EBS)	Include		X	X		
2.1.04.01.00	**Preferential pathways in the backfill**	**Include**	**X**	**X**	**X**	**X**	
2.1.04.01.02	Flow through buffer/backfill	Exclude	X	X	X	X	
2.1.04.01.03	Flow through buffer/backfill	Exclude	X	X	X	X	
2.1.04.02.00	**Physical and chemical properties of backfill**	**Include**	**X**	**X**	**X**	**X**	
2.1.04.02.01	Backfill characteristics	Include	X	X	X	X	
2.1.04.02.02	Inhomogeneities (properties and evolution) (in buffer/backfill)	Include	X	X	X	X	
2.1.04.02.03	Chemical alteration of buffer/backfill	Exclude	X	X	X	X	
2.1.04.02.06	Chemical degradation of backfill	Exclude	X	X	X	X	
2.1.04.02.07	Backfill materials deficiencies	Include	X	X	X	X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.04.02.09	Water chemistry, tunnel backfill	Include	X	X	X	X	
2.1.04.03.00*	**Erosion or dissolution of backfill**	**Exclude**	**X**	**X**	**X**	**X**	
2.1.04.03.01	Erosion of buffer/backfill	Exclude	X	X	X	X	
2.1.04.05.00	**Backfill evolution**	**Include**	**X**	**X**	**X**	**X**	
2.1.04.05.01	Hydrothermal alteration (in buffer/backfill)	Exclude	X	X	X	X	
2.1.04.05.02	Small pieces of backfill undergo phase changes when heated and welded together	Exclude	X	X	X	X	
2.1.04.05.03	Thermal degradation of buffer/backfill	Exclude	X	X	X	X	
2.1.04.08.00	**Diffusion in backfill**	**Include**				**X**	
2.1.04.09.00	**Radionuclide transport through backfill**	**Include**				**X**	
2.1.04.09.02	Transport and release of nuclides, tunnel backfill	Exclude				X	
2.1.05.01.00	**Seal physical properties**	**Include**	**X**				
2.1.05.01.02	Consolidation of seals	Include	X				
2.1.05.03.00	**Seal degradation**	**Include**	**X**				
2.1.05.03.01	Seal evolution	Include	X				
2.1.05.03.02	Seal failure	Exclude	X				
2.1.05.03.03	Degradation of hole and shaft seals	Include	X				
2.1.05.03.04	Shaft or access tunnel seal failure and	Include	X				

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
	degradation						
2.1.05.03.05	Degradation of hole and shaft seals	Include	X				
2.1.05.03.06	Loss of integrity of shaft or access tunnel seals	Include	X				
2.1.05.03.07	Mechanical degradation of seals	Include	X				
2.1.05.03.08	Chemical degradation of seals	Include	X				
2.1.06.01.00	**Degradation of cementitious materials in drift**	**Include**	**X**	**X**	**X**	**X**	
2.1.06.01.01	Physio-chemical degradation of concrete	Include	X	X	X	X	
2.1.06.01.02	Seal chemical composition	Exclude	X	X	X	X	
2.1.06.01.03	Microbial growth on concrete	Exclude	X	X	X	X	
2.1.06.02.00	**Effects of rock reinforcement materials**	**Include**	**X**	**X**			
2.1.06.02.01	Degradation of rock reinforcement and grout	Include	X	X			
2.1.06.03.00	**Degradation of the liner**	**Include**	**X**	**X**	**X**	**X**	
2.1.06.04.00*	**Flow through the liner**	**Exclude**	**X**	**X**	**X**	**X**	
2.1.06.04.01	Fracture flow through the liner	Exclude	X	X	X	X	
2.1.06.05.00	**Degradation of invert and pedestal**	**Include**	**X**	**X**		**X**	
2.1.06.05.01	Cementitious invert	Include	X	X		X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.06.06.00*	**Effects and degradation of drip shield**		**X**	**X**	**X**	**X**	
2.1.06.06.01	Oxygen embrittlement of Ti drip shield		X	X	X	X	
2.1.06.07.00	**Effects at material interfaces**	**Include**	**X**	**X**	**X**	**X**	
2.1.08.01.00	**Increased unsaturated water flux at the repository**	**Include**	**X**				
2.1.08.01.01	Waste container is thermally quenched by rapid influx of water	Include	X				
2.1.08.02.00	**Enhanced influx (Philip's drip)**	**Include**	**X**				
2.1.08.04.00	**Condensation forms on backs of drifts**	**Include**	**X**	**X**			
2.1.08.05.00	**Flow through invert**	**Include**	**X**			**X**	
2.1.08.05.01	Fracture flow through the invert	Include	X			X	
2.1.08.05.02	UZ flow through/around the collapsed invert	Include	X			X	
2.1.08.07.00*	**Pathways for unsaturated flow and transport in the waste and EBS**	**Include?**		**X**	**X**	**X**	
2.1.08.07.01	Residual canister (crack/holes effects)	Include		X	X	X	
2.1.08.07.02	Properties of failed canister	Exclude		X	X	X	
2.1.08.07.03	Container-partial corrosion	Include		X	X	X	
2.1.08.07.04	Hydraulic conductivity (in waste and EBS)	Exclude		X	X	X	
2.1.08.07.05	Waste form and backfill consolidation	Include		X	X	X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.08.07.07	Channeling within the waste	Exclude		X	X	X	
2.1.08.07.09	Radionuclide transport (water transport)	Exclude				X	
2.1.08.08.00	**Induced hydrological changes in the waste and EBS**	**Include**	**X**	**X**	**X**	**X**	
2.1.08.11.00	**Resaturation of repository**	**Include**	**X**	**X**	**X**	**X**	
2.1.09.01.00	**Properties of the potential carrier plume in the waste and EBS**	**Include**		**X**	**X**	**X**	
2.1.09.01.01	Reactions with cement pore water	Include		X	X	X	
2.1.09.01.02	Reactions with cement pore water	Include		X	X	X	
2.1.09.01.03	Induced chemical changes (in waste and EBS)	Include		X	X	X	
2.1.09.01.04	Interactions of host materials and ground water with repository material	Include		X	X	X	
2.1.09.01.06	Water chemistry, canister	Include		X	X	X	
2.1.09.01.07	Transport of chemically-active substances into the near-field	Include				X	
2.1.09.01.08	Incomplete near-field chemical conditioning	Exclude		X	X	X	
2.1.09.01.10	Hyperalkaline carrier plume forms	Include		X	X	X	
2.1.09.01.11	Chemical interactions (in waste and EBS)	Include		X	X	X	
2.1.09.01.13	Interactions of waste and repository materials with host materials	Include		X	X	X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.09.02.00*	**Interaction with corrosion products**	**Exclude?**			**X**	**X**	
2.1.09.02.02	Effects of metal corrosion (in waste and EBS)	Include		X	X	X	
2.1.09.02.03	Container corrosion products	Include			X	X	
2.1.09.02.04	Chemical buffering (canister corrosion products)	Include		X	X	X	
2.1.09.02.05	Radionuclide sorption and coprecipitation (in EBS)	Include			X	X	
2.1.09.03.00	**Volume increase of corrosion products**	**Exclude**		**X**			
2.1.09.03.01	Swelling of corrosion products (in waste and EBS)	Exclude		X			
2.1.09.04.00	**Radionuclide solubility, solubility limits, and speciation in the waste form and EBS**	**Include**			**X**	**X**	
2.1.09.04.01	Elemental solubility (in waste and EBS)	Include			X	X	
2.1.09.04.02	Speciation (in waste and EBS)	Include			X	X	
2.1.09.04.03	Geochemical pump (in waste and EBS)	Include			X	X	
2.1.09.04.04	Precipitation and dissolution (in waste and EBS)	Include			X	X	
2.1.09.04.05	Selective dissolution of contaminants contained in spent nuclear fuel	Include			X		
2.1.09.04.06	Precipitation (release/migration factors)	Include			X	X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.09.04.07	Speciation control of contaminants by hyperalkaline plume formed in the EBS	Include			X	X	
2.1.09.04.08	Solubility within fuel matrix	Include			X		
2.1.09.04.09	Solubility and precipitation (contaminant speciation and solubility)	Include			X	X	
2.1.09.04.10	Solubility limit (contaminant speciation and solubility)	Include			X	X	
2.1.09.04.13	Speciation (contaminant speciation and solubility)	Include			X	X	
2.1.09.05.00	**In-drift sorption**	**Include**				**X**	
2.1.09.05.01	Selective sorption of Pu from solution	Include				X	
2.1.09.05.02*	Sorption	Exclude				X	
2.1.09.06.00	**Reduction-oxidation potential in waste and EBS**	**Include**		**X**	**X**	**X**	
2.1.09.06.01	Redox front (in waste and EBS)	Include		X	X	X	
2.1.09.06.02	Reduction-oxidation fronts (in waste and EBS)	Include		X	X	X	
2.1.09.06.03	Localized reducing zones (in waste and EBS)	Include		X	X	X	
2.1.09.06.04	Redox front (in buffer/backfill)	Include		X	X	X	
2.1.09.06.05	Fe control of oxidation state of contaminants	Include		X	X	X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.09.07.00*	**Reaction kinetics in waste and EBS**	**Exclude**		**X**	**X**	**X**	
2.1.09.07.01	Chemical kinetics (in waste and EBS)	Include		X	X	X	
2.1.09.08.00	**Chemical gradients/enhanced diffusion in waste and EBS**	**Include**		**X**	**X**	**X**	
2.1.09.08.01	Enhanced diffusion (in waste and EBS)	Include?		X	X	X	
2.1.09.08.02	Chemical gradients (in waste and EBS)	Include		X	X	X	
2.1.09.08.03	Diffusion in and through failed canister	Include		X	X	X	
2.1.09.09.00*	**Electrochemical effects (electrophoresis, galvanic coupling) in waste and EBS**	**Exclude**		**X**			
2.1.09.09.02	Natural telluric electrochemical reactions (in waste and EBS)	Include?		X			
2.1.09.09.03	Electrochemical cracking (in waste and EBS)	Include		X			
2.1.09.09.04	Electrochemical effects/gradients (in waste and EBS)	Include		X			
2.1.09.09.05	Electrochemical effects of metal corrosion	Include		X			
2.1.09.09.06	Electrochemical effects (in waste and EBS)	Include		X			
2.1.09.09.07	Galvanic coupling (in waste and EBS)	Exclude		X			
2.1.09.09.08	Electrophoresis (in waste and EBS)	Exclude		X			
2.1.09.09.09	Electrochemical gradients (in waste and EBS)	Include		X			

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.09.09.10	Galvanic coupling (in waste and EBS)	Exclude		X			
2.1.09.09.11	Galvanic coupling (in waste and EBS)	Include		X			
2.1.09.10.00	**Secondary phase effects on dissolved radionuclide concentrations at the waste form**	**Include**			**X**		
2.1.09.11.00*	**Waste-rock contact**	**Exclude**			**X**		
2.1.09.12.00	**Rind (altered zone) formation in waste, EBS, and adjacent rock**	**Include**	**X**	**X**	**X**	**X**	
2.1.09.12.01	Deep alteration of the porosity of drift walls	Include	X	X	X	X	
2.1.09.13.00	**Complexation by organics in waste and EBS**	**Include**			**X**	**X**	
2.1.09.13.01	Methylation (in waste and EBS)	Exclude			X	X	
2.1.09.13.02	Humic and fulvic acids	Exclude			X	X	
2.1.09.13.03	Complexation by organics	Include			X	X	
2.1.09.13.04	Fulvic acid	Include			X	X	
2.1.09.13.05	Humic acid	Include			X	X	
2.1.09.13.06	Complexing agents	?			X	X	
2.1.09.13.07	Organics (complexing agents)	Include ?			X	X	
2.1.09.13.08	Organics (complexing agents)	Exclude			X	X	
2.1.09.13.09	Organic complexation	Exclude			X	X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.09.13.10	Organic ligands	Exclude			X	X	
2.1.09.13.11	Kinetics of organic complexation	Exclude			X	X	
2.1.09.13.12	Introduced complexing agents	Exclude			X	X	
2.1.09.14.00	**Colloid formation in waste and EBS**	**Include**			**X**		
2.1.09.14.01	Colloid generation-source (in waste and EBS)	Include			X		
2.1.09.14.02	Agglomeration of Pu colloids	Include			X		
2.1.09.14.03	Colloids (in waste and EBS)	Include			X		
2.1.09.14.04	Colloids/particles in canister	Include			X		
2.1.09.14.05	Colloid formation	Include			X		
2.1.09.14.06	Colloids	Include			X		
2.1.09.14.07	Colloids, complexing agents	Include			X		
2.1.09.14.08	Colloid generation and transport	Include			X		
2.1.09.14.09	Colloid formation, dissolution and transport	Include			X		
2.1.09.14.10	Colloid generation and transport	Include			X		
2.1.09.14.11	Colloid formation and stability	Include			X		
2.1.09.15.00	**Formation of true colloids in waste and EBS**	**Include**			**X**		
2.1.09.16.00	**Formation of pseudo-colloids (natural) in**	**Include**			**X**		

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
	waste and EBS						
2.1.09.16.01	Colloidal phases are produced by coprecipitation (in waste and EBS)	Include			X		
2.1.09.16.02	Pseudo-colloids	Include			X		
2.1.09.16.03	Pseudo-colloids	Include			X		
2.1.09.16.04	Natural colloids	Include			X		
2.1.09.16.05	Natural colloids	Include			X		
2.1.09.17.00	**Formation of pseudo-colloids (corrosion products) in waste and EBS**	**Include**			**X**		
2.1.09.17.01	Colloid formation is associated with container hydrolysis products	Include			X		
2.1.09.18.00	**Microbial colloid transport in the waste and EBS**	**Include**			**X**	**X**	
2.1.09.19.00	**Colloid transport and sorption in the waste and EBS**	**Include**				**X**	
2.1.09.19.01	Colloid transport	Include				X	
2.1.09.20.00	**Colloid filtration in the waste and EBS**	**Include**				**X**	
2.1.09.20.01	Colloid filtration by the invert	Exclude				X	
2.1.09.20.02	Colloid filtration (in pores and fractures)	Include				X	
2.1.09.20.03	Colloid filtration	Exclude				X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.09.21.00*	**Suspensions of particles larger than colloids**	**Exclude**				**X**	
2.1.09.21.01	Suspended sediment transport	Exclude				X	
2.1.09.21.02	Rinse	Exclude				X	
2.1.10.01.00*	**Biological activity in waste and EBS**	**Include ?**		**X**	**X**	**X**	
2.1.10.01.01	Microbial activity accelerates corrosion of containers	Include		X			
2.1.10.01.02	Microbial activity accelerates corrosion of cladding	Include		X	X		
2.1.10.01.03	Microbial activity accelerates corrosion of contaminants	Include		X	X		
2.1.10.01.04	Microbes (in waste and EBS)	Include		X	X	X	
2.1.10.01.05	Microorganisms (in waste and EBS)	Include		X	X	X	
2.1.10.01.06	Microbiological effects (in waste and EBS)	Include		X	X	X	
2.1.10.01.07	Microbial activity (in waste and EBS)	???		X	X	X	
2.1.10.01.08	Microbial activity (in waste and EBS)	Include		X	X	X	
2.1.10.01.09	Microbial activity (in waste and EBS)	Include		X	X	X	
2.1.10.01.10	Microbial interactions	Include		X	X	X	
2.1.10.01.11	Biofilms	Exclude		X	X	X	
2.1.11.01.00	**Heat output/temperature in waste and**	**Include**		**X**	**X**	**X**	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
	EBS						
2.1.11.01.02	Canister temperature	Include		X	X	X	
2.1.11.01.04	Temperature, canister	Include		X	X	X	
2.1.11.01.05	Temperature, tunnel backfill	Exclude		X	X	X	
2.1.11.01.06	Heat generation from waste containers	Include		X	X	X	
2.1.11.01.07	Radioactive decay heat	Include		X	X	X	
2.1.11.01.08	DOE SNF expected waste heat generation			X	X	X	
2.1.11.01.09	DOE SNF expected waste heat generation			X	X	X	
2.1.11.02.00	**Nonuniform heat distribution/edge effects in repository**	**Include**	**X**	**X**	**X**	**X**	
2.1.11.02.01	Panel/repository edge effects—thermal	Include	X	X	X	X	
2.1.11.02.02	Panel/repository edge effects—post-thermal	Include	X	X	X	X	
2.1.11.02.03	Vault heating effects	Include	X	X	X	X	
2.1.11.03.00	**Exothermic reactions in waste and EBS**	**Exclude**		**X**	**X**		
2.1.11.03.01	Concrete hydration	Exclude		X	X		
2.1.11.04.00	**Temperature effects/coupled processes in waste and EBS**	**Include**		**X**	**X**	**X**	
2.1.11.04.03	Heat from radioactive decay (in waste and EBS)	Include		X	X	X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.11.04.04	Long-term transients (in waste and EBS)	Include		X	X	X	
2.1.11.04.05	Time dependence (in waste and EBS)	Include		X	X	X	
2.1.11.04.06	Coupled processes (in waste and EBS)	Include		X	X	X	
2.1.11.06.00	**Thermal sensitization of waste containers increases fragility**	**Include**		**X**			
2.1.11.08.00*	**Thermal effects: chemical and microbiological changes in the waste and EBS**	**Exclude**		**X**	**X**	**X**	
2.1.11.09.00	**Thermal effects on liquid or two-phase fluid flow in the waste and EBS**	**Include**		**X**	**X**	**X**	
2.1.11.09.01	Convection effects on transport (enhanced vapor diffusion)			X	X	X	
2.1.11.09.02	Multiphase flow and gas-driven transport (water transport)	Include		X	X	X	
2.1.11.10.00	**Thermal effects on diffusion (Soret effect) in waste and EBS**	**Exclude**			**X**	**X**	
2.1.11.10.01	Soret effect (in waste and EBS)	Exclude			X	X	
2.1.11.10.02	Thermal effects: Transport (diffusion) effects (in waste and EBS)	Exclude			X	X	
2.1.11.10.03	Soret effect (water transport)	Exclude			X	X	
2.1.12.01.00*	**Gas generation**	**Exclude**		**X**	**X**	**X**	
2.1.12.01.01	Formation of gases (in wastes and EBS)	Exclude		X	X	X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.12.01.02	Gas generation	Exclude		X	X	X	
2.1.12.01.03	Gas generation, buffer/backfill	Exclude		X	X	X	
2.1.12.01.04	Chemotoxic gases (in waste and EBS)	Exclude		X	X	X	
2.1.12.01.05	Pressurization (in waste and EBS)	Exclude		X	X	X	
2.1.12.02.00*	**Gas generation (He) from fuel decay**	**Exclude**			**X**		
2.1.12.02.01	Helium gas production	Exclude			X		
2.1.12.02.02	Internal pressure (in waste and EBS)	Exclude			X		
2.1.12.02.03	Gas generation, canister	Exclude			X		
2.1.12.02.04	Internal pressure (in waste and EBS)	Exclude			X		
2.1.12.02.05	He gas production (in waste and EBS)	Exclude			X		
2.1.12.03.00*	**Gas generation (H_2) from metal corrosion**	**Exclude**		**X**	**X**	**X**	
2.1.12.03.01	Chemical effects of corrosion	Exclude		X	X	X	
2.1.12.03.02	Effect of hydrogen on corrosion	Exclude		X	X	X	
2.1.12.03.03	Hydrogen production (in waste and EBS)	Exclude		X	X	X	
2.1.12.03.04	Hydrogen production by metal corrosion	Exclude		X	X	X	
2.1.12.04.00	**Gas generation (CO_2, CH_4, H_2S) from microbial degradation**	**Exclude**		**X**	**X**	**X**	
2.1.12.04.01	Effect of temperature on microbial gas generation	Exclude		X	X	X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.12.04.02	Effect of pressure on microbial gas generation	Exclude		X	X	X	
2.1.12.04.03	Effect of radiation on microbial gas generation	Exclude		X	X	X	
2.1.12.04.04	Effect of biofilms on microbial gas generation	Exclude		X	X	X	
2.1.12.04.05	Methane and carbon dioxide by microbial degradation	Exclude		X	X	X	
2.1.12.05.00*	**Gas generation from concrete**	**Exclude**		**X**		**X**	
2.1.12.06.00*	**Gas transport in waste and EBS**	**Exclude**		**X**	**X**	**X**	
2.1.12.06.01	Thermochemical effects (related to gas in waste and EBS)	Exclude		X	X	X	
2.1.12.06.02	Gas transport	Exclude		X	X	X	
2.1.12.06.03	Gas effects (in waste and EBS)	Exclude		X	X	X	
2.1.12.06.04	Gas escape from canister	Exclude		X	X	X	
2.1.12.06.05	Gas flow and transport, buffer/backfill	Exclude		X	X	X	
2.1.12.06.06	Gas transport	Exclude		X	X	X	
2.1.12.06.07	Unsaturated flow due to gas production (in waste and EBS)	Exclude		X	X	X	
2.1.12.06.08	Gas permeability (in buffer/backfill)	Exclude		X	X	X	
2.1.12.07.00*	**Radioactive gases in waste and EBS**	**Exclude**			**X**	**X**	

Table 3-1. All U.S. Department of Energy features, events, and processes database (Revision 00b) entries relevant to the evolution of the near-field environment key technical issue with relevance to specific subissues indicated. Entries in bold are primary entries or secondary entries for which the corresponding primary entry was not included in the table. An asterisk in the first column indicates that the item is in table 3-2. (cont'd)

Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.12.07.01	Radioactive gas (in waste and EBS)	Exclude			X	X	
2.1.12.07.02	Gaseous and volatile isotopes	Exclude			X	X	
2.1.12.08.00	**Gas explosions**	**Exclude**			**X**	**X**	
2.1.12.08.01	H_2/O_2 explosions (in waste and EBS)	Exclude			X	X	
2.1.12.08.02	Flammability (in waste and EBS)	Exclude			X	X	
2.1.12.08.03	Explosions	Exclude			X	X	
2.1.12.08.04	Explosion	Exclude			X	X	
2.1.13.01.00	**Radiolysis**	**Include**		**X**	**X**	**X**	
2.1.13.01.01	Radiolysis (in waste and EBS)	Include		X	X	X	
2.1.13.01.02	Radiolysis	Include		X	X	X	
2.1.13.01.03	Radiolysis (in waste and EBS)	Include		X	X	X	
2.1.13.01.04	Radiolysis (in waste and EBS)	Include		X	X	X	
2.1.13.01.05	Radiolysis prior to wetting (in waste and EBS)	Include		X			
2.1.13.01.08	Radiolysis	Include		X	X	X	
2.1.13.01.09	Radiolysis	Include		X			
2.1.13.02.00*	**Radiation damage in waste and EBS**	**Include, Exclude (backfill, seals, rock)**		**X**	**X**		
2.1.13.02.01	Radiation effects (in waste and EBS)	Include		X	X		

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.13.02.03	Material property changes (due to radiation in waste and EBS)	Include		X	X		
2.1.13.02.04	Radiation damage (in waste and EBS)	Include		X	X		
2.1.13.02.05	Radiation shielding (in waste and EBS)	Include		X	X		
2.1.13.02.06	Radiation effects on buffer/backfill	Exclude		X	X		
2.1.13.02.07	Radiation effects on canister	Include		X	X		
2.1.13.02.08	Radiological effects on waste	Include		X	X		
2.1.13.02.09	Radiological effects on containers	Include		X	X		
2.1.13.02.10	Radiological effects on seals	Exclude		X	X		
2.1.13.02.11	Radiation effects on canister	Include		X	X		
2.1.14.01.00	**Criticality in waste and EBS**	**Include**					**X**
2.1.14.01.01	Criticality (in waste and EBS)	Include					X
2.1.14.01.03	Nuclear criticality (in waste and EBS)	Include					X
2.1.14.01.04	Nuclear criticality (in waste and EBS)	Include					X
2.1.14.01.05	Nuclear criticality (in waste and EBS)	Include					X
2.1.14.01.06	Nuclear criticality: heat (in waste and EBS)	Include					X
2.1.14.01.07	Nuclear explosions (in waste and EBS)	Exclude					X
2.1.14.01.10*	DOE SNF criticality near-field (radionuclide inventory impact)						X

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.14.09.00	**Near-field criticality, fissile material deposited in near-field pond**	**Include**					**X**
2.1.14.09.01	Criticality—container gone, intact rods, flooded	Include					X
2.1.14.09.02	Criticality—container gone, intact rods, dry	Exclude					X
2.1.14.09.03	Criticality—container gone, pile of fuel pellets, dry	Exclude					X
2.1.14.09.04	Criticality—container gone, pile of fuel pellets, flooded	Include					X
2.1.14.09.05	Criticality—container and cladding gone, fuel powder, flooded	Include					X
2.1.14.09.06	Criticality—container gone, pile of fuel pellets, dry	Exclude					X
2.1.14.09.07	Formation of a critical assembly in a pool (in waste and EBS)	Include					X
2.1.14.09.08	Pu accumulates in basin pool (in waste and EBS)	Include					X
2.1.14.09.09	Accumulated 239Pu decays to 235U in basin pool (in waste and EBS)	Include					X
2.1.14.10.00	**Near-field criticality, fissile solution flows into drift lowpoint**	**Include**					**X**
2.1.14.10.01	Accumulation of clays and sediments in basin (in EBS)	Include					X

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.1.14.10.02	Differential solubility of neutron poisons	Include					X
2.1.14.10.03	Selective leaching of fissile materials	Include					X
2.1.14.11.00*	**Near-field criticality, fissile solution is adsorbed or reduced in invert**	**Exclude**					**X**
2.1.14.11.01	Differential solubility of fissile isotopes	Include					X
2.1.14.12.00	**Near-field criticality, filtered slurry or colloidal stream collects on invert surface**	**Include**					**X**
2.1.14.13.00*	**Near-field criticality associated with colloidal deposits**	**Exclude**					**X**
2.1.14.14.00*	**Out-of-package criticality, fuel/magma mixture**	**Exclude**					**X**
2.2.01.02.00	**Thermal and other waste and EBS-related changes in the adjacent host rock**	**Include**	**X**			**X**	
2.2.01.02.01	Hydraulic conductivity change (host rock disturbed zone)	Include	X			X	
2.2.01.02.03	Properties of near-field rock (host rock disturbed zone)	Include	X			X	
2.2.01.03.00	**Changes in fluid saturations in the EDZ**	**Include**	**X**			**X**	
2.2.01.03.01*	Gas transport/dissolution (in the EDZ)		X			X	
2.2.01.04.00	**Elemental solubility in EDZ**	**Include**				**X**	
2.2.01.05.00	**Radionuclide transport in EDZ**	**Include**				**X**	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.2.01.05.01	Radionuclide retardation (EDZ)	Include				X	
2.2.01.05.02	Radionuclide release from EDZ	Include				X	
2.2.03.02.00	**Rock properties of host rock and other units**	**Include**	**X**				
2.2.03.02.01	Rock heterogeneity (host rock)	Include	X				
2.2.03.02.05	Properties of far-field rock	Include	X				
2.2.07.05.00	**Flow and transport in the UZ from episodic infiltration**	**Include**	**X**			**X**	
2.2.07.05.01	Episodic infiltration enhances colloid transport		X			X	
2.2.07.06.00*	**Episodic/pulse release from repository**		**X**		**X**	**X**	
2.2.07.07.00*	**Perched water develops**	**Exclude**	**X**			**X**	
2.2.07.07.01*	Perched water develops at base of Topopah Spring welded unit		X			X	
2.2.07.10.00	**Condensation zone forms around drifts**	**Include**	**X**	**X**			
2.2.07.10.01	Condensation cap forms above repository	Include	X	X			
2.2.07.10.02	Formation of condensate over individual containers	Include	X	X			
2.2.07.10.03	Formation of condensate over individual panels	Include	X	X			
2.2.07.10.04	Formation of condensate over the entire	Include	X	X			

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
	repository						
2.2.07.10.05	Shedding of condensation cap over one drift to another drift	Exclude	X	X			
2.2.07.10.06	Vault geometry	Include	X	X			
2.2.07.11.00	**Return flow from condensation cap/resaturation of dry-out zone**	**Include**	**X**	**X**			
2.2.07.11.01	Auto-catalytic drainage of locally saturated flow thru condensation cap	Include	X	X			
2.2.07.11.02	Resaturation, near-field rock	Exclude	X	X			
2.2.07.11.03	Return of condensate to same panel	Include	X	X			
2.2.07.11.04	Resaturation of dry-out zone is affected by vapor flow	Exclude	X	X			
2.2.07.11.05	Resaturation of dry-out zone is affected by liquid under capillary forces	Include	X	X			
2.2.07.11.06	Unsaturated flow plume returns flow from the condensation cap	Include	X	X			
2.2.07.14.00*	**Density effects on groundwater flow**	**Exclude**	**X**				
2.2.07.15.06	**Convection (water transport)**	**Exclude**	**X**				
2.2.07.15.07	**Dispersion (water transport)**	**Include**	**X**				
2.2.07.15.12	**Transport and release of nuclides, near-field rock**	**Include**				**X**	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.2.08.01.00	**Groundwater chemistry/composition in UZ and SZ**	**Include**	**X**	**X**	**X**	**X**	
2.2.08.01.01	Groundwater chemistry (in geosphere)	Include	X	X	X	X	
2.2.08.01.03	Interface different waters (in geosphere)	Include	X	X	X	X	
2.2.08.01.04	Water chemistry in near-field rock	Include	X	X	X	X	
2.2.08.01.05	Groundwater geochemistry (in geosphere)	Include	X	X	X	X	
2.2.08.01.08*	Changes in groundwater Eh	Exclude	X	X	X	X	
2.2.08.01.09*	Changes in groundwater pH	Exclude	X	X	X	X	
2.2.08.01.10	Oxidizing conditions	Include	X	X	X	X	
2.2.08.01.11	Groundwater composition	Include	X	X	X	X	
2.2.08.01.12	pH-deviations	Include	X	X	X	X	
2.2.08.01.13	Change of groundwater chemistry in nearby rock	Include	X	X	X	X	
2.2.08.01.17	Chemical gradients	Exclude	X	X	X	X	
2.2.08.01.18	Nonradioactive solute plume in geosphere	Include	X	X	X	X	
2.2.08.01.21	Groundwater conditions	Include	X	X	X	X	
2.2.08.02.00	**Radionuclide transport occurs in a carrier plume in geosphere**	**Include**				**X**	
2.2.08.02.01	Locally-saturated carrier plume forms (in geosphere)	Include				X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.2.08.02.02	Unsaturated carrier plume forms (in geosphere)	Include				X	
2.2.08.02.03	Precipitation/dissolution (release/migration factors)	Exclude				X	
2.2.08.03.00	**Geochemical interactions in geosphere (dissolution, precipitation, weathering) and effects on RT**	**Include**				**X**	
2.2.08.03.03	Rock property changes (in geosphere)	Include				X	
2.2.08.03.04	Hydraulic properties-evolution	Include				X	
2.2.08.03.05	Dissolution of fracture fillings/precipitations (in geosphere)	Include				X	
2.2.08.03.06	Weathering of flow paths (in geosphere)	Include				X	
2.2.08.03.07	Fracture mineralization and weathering (in geosphere)	Include				X	
2.2.08.03.08	Alteration/weathering of flow paths	Include				X	
2.2.08.03.09	Precipitation and dissolution (release/migration factors)	Include				X	
2.2.08.03.10	Chemical precipitation (release/migration factors)	Include				X	
2.2.08.03.11	Dissolution, precipitation and crystallization (release/migration factors)	Include				X	
2.2.08.03.12	Kinetics of precipitation and dissolution (release/migration factors)	Include?				X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.2.08.03.13	Speciation (contaminant speciation and solubility)	Include				X	
2.2.08.03.14	Speciation (geosphere) (contaminant speciation and solubility)	Include				X	
2.2.08.03.15	Recrystallization (contaminant speciation and solubility)	Include				X	
2.2.08.03.16	Speciation (contaminant speciation and solubility)	Include				X	
2.2.08.03.17	Kinetics of speciation (contaminant speciation and solubility)	Include				X	
2.2.08.03.18	Groundwater chemistry (sorption/desorption processes)	Exclude ?				X	
2.2.08.04.00*	**Redissolution of precipitates directs more corrosive fluids to containers**	**Exclude**		**X**			
2.2.08.05.00	**Osmotic processes**	**Exclude**				**X**	
2.2.08.06.00	**Complexation in geosphere**	**Include**				**X**	
2.2.08.07.00*	**Radionuclide solubility limits in the geosphere**	**Exclude**				**X**	
2.2.08.07.03	Solubility limits/colloid formation	Include				X	
2.2.08.07.04	Solubility limits/colloid formation	Include				X	
2.2.08.08.00	**Matrix diffusion in geosphere**	**Include**				**X**	
2.2.08.08.01	Matrix diffusion (water transport)	Include				X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.2.08.08.02	Matrix diffusion (water transport)	Include				X	
2.2.08.08.03	Matrix diffusion (water transport)	Include				X	
2.2.08.08.04	Matrix diffusion (water transport)	Include				X	
2.2.08.08.05	Matrix diffusion (water transport)	Include				X	
2.2.08.08.06	Matrix diffusion (water transport)	Include				X	
2.2.08.08.07	Matrix diffusion (water transport)	Include				X	
2.2.08.08.08	Matrix diffusion	Include				X	
2.2.08.09.00	**Sorption in UZ and SZ**	**Include**				**X**	
2.2.08.09.03	Anion-exclusion General: (in geosphere)	Include				X	
2.2.08.09.07	Sorption (reversible and irreversible)	Include				X	
2.2.08.09.08	Sorption—nonlinear	Include				X	
2.2.08.09.09	Saturation (of sorption sites)	Include				X	
2.2.08.09.10	Sorption (geosphere)	Include				X	
2.2.08.09.12	Sorption	Include				X	
2.2.08.09.13	Nonlinear sorption	Include				X	
2.2.08.09.14	Sorption	Include				X	
2.2.08.09.15	Nonlinear sorption	Include				X	
2.2.08.09.17	Radionuclide sorption	Include				X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.2.08.09.18	Sorption	Include				X	
2.2.08.09.19	Actinide sorption	Include				X	
2.2.08.09.20	Kinetics of sorption	Include				X	
2.2.08.09.21	Changes in sorptive surfaces	Include				X	
2.2.08.09.22	Sorption—nonlinear (geosphere)	Include				X	
2.2.08.10.00	**Colloidal transport in geosphere**	**Include**				**X**	
2.2.08.10.02	Colloid transport occurs in a carrier plume (in geosphere)	Include				X	
2.2.09.01.00	**Microbial activity in geosphere**	**Include**				**X**	
2.2.09.01.01	Microbes (in geosphere)	Include				X	
2.2.09.01.02	Microbes (in geosphere)	Include				X	
2.2.09.01.03	Microbial activity (in geosphere)	Include				X	
2.2.10.01.00	**Repository-induced thermal effects in geosphere**	**Include**	**X**	**X**		**X**	
2.2.10.01.02	Temperature, near-field rock	Include	X	X		X	
2.2.10.01.03	Thermal effects on groundwater flow	Include	X	X		X	
2.2.10.01.04	Groundwater—evolution	Include	X	X		X	
2.2.10.01.05	Thermal effects on material properties (in waste and EBS)	Include	X	X		X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.2.10.01.06*	Thermal effects: Rock-mass changes	Exclude	X	X		X	
2.2.10.01.07	Thermal effects: Hydrogeological changes	Exclude	X	X		X	
2.2.10.02.00	**Thermal convection cell develops in SZ**	**Include**				**X**	
2.2.10.06.00	**Thermo-chemical alteration (solubility, speciation, phase changes, precipitation/dissolution)**	**Include**	**X**			**X**	
2.2.10.06.01	Silica phase changes (accompanied by volume change) occur due to elevated temperature	Include	X			X	
2.2.10.06.02	Thermochemical change	Include	X			X	
2.2.10.06.03	Alteration of rock properties because of two-phase flow	Include	X			X	
2.2.10.06.04	Heat-induced chemical reactions plug small fractures; flow is preferentially redirected to large fractures	Include	X				
2.2.10.06.05	Alteration of minerals to clays (in geosphere)	Include	X			X	
2.2.10.06.06	Calcite precipitation in hot region produces fluids depleted in calcite that dissolve calcite below the repository	Include	X			X	
2.2.10.06.07	Precipitates from dissolved constituents of tuff and repository materials form by evaporation during thermal period	Include	X			X	

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.2.10.07.00	**Thermo-chemical alteration of the Calico Hills unit**	**Include**	**X**			**X**	
2.2.10.08.00	**Thermo-chemical alteration of the SZ**	**Include**				**X**	
2.2.10.08.01	Precipitation of zeolites in the SZ plugs pores	Include				X	
2.2.10.09.00	**Thermo-chemical alteration of the Topopah Spring basal vitrophyre**	**Include**	**X**			**X**	
2.2.10.09.01	Formation of perched water on the altered Topopah Spring basal vitrophyre	Include	X				
2.2.10.09.02	Sorption of contaminants by the altered Topopah Spring basal vitrophyre	Include				X	
2.2.10.09.03	Redirection of transport paths by the altered Topopah Spring basal vitrophyre	Include	X				
2.2.10.09.04	Sorption of actinides on altered Topopah Spring basal vitrophyre	Include				X	
2.2.10.09.05	Alteration of the Topopah Spring basal vitrophyre	Include	X				
2.2.10.10.00	**Two-phase buoyant flow/heat pipes**	**Include**	**X**				
2.2.10.10.01	Heat pipe-evolving	Include	X				
2.2.10.10.02	Heat pipe-continuing	Include	X				
2.2.10.10.03	Heat pipe formation, two-phase system	Include	X				
2.2.10.11.00	**Natural airflow in UZ**	**Include**	**X**				

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Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.2.10.12.00	**Geosphere dryout due to waste heat**	**Include**	**X**				
2.2.11.01.05*	**Gas generation and gas sources, far-field**	**Exclude**	**X**	**X**		**X**	
2.2.11.02.00*	**Gas pressure effects**	**Exclude**	**X**				
2.2.11.02.01	Gas pressure effects	Exclude	X				
2.2.11.02.02	Fluid flow due to gas pressurization (in waste and EBS)	Exclude	X				
2.2.11.03.00*	**Gas transport in geosphere**	**Exclude**				**X**	
2.2.11.03.01	Gases and gas transport (in geosphere)	Exclude				X	
2.2.14.03.00*	**Far-field criticality, sorption on clay/zeolite in TSbv**	**Exclude**					**X**
2.2.14.03.01	Accumulation of solute in topographic lows of the altered TSbv	Include					X
2.2.14.07.00	**Far-field criticality, dryout produces fissile salt in a perched water basin**	**Include**					**X**
2.2.14.08.00*	**Far-field criticality associated with colloidal deposits**	**?**					**X**
2.3.11.03.00	**Infiltration and recharge (hydrologic and chemical effects)**	**Include**		**X**		**X**	
2.3.11.03.05	Recharge groundwater	Include		X		X	

Table 3-1. All U.S. Department of Energy features, events, and processes database (Revision 00b) entries relevant to the evolution of the near-field environment key technical issue with relevance to specific subissues indicated. Entries in bold are primary entries or secondary entries for which the corresponding primary entry was not included in the table. An asterisk in the first column indicates that the item is in table 3-2. (cont'd)

Features, Events, and Processes #	Features, Events, and Processes Name	Screening	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5
2.3.13.03.00*	**Effects of repository heat on biosphere**	**Exclude**	**X**				
3.1.01.01.00	**Radioactive decay and ingrowth**	**Include**	**X**	**X**	**X**	**X**	
3.1.01.01.01	Radioactive decay	Include			X		
3.1.01.01.02	Radioactive decay	Include				X	
3.1.01.01.06	Radioactive decay	Include	X	X		X	
3.1.01.01.07	Radioactive decay of mobile nuclides	Include				X	
3.2.07.01.02*	**Natural radionuclides/elements (in host rock disturbed zone)**	**Exclude**			**X**	**X**	

SZ = saturated zone
UZ = unsaturated zone
DOE = U.S. Department of Energy
SNF = spent nuclear fuel
HLW = high level waste
WP = waste package
DSNF = Department of Energy spent nuclear fuel
CSNF = commercial spent nuclear fuel
DHLW = defense high level waste
YMP = Yucca Mountain Project
MIC =microbially induced corrosion
EBS = engineered barrier system
EDZ = excavation disturbed zone

The last column in table 3-2 indicates the FEP AMRs to be published by DOE that will document detailed technical bases for screening of the FEP (see also section 1.1). These reports were taken from a field in the FEP database (Revision 00b), with the names changed to more recent terminology (U.S. Department of Energy, 1999b). NRC/CNWRA review of these AMRs will provide a path-forward to resolution of these issues. In the table, "ASTROID" refers to a FEPs analysis for items outside the PMR structure; this analysis has been given an activity ID of SLPA4306 under Performance Assessment Operations (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1999). NRC does not yet know how screening of ASTROID entries will be documented. There is not a FEP AMR relevant to criticality, so the last column in table 3-2 is blank for criticality-related entries. Screening of these FEPs is to be documented as part of the criticality analysis described in U.S. Department of Energy (1998a).

3.3.1 Features, Events, and Processes Not Included in the Database

Some FEPs identified or suggested by discussions in the ENFE IRSR (Nuclear Regulatory Commission, 1999a) are not represented in the DOE FEP database. This type of deficiency is potentially more serious than those discussed in section 3.2.1 because resolution may require additions to the database. These FEPs are presented in table form for emphasis and convenience (table 3-3). DOE-funded Yucca Mountain investigators have described the first two of these and asserted them to be potentially important to performance (Nuclear Regulatory Commission, 1999a). This list may grow as more NRC/CNWRA staff become familiar with ENFE coverage in the database. Because of lack of specificity in many parts of the database (e.g., with respect to mineralogic alteration), currently there is no assurance that FEPs assumed to be covered in the database are in fact included in the DOE FEP screening. The true breadth of considered FEPs will only be apparent after completion of AMRs and PMRs and release of the Revision 00 database. The items listed in table 3-3 do not include more global deficiencies in the database as discussed in section 3.4.

3.4 ASSIGNMENT TO SUBISSUES

Binning of DOE database entries into the five ENFE subissues is documented in table 3-1. Because this table is intended to provide guidance to subissue teams on potential relevance in the database, entries were generously distributed among subissues with a bias in favor of inclusion. There is therefore considerable overlap among the subissues.

An example will serve to illustrate the binning process. Entry 2.1.04.01.00—Preferential pathways in the backfill—was assigned to subissue 1 because flow through the backfill, and along its contact with the drift walls, are components of unsaturated zone flow. This entry is relevant to subissue 2 because the nature of pathways through the backfill may affect water chemistry at the waste package. The relevance to subissue 3 regarding the chemical environment for release is that the nature of delivery paths of water to the waste form affects the chemistry. This entry was assigned also to subissue 4 regarding radionuclide transport because of its potential impact on flow out of the waste package.

3.5 COMMENTS ON DATABASE STRUCTURE, ORGANIZATION, AND USABILITY

Presentations made at the Appendix 7 meeting on September 8, 1999, indicate that both DOE and NRC consider it useful for NRC to provide early feedback on the way in which the database is structured,

Table 3-2. U.S. Department of Energy features, events, and processes database entries (Revision 00b) that are excluded but are considered unresolved. Unless otherwise noted, the entry was screened as "exclude". The final column lists the DOE FEP AMRs that may provide a path to resolution.

Features, Events, and Processes #	*Features, Events, and Processes Name* and notes on database entry	Comments from this review	Relevant DOE AMRs (U.S. Department of Energy, 1999b)
1.1.02.00.00	*Excavation/construction* Concerns effects on rock properties (exclusive of stress relief effects) and geochemistry. States, "These changes are trivial in comparison to changes that will occur during the thermal period following repository closure, and have therefore been excluded from the TSPA on the basis of low consequence."	Exclusion requires a more detailed justification for the claim of low consequence.	E0015 U0170 N0080
1.1.02.02.00	*Effects of preclosure ventilation* Refers to control of "the extent of the boiling front." Screened as "??"	No screening given.	E0015 N0080
1.1.02.03.00	*Undesirable materials left* Decontamination materials are stressed. States, "It is presumed that any materials unacceptable to [NRC and EPA] will be removed. Further, it is not at all clear that decontamination solvents won't be so altered by heat and radiation as to be of no consequence."	Will be taken care by NRC inspectors. Operational errors cannot be excluded without knowledge of quality control procedures. In addition, thermal and radiolytic degradation of solvents as a mitigating factor requires a technical basis.	
1.1.03.01.00	*Error in waste or backfill emplacement* States, "Significant deviations [from design] that are detected during the operational period will be corrected, and, therefore, are excluded from the TSPA on the basis of low probability."	Operational errors cannot be excluded without knowledge of quality control procedures.	E0015 W0055
1.1.07.00.00	*Repository design* Screened as "Include (exclude deviation s from design)." States, "Deviations from design during the operational period are the subject of an extensive quality control program, and are outside the scope of the long-term performance assessment. If the repository does not meet regulatory criteria it will not be licensed and waste will not be emplaced."	Deviations from design that may affect performance cannot be excluded without knowledge of quality control procedures. Directly related to 1.1.03.01.00.	ASTROID E0015
1.1.08.00.00	*Quality control* Screened as "Include (exclude defects and deviations)." Screening argument is identical to that for 1.1.07.00.00.	Operational and design errors cannot be excluded without knowledge of quality control procedures. Furthermore, exclusion of defects contradicts inclusion of juvenile failures (2.1.03.08.00).	ASTROID E0015

Table 3-2. U.S. Department of Energy features, events, and processes database entries (Revision 00b) that are excluded but are considered unresolved. Unless otherwise noted, the entry was screened as "exclude". The final column lists the DOE FEP AMRs that may provide a path to resolution. (cont'd)

Features, Events, and Processes #	*Features, Events, and Processes Name* and notes on database entry	Comments from this review	Relevant DOE AMRs (U.S. Department of Energy, 1999b)
1.1.12.01.00	*Accidents and unplanned events during operation* States, "Any deviation [from design] would be detected during regulator audits and inspections and be corrected before further work in the repository would be allowed to continue."	Unplanned events cannot be excluded without knowledge of quality control procedures.	ASTROID E0015
1.2.06.00.00	*Hydrothermal activity* Citing a report concluding that no hydrothermal alteration has occurred for 10 million years, states that "Naturally-occurring hydrothermal activity has therefore been excluded from the TSPA on the basis of low probability of occurrence during the period of regulatory interest."	The potential for hydrothermal activity affecting the repository is still an open issue. DOE is sponsoring an investigation into fluid inclusion evidence for hydrothermal activity by the University of Nevada at Las Vegas in cooperation with the State of Nevada.	S0075 U0170
2.1.02.03.04	*Rate of glass dissolution* Screening argument states, "The expectation at Yucca Mt is that once the container walls are breached, the glass (DHLW) will see a warm, high pH fluid and will be rapidly converted to clays and zeolites. The details about glass dissolution rates then become unimportant in this case."	The screening argument is based on assumptions of the chemical effects of cementitious materials (i.e., rapid glass degradation) and contradicts DOE model descriptions for glass dissolution (DOE, 1998). The corresponding primary entry does not mention glass dissolution rate.	F0185
2.1.02.03.09	*Radionuclide release from glass* Concerns release by congruent dissolution of glass. Screening argument states, "It is expected that at Yucca Mt, because the fluids will be of high pH and warm, glass will be rapidly converted to clays and zeolites. Congruent leaching may be impossible because the residual water would require solutes to exceed their solubility limits."	The screening argument is dependent on an assumption of rapid degradation due to the chemical effects of cementitious materials. See discussion in this table of 2.1.02.03.04. This entry is "unresolved" because, unlike the corresponding primary entry, it addresses glass release rates.	F 0185
2.1.02.04.00	*Alpha recoil enhances dissolution* Concerns effects on both bulk waste and on particular radionuclides. Screening argument states, "Preferential dissolution because of alpha recoil...may influence the apparent dissolution rates and solubility of certain daughters. However, the alpha-produced daughters still have the same chemical solubility limits as those produced [otherwise]."	Sole secondary entry is listed as included, and states that this process is "Included implicitly in summary description of mobilization as determined experimentally." It is therefore unclear why this primary entry is listed as excluded.	F0185

Table 3-2. U.S. Department of Energy features, events, and processes database entries (Revision 00b) that are excluded but are considered unresolved. Unless otherwise noted, the entry was screened as "exclude". The final column lists the DOE FEP AMRs that may provide a path to resolution. (cont'd)

Features, Events, and Processes #	*Features, Events, and Processes Name* and notes on database entry	Comments from this review	Relevant DOE AMRs (U.S. Department of Energy, 1999b)
2.1.02.05.00	*Glass cracking and surface area* Concerns effects on alteration and dissolution. The screening argument states that "The robust container used at Yucca Mt means that the concerns about fragmentation (and increased leach rate) of vitrified wastes are secondary."	Exclusion of surface area effects contradicts DOE model dependence on surface area as utilized in TSPA-VA (DOE, 1998b).	F0185
2.1.02.08.00	*Pyrophoricity* Concerns thermal and waste form degradation effects of ignition of pyrophoric material and/or acetylene from DSNF, including a possible effect of "increased fuel particles small enough to enhance colloidal transport mechanisms."	The screening argument is a proposal for an approach to screening, rather than an actual argument.	F0185
2.1.02.13.00	*General corrosion of cladding* Concerns zirconium oxidation as a mechanism for cladding degradation.	The screening argument provides a description of the process, rather than a rationale for exclusion.	F0050 F0185
2.1.02.14.00	*Microbial corrosion (MIC) of cladding* The screening argument states only that this process has not been observed.	A stronger technical basis for exclusion is required (NRC, 1999b).	F0050 F0185
2.1.02.15.00	*Acid corrosion of cladding from radiolysis* Screening is tentative, "Exclude (?)"and the TSPA disposition field states, "Not a major issue, could use analysis at later time."	There is no screening argument for this potentially significant process (Cragnolino et al., 1999).	F0050 F0185
2.1.02.19.00	*Creep rupture of cladding* Screening argument states, "Creep failure was postulated as the dominant failure mode for fuel in dry storage but has not been observed."	A stronger technical basis is required (NRC, 1999b); in fact, the TSPA disposition field says that "NRC wants comparison of various models and study of uncertainties." An argument for exclusion is in the TSPA-VA technical basis document (DOE, 1998b), but is not presented in the database.	F0050 F0185
2.1.04.03.00	*Erosion or dissolution of backfill* Screening argument states, "Backfill material at Yucca Mountain will not be highly soluble, and no significant loss due to dissolution is anticipated. Flow rates in the unsaturated environment of the repository will be too low to cause erosion."	Because backfill composition has not been defined, a stronger technical basis is required for stating that it is not expected to dissolve appreciably.	E0015

Table 3-2. U.S. Department of Energy features, events, and processes database entries (Revision 00b) that are excluded but are considered unresolved. Unless otherwise noted, the entry was screened as "exclude". The final column lists the DOE FEP AMRs that may provide a path to resolution. (cont'd)

Features, Events, and Processes #	*Features, Events, and Processes Name* and notes on database entry	Comments from this review	Relevant DOE AMRs (U.S. Department of Energy, 1999b)
2.1.06.04.00	*Flow through the liner* Focused on groundwater flow effects of liner. The screening argument makes specific reference to a concrete liner, but additional notes suggest that the entry be made more general. Another note says that, "With EDA-II design this process is no longer applicable."	Appears to be excluded based on the absence of a concrete liner in EDA-II, but the screening argument is not clear. Included FEPs cover degradation of the liner and/or support materials (e.g., 2.1.06.01.00, 2.1.06.02.00, and 2.1.06.03.00) but none appear to address the effect of the liner on flow. Absent a definitive description of the liner or its absence, this FEP should be included.	E0015
2.1.06.06.00	*Effects and degradation of drip shield* The YMP description of this FEP suggests that it will be included in TSPA, but there is no screening argument.	No screening or screening argument given.	E0015 W0055
2.1.08.07.00	*Pathways for unsaturated flow and transport in the waste and EBS* Screened as "Include?" Includes consideration of "Physical and chemical properties of the EBS and waste form, in both intact and degraded states..." affecting transport. The screening argument says, "The details of internal pathways providing release from a container are subsumed in an integrated release distribution."	Although it appears this FEP is included, the screening should be clarified.	E0015 F0185
2.1.09.02.00	*Interaction with corrosion products* Screened as "Exclude?" The screening argument states that "Interaction of contaminants with corrosion products is expected to control mobilization and speciation of the contaminants." In addition, the TSPA disposition field says, "Included only in the integrated source term and associated sorption parameters."	It is not clear why this FEP is classified as it is, given the screening argument and TSPA disposition statement. In addition, four of the five secondary entries are included.	E0015
2.1.09.05.02	*Sorption* Concerns sorption in the EBS, specifically buffer and backfill. Screening argument states that no sorptive materials are planned; however, EDA-II includes backfill.	The corresponding primary entry—2.1.09.05.00, In-drift sorption—is included, but mentions sorption only in the liner and invert. If sorption in the backfill is excluded because it is beneficial, this should be made clear.	E0015

Table 3-2. U.S. Department of Energy features, events, and processes database entries (Revision 00b) that are excluded but are considered unresolved. Unless otherwise noted, the entry was screened as "exclude". The final column lists the DOE FEP AMRs that may provide a path to resolution. (cont'd)

Features, Events, and Processes #	*Features, Events, and Processes Name* and notes on database entry	Comments from this review	Relevant DOE AMRs (U.S. Department of Energy, 1999b)
2.1.09.07.00	*Reaction kinetics in waste and EBS* The FEP as stated concerns chemical reactions in general, but the screening argument addresses only redox. DOE is relying on "experimentally derived K_ds" to include these effects. "Specific effects of redox kinetics are therefore excluded from the TSPA on the basis of low consequence."	Reliance on experimental K_ds, and discussion of kinetics only in the context of redox, constitutes an oversimplification of chemical processes in waste and EBS. In addition, the sole secondary entry—2.1.09.07.01—is "included" and the argument says that kinetics "...are to be included in detailed modeling of chemical interactions using EQ3/6."	E0015
2.1.09.09.00	*Electrochemical effects (electrophoresis, galvanic coupling) in waste and EBS* Concerns effects on corrosion and radionuclide transport. The screening argument states only that "Galvanic protection is considered for Yucca Mt containers."	The screening argument is insufficient and some secondary entries are "included."	W0055
2.1.09.11.00	*Waste-rock contact* Concerns enhancement of spent fuel dissolution reactions when rock and waste come into contact. Screening argument states, "The rock-water interactions and the Fe of the container is expected to be more controlling on U solubility than the interactions suggested in this FEP."	The FEP as stated includes rock-water interactions because the description mentions "reactions between uranium, rock minerals, and water...." The screening argument therefore is inconsistent. Exclusion of this FEP suggests (perhaps wrongly) that geochemical modeling will not include both rock and waste form.	F0185 E0015
2.1.09.21.00	*Suspensions of particles larger than colloids* The screening argument states, "Suspension of particles in the flow system (carrier plume) descending through the UZ via fractures is possible. The low groundwater velocities in the SZ would likely lead to settlement."	Because transport through the UZ is considered credible, its exclusion in the SZ needs a technical basis.	E0015 S0075
2.1.10.01.00	*Biological activity in waste and EBS* Screened as "Include?" Includes effects on degradation, transport, and gas generation.	This FEP is unresolved, and nine of its eleven secondary entries are "included."	F0185 E0015 W0055

Table 3-2. U.S. Department of Energy features, events, and processes database entries (Revision 00b) that are excluded but are considered unresolved. Unless otherwise noted, the entry was screened as "exclude". The final column lists the DOE FEP AMRs that may provide a path to resolution. (cont'd)

Features, Events, and Processes #	*Features, Events, and Processes Name* and notes on database entry	Comments from this review	Relevant DOE AMRs (U.S. Department of Energy, 1999b)
2.1.11.08.00	*Thermal effects: chemical and microbiological changes in the waste and EBS* This FEP is very broadly defined. The screening argument refers to other entries—2.1.10.01.00 and subentries under 2.1.09.00.00—but does not provide a rationale for exclusion.	None of the primary entries cited in the screening argument deal specifically with thermal effects. Coverage of thermal effects in other entries should be more clearly cited.	N0080 E0015 F0185
2.1.12.01.00	*Gas generation* Description says, "Gas generation might lead to pressurization of the repository, produce multiphase flow, and affect radionuclide transport." The screening argument states that "Since the repository would be in the UZ, which is well connected to the surface, gas produced by whatever reaction is expected to escape or at least be only temporarily confined beneath the condensate zone above the drifts."	Exclusion of this FEP implies that gases generated in the near field will have no chemical impact. The conclusion that gas will escape with no effect needs a technical basis, particularly since the possibility of temporary confinement is acknowledged.	E0015 U0170
2.1.12.02.00	*Gas generation (He) from fuel decay* Concerns cladding failure due to pressure buildup from radiogenic He (also covered in 2.1.02.20.00).	While this effect alone may produce insufficient pressure buildup to lead to failure, it may enhance other cladding failure mechanisms such as hydride embrittlement (Cragnolino et al., 1999).	E0015 F0185
2.1.12.03.00	*Gas generation (H_2) from metal corrosion* Includes effects on chemical conditions and transport. The screening argument states that "Gas generated by metal corrosion will interact with the containers or escape from the drifts," but does not argue against any effects.	Exclusion of this FEP implies that H_2 gas generated in the near field will have no chemical impact. The conclusion that gas will escape with no effect needs a technical basis.	E0015 F0050 W0055
2.1.12.05.00	*Gas generation from concrete* The screening argument states that "decomposition of concrete includes radiolysis, microbial decomposition and thermal decomposition." The TSPA disposition field says, "Ignored until importance, if any, can be quantified."	No rationale for exclusion is given. Exclusion of this FEP implies that gases generated from concrete in the near field will have no chemical impact. The conclusion that gas will escape with no effect needs a technical basis.	E0015

Table 3-2. U.S. Department of Energy features, events, and processes database entries (Revision 00b) that are excluded but are considered unresolved. Unless otherwise noted, the entry was screened as "exclude". The final column lists the DOE FEP AMRs that may provide a path to resolution. (cont'd)

Features, Events, and Processes #	*Features, Events, and Processes Name* and notes on database entry	Comments from this review	Relevant DOE AMRs (U.S. Department of Energy, 1999b)
2.1.12.06.00	*Gas transport in waste and EBS* Broadly concerns effects on performance of gases in waste and EBS. The screening argument focuses, however, on radioactive gases, stating, "For a repository in the UZ, these escape to the atmosphere. Usually only $^{14}CO_2$ is considered and it is expected that it will not be part of the standard."	Exclusion of this FEP implies that gases generated in the near field will have no chemical impact. The screening argument discusses only radioactive gases and bubble effects, to the exclusion of chemical effects. In addition, the argument presupposes no dose effect from radioactive gases.	E0015
2.1.12.07.00	*Radioactive gases in waste and EBS* Screening argument states, "FEPs related exclusively to the behavior of radioactive gases have been excluded from the TSPA on the basis of low consequence, because radioactive gases are not a significant component of the future radionuclide inventory of the proposed Yucca Mountain repository."	The screening argument presupposes no dose effect from radioactive gases. In addition, there is an inconsistency in that the TSPA Disposition field indicates "included."	E0015 F0185
2.1.13.02.00	*Radiation damage in waste and EBS* Screened as "include, exclude (backfill, seals, rock)." In excluding damage to rock, the screening arguments states, "Metamict energy—radiation damage—is deposited in the rock with an e-folding distance of about 30 cm, so little rock is actually affected."	Screening argument suggests very little energy penetration in rock, but does not address the more proximal backfill. Exclusion of effects in the backfill requires a technical basis.	F0185 W0055 E0015
2.1.14.01.10	*DOE SNF criticality near-field (radionuclide inventory impact)* The description reads, in part, "The DOE SNF to be disposed of in Yucca Mountain might have the potential to result in a criticality within the near-field region...."	No screening or screening argument is given. The entry should either cite other entries regarding near-field criticality or be removed.	
2.1.14.11.00	*Near-field criticality, fissile solution is adsorbed or reduced in invert* The screening argument is incomplete and does not reach a conclusion.	Although they may not be included in TSPA, configurations to be assessed in the separate criticality analysis (U.S. Department of Energy, 1998a) should not be listed as "excluded."	
2.1.14.13.00	*Near-field criticality associated with colloidal deposits* The screening argument is incomplete and does not reach a conclusion.	Although they may not be included in TSPA, configurations to be assessed in the separate criticality analysis (U.S. Department of Energy, 1998a) should not be listed as "excluded."	

Table 3-2. U.S. Department of Energy features, events, and processes database entries (Revision 00b) that are excluded but are considered unresolved. Unless otherwise noted, the entry was screened as "exclude". The final column lists the DOE FEP AMRs that may provide a path to resolution. (cont'd)

Features, Events, and Processes #	*Features, Events, and Processes Name* and notes on database entry	Comments from this review	Relevant DOE AMRs (U.S. Department of Energy, 1999b)
2.1.14.14.00	*Out-of-package criticality, fuel/magma mixture* The screening argument is incomplete and does not reach a conclusion.	Although they may not be included in TSPA, configurations to be assessed in the separate criticality analysis (U.S. Department of Energy, 1998a) should not be listed as "excluded."	
2.2.01.03.01	*Gas transport/dissolution (in the EDZ)* Refers to behavior of gas in the EDZ. The original description says, "Any gas in the EDZ (trapped at closure, from corrosion/degradation of repository elements or natural sources) is assumed to move freely in the open joints of the EDZ and dissolve in the porewater or escape to the transmissive elements of the low permeability domain." The YMP screening argument states, "For a repository in the UZ and well-connected to the atmosphere, it is expected that any gas included by closure will be able to escape."	This secondary entry has no apparent relevance to its corresponding primary entry, which concerns changes in fluid saturations. No screening is given, but the TSPA Disposition field says, "not considered." This FEP raises the same concerns regarding treatment of gases as discussed in this table for entries 2.1.12.XX.XX, e.g., no consideration is given to chemical effects of generated gases that may be dissolved in water.	N0080
2.2.07.06.00	*Episodic / pulse release from repository* Description states, "Episodic release of radionuclides from the repository and radionuclide transport in the UZ may occur both because of episodic flow into the repository (see 2.2.07o, episodic flow in UZ) and because of other factors including intermittent failures of waste packages." (2.207o is the NEA notation corresponding to DOE entry 2.2.07.05.00)	No screening given. Episodic UZ flow is covered in 2.2.07.05.00. Although 2.2.07.06.00 mentions that there may be other factors affecting episodic release, they are not addressed.	E0015 U0170
2.2.07.07.00	*Perched water develops* Refers to the potential for perched zones both above and below the repository, affecting flow to and transport from the repository. The screening argument states, "The development of a sufficiently large body of perched water above the repository to affect flow into the repository has been excluded from the TSPA on the basis of low probability."	The screening argument does not address perched water below the repository. This FEP is included here because of the THC processes addressed in the secondary entry 2.2.07.07.01 discussed below in this table.	U0170

Table 3-2. U.S. Department of Energy features, events, and processes database entries (Revision 00b) that are excluded but are considered unresolved. Unless otherwise noted, the entry was screened as "exclude". The final column lists the DOE FEP AMRs that may provide a path to resolution. (cont'd)

Features, Events, and Processes #	*Features, Events, and Processes Name* and notes on database entry	Comments from this review	Relevant DOE AMRs (U.S. Department of Energy, 1999b)
2.2.07.07.01	*Perched water develops at base of Topopah Spring welded unit* Concerns effects on flow. Screening argument states, "Perched water is found at this stratum.... At this proximity to the repository, considerable interaction with vitric components is expected during the thermal period with possible profound alteration of the rock properties."	No screening given. Coupled THC processes affecting the basal Topopah Spring are considered elsewhere in the database (2.2.10.09.00), and these could affect the potential for perched water below the repository.	U0170
2.2.07.14.00	*Density effects on groundwater flow* Includes thermal and chemical density effects. Screening argument says, "At Yucca Mt, if a carrier/contaminant plume reaches the water table with the signature of the repository (temperature and solutes) it is possible for it to be buoyant in the SZ and flow along at the water table, relatively unmixed, for considerable distance."	The screening argument does not support exclusion. The TSPA disposition field says, "Ignored at present, approximated indirectly by flow tubes."	S0075
2.2.08.01.08	*Changes in groundwater Eh* The screening argument states, "Except for local isolation due to condensate gas caps (if formed), this connection to the atmosphere should control the Eh." The TSPA disposition is described as, "Ignored, except as already included in corrosion calculations." Wording in the corresponding primary entry (2.2.08.01.00), which is included, suggests that these entries are concerned with groundwater only outside the drift.	While the primary entry 2.2.08.01.00 ("Groundwater chemistry / composition in UZ and SZ") does include possible Eh changes, it is troublesome that this secondary entry dismisses them. Furthermore, the primary entry states that such changes in groundwater chemistry are "ignored at present with respect to the carrier plume." Exclusion of possible redox variations in the near field requires a technical basis or citation of other relevant FEPs.	U0170 S0075

Table 3-2. U.S. Department of Energy features, events, and processes database entries (Revision 00b) that are excluded but are considered unresolved. Unless otherwise noted, the entry was screened as "exclude". The final column lists the DOE FEP AMRs that may provide a path to resolution. (cont'd)

Features, Events, and Processes #	*Features, Events, and Processes Name* and notes on database entry	Comments from this review	Relevant DOE AMRs (U.S. Department of Energy, 1999b)
2.2.08.01.09	*Changes in groundwater pH* The screening argument refers to the hyperalkaline plume generated by the repository. The TSPA disposition is described as, "Ignored, except as already included in corrosion calculations." Wording in the corresponding primary entry (2.2.08.01.00), which is included, suggests that these entries are concerned with groundwater only outside the drift.	While the primary entry 2.2.08.01.00 ("Groundwater chemistry / composition in UZ and SZ") does include possible pH changes, it is troublesome that this secondary entry dismisses them. Furthermore, the primary entry states that such changes in groundwater chemistry are "ignored at present with respect to the carrier plume." Exclusion of possible pH variations in the near field requires a technical basis, or citation of other relevant FEPs.	U0170 S0075
2.2.08.04.00	*Redissolution of precipitates directs more corrosive fluids to containers* Screening argument says, "Changes in the chemistry of hot fluids flowing through the dryout zone have been excluded from the TSPA on the basis of low consequence.... Flow is likely to have chemistry associated with redissolution, however it is still likely that the chemistry of the fluids will be driven by interaction with drift liner, dissolved constituents such as Fe and the residual temperature of the repository."	That this FEP will have negligible impact on the waste package chemical environment relative to other repository materials and processes needs a stronger technical basis (Nuclear Regulatory Commission, 1999a). Notes in the screening argument field such as "text needed" acknowledge this need.	E0015 N0080 U0170
2.2.08.07.00	*Radionuclide solubility limits in the geosphere* Description states, "Solubility limits for radionuclides may [be] different in geosphere groundwater than in the water in the waste and EBS." The screening argument says that "...solubility limits [will] be determined by the plume-rock interaction. This assumes that some place along the path from the waste a solubility limit is attained."	The argument does not provide an explicit case for exclusion. A parenthetical note suggests conservatism as a basis for exclusion, but provides no technical basis.	U0170 S0075
2.2.10.01.06	*Thermal effects: Rock-mass changes* Refers to possible thermal changes to "...physical properties, which in turn could affect radionuclide transport in the far-field." The screening argument states, "Thermal effects, which alter fracture properties, dominate; they are much more than the effects of this FEP and are treated as separate FEPs."	The corresponding primary entry is included, but does not mention rock-mass changes. Screening argument is somewhat confusing and needs a stronger technical basis. No other database entries discuss changes to rock mass from repository THC effects.	U0170 S0075

Table 3-2. U.S. Department of Energy features, events, and processes database entries (Revision 00b) that are excluded but are considered unresolved. Unless otherwise noted, the entry was screened as "exclude". The final column lists the DOE FEP AMRs that may provide a path to resolution. (cont'd)

Features, Events, and Processes #	*Features, Events, and Processes Name* and notes on database entry	Comments from this review	Relevant DOE AMRs (U.S. Department of Energy, 1999b)
2.2.11.01.05	*Gas generation and gas sources, far-field* The description includes "...gas generated in the near-field of the repository and transported to the far-field." The screening argument says that gases generated by the repository "...are expected to escape to the atmosphere. Changes to the chemistry of the water as a result have been ignored. Water chemistry is expected to be dominated by interaction with the concrete liner, temperature and connection to the atmosphere."	The corresponding primary entry 2.2.11.01.00 ("naturally-occurring gases in geosphere") does not refer to repository-generated gases. The conclusion that such gas will escape with no chemical effect needs a stronger technical basis. This entry is closely related to others in this table, i.e., 2.1.12.01.00, 2.1.12.03.00, 2.1.12.05.00, 2.1.12.06.00, 2.2.01.03.01, and 2.2.11.03.00.	U0170 S0075
2.2.11.02.00	*Gas pressure effects* Concerns effects of repository-generated gas on flow and transport. The screening argument says, "For a repository located in the UZ at Yucca Mtn, the connections to the atmosphere assure that a significant buildup of gas pressure is not likely. Studies on 2-phase flow are, however, just beginning to consider certain special aspects of the problem."	Because the screening argument refers to ongoing studies that may improve understanding of the process, this FEP should not yet be excluded.	U0170
2.2.11.03.00	*Gas transport in geosphere* Concerns both chemical effects of gases and gaseous radionuclide transport. The screening argument states, "Yucca Mtn would be located in the UZ, so any gas produced would be expected to escape to the surface and no bubbles to form."	Exclusion of this FEP implies that gases generated in the near field and transported to the geosphere will have no chemical impact. The conclusion that gas will escape with no effect needs to be more strongly supported.	U0170
2.2.14.03.00	*Far-field criticality, sorption on clay/zeolite in TSbv* In parentheses, the screening argument says, "Clay/zeolite zones appear to be too diffuse."	Although listed as "far-field," this FEP could be affected by repository-driven alteration of the Topopah Spring basal vitrophyre (TSbv; see 2.2.10.09.00) yielding greater abundance of clays and zeolites. In addition, configurations to be assessed in the separate criticality analysis (U.S. Department of Energy, 1998a) should not be listed as "excluded."	

Table 3-2. U.S. Department of Energy features, events, and processes database entries (Revision 00b) that are excluded but are considered unresolved. Unless otherwise noted, the entry was screened as "exclude". The final column lists the DOE FEP AMRs that may provide a path to resolution. (cont'd)

Features, Events, and Processes #	*Features, Events, and Processes Name* and notes on database entry	Comments from this review	Relevant DOE AMRs (U.S. Department of Energy, 1999b)
2.2.14.08.00	*Far-field criticality associated with colloidal deposits* The description refers to colloid deposition "...in clays/zeolites in TSbv or deposited in perched water above the relatively impermeable Tsbv." Screening has yet to be determined, denoted by "?."	Like 2.2.14.03.00, this FEP would be affected by repository-driven alteration of the TSbv, including an increase in clay and zeolite abundance and the potential for perched water (see discussion in this table of 2.2.07.07.01).	
2.3.13.03.00	*Effects of repository heat on biosphere* The description reads, "The heat released from radioactive decay of the waste will increase the temperatures at the surface above the repository. This could result in local or extensive changes in the ecological characteristics."	This FEP is relevant because it concerns a repository effect that could affect UZ flow, for example, by altering subsurface chemistry. There is no actual screening argument, but rather a citation of an included FEP (2.1.11.01.00) that is not relevant to the biosphere.	U0170
3.2.07.01.02	*Natural radionuclides/elements (in host rock-disturbed zone)* Concerns chemical gradients involving natural radionuclides leached from host rocks. Screening argument states, "Concentrations of naturally-occurring radionuclides in groundwater in the disturbed zone surrounding the repository have been considered in the modeling of radionuclide concentrations."	The corresponding primary entry discusses only effects on dose from dilution with less-radioactive or non-radioactive isotopes, whereas this entry is ENFE-relevant because it addresses chemical effects on release. Given the screening argument, it is not clear why this FEP is classified as excluded.	S0075

TSPA = total system performance assessment **FEP = feature, event, or process** **EDZ = excavation disturbed zone**
MIC = microbially induced corrosion **EBS = engineered barrier system**
EDA = enhanced design alternative **UZ = unsaturated zone**
YMP = Yucca Mountain Project **SZ = saturated zone**

Table 3-3. Evolution of the near-field environment-relevant features, events, and processes not present in the U.S. Department of Energy database (Revision 00b)

Features, Events, and Processes	Possibly Related Department of Energy Database Entries
Dehydration of zeolites below the repository leads to large-scale volume changes affecting flow and/or drift stability	2.2.10.01.06
Mineralogic dehydration reactions release water affecting hydrologic conditions	None
Condensation of water on the underside of the drip shield affects waste package hydrologic and chemical environment	2.1.06.06.00
Interaction with and degradation of drip shield affects chemistry of the water contacting the waste package	2.1.06.06.00

how secondary entries are rolled up into primary entries, the ease of navigating the database, and other usability issues. The database is a tool to aid in transparency and traceability of the scenario development process and so must be made useful to the potential licensing body. This section documents comments on the database compiled from NRC and CNWRA staff. This critique will deemphasize the unfinished nature of the database (e.g., the general lack of complete TSPA disposition statements) because this type of shortcoming was understood before the review began. Some of the comments refer to FEPs not considered ENFE-relevant.

The criticisms described in section 3.4.1, and particularly in section 3.4.2, were developed in an audit-like manner as part of the staff's initial familiarization with the database (Revision 00b). The NRC's staff briefly reviewed every database entry and noted specific comments or examples that demonstrated a weakness in the database. Early in the review process these draft comments were shared with DOE, at their request, in a follow-up teleconference call after the Appendix 7 meeting of September 8, 1999. This early preliminary feedback was necessary so that DOE could address the staff concerns in the first revision of the AMRs.

3.5.1 General Issues

1. The database is not structured in a way that readily reveals coupling, especially for chemical processes, and coupling is central to the technical concerns of the ENFE KTI. The database is a list of FEPs, some of which represent coupled processes, but coupling among separate FEPs is either not addressed or is inconsistently contained in screening arguments. For example, sorption in the unsaturated zone is partly controlled by water chemistry. However, the FEP on unsaturated zone and saturated zone sorption—2.2.08.09.00—provides no information on this chemical dependence, nor a link to FEPs concerned with water chemistry such as 2.2.08.01.00. A third primary FEP—2.2.08.03.00, concerned with geochemical interactions—does provide linkage to these related processes, but the linkages are not apparent from a wider perspective.

This deficiency in the database may grow out of its recent origin more as a tool for reporting the scenario analysis rather than as a tool for performing the scenario analysis itself. It is not apparent from the database (Revision 00b) that DOE has performed a systematic analysis of FEPs and their interactions. The results of such a process can be provided in a transparent manner that involves visualization of couplings and interactions between FEPs (Kozak and Zhou, 1998). An external review of the NRC/CNWRA performance assessment effort (Weldy et al., 1999) raised a similar criticism. Reviewers pointed to a lack of visual guides such as interaction matrices or influence diagrams (e.g., Swedish Nuclear Power Inspectorate, 1996), or other systematic descriptions of process coupling, and recommended alternative approaches.

The issue of transparency was presented by J. Kessler [Electric Power Research Institute (EPRI)] at the September 8, 1999, Appendix 7 meeting. (J. Kessler attended the meeting as an observer. At the end of the meeting he was allowed, by the mutual consent of DOE and NRC, to present the results of some ERPI-funded work). An interaction matrix approach to document FEPs interactions used in an independent EPRI Yucca Mountain performance assessment was presented (Kozak and Zhou, 1998). Kessler concluded that FEPs lists, such as the DOE database as it currently exists, have limited transparency because interactions among FEPs are not easily visualized.

2. While the FEP database follows a logical outline, it is difficult to visualize the categorization without aids such as a hierarchical directory or diagram. This compounds the difficulty in recognizing interactions among FEPs. Furthermore, the inability to take a wider view makes more difficult the recognition of redundancy and incompleteness in the database.

3. The database lacks enough detail in some areas to assure the reader that a specific FEP has been considered. For example, a number of FEPs refer to mineralogic phase changes that can affect coupled THC processes (e.g., 2.1.04.05.00, 2.1.09.10.00, 2.2.08.03.00, and 2.2.10.06.00), but the minerals involved are typically not mentioned or are cited only in general terms (e.g., clays).

4. There is inconsistency in the level of specificity assigned to primary FEPs, reducing the transparency of how individual FEPs may be addressed in a performance assessment. Some primary entries represent quite specific FEPs, while others serve more as categories of related FEPs that are listed as secondary entries. An example may be seen in comparing entries related to cladding degradation and those related to geochemical interactions in the geosphere. Cladding degradation in the EBS is described in 13 separate primary entries describing distinct mechanisms. In contrast, a single primary entry—2.2.08.03.00, Geochemical interactions in geosphere (dissolution, precipitation, weathering) and effect on radionuclide transport—is provided that covers a wide variety of geochemical processes such as mineral precipitation and radionuclide speciation. This latter example does not meet the definition of a FEP. A FEP has been defined as *a* feature, event, or process (Swift et al., 1999)

5. Primary entries do not always contain the technical substance of all relevant secondary entries listed below them. Specific examples are provided in section 3.4.2, and some are discussed in table 3-2. The relationship between primary and secondary entries is critical because DOE intends to perform all FEPs screening at the primary entry level.

6. Some secondary entries were not relevant to their corresponding primary entry. This resulted in some secondary entries being judged ENFE-relevant while their corresponding primary entry was not. These "orphan" secondary entries are denoted in table 3-1 as bold entries that do not end with two zeros (see section 2.1).

7. Screening was not consistently applied. In many cases, excluded secondary entries reflected FEPs incorporated into their corresponding included primary entry. This may give the erroneous impression that the FEP described in the secondary entry was screened. Conversely, some secondary entries were classified as included, but were listed under excluded primary entries.

8. Descriptions and screening arguments in the database tend to be excessively design-specific, reflecting outdated designs. This results, for example, in the neglect of backfill effects and the overemphasis of cementitious material effects. The revised database should be updated to be compatible with the pertinent project design.

9. FEP names are not all sufficiently descriptive of the content of the entry.

10. Cross-referencing among related entries could be improved. This would help alleviate the nontransparency of process coupling discussed in item 1 of this section. In addition, reference to an included FEP that covers the content of an excluded FEP would help justify the screening. Cross-referencing should employ DOE, rather than NEA, numbering.

11. Some primary entries are more general than others and appear to constitute a category occupied by others. For example, entry 2.1.03.01.00 (Corrosion of waste containers) encompasses corrosion mechanisms addressed in primary entries 2.1.03.02.00 through

2.1.03.07.00. The same may be said about 2.1.09.14.00 (Colloid formation in waste and EBS) and the subsequent three primary entries.

12. Classification of categorical entries that are not FEPs (x.x.xx.00.00) as secondary is confusing. Furthermore, some x.x.xx.00.00 entries are, in fact, primary FEPs [e.g., 1.2.06.00.00 (Hydrothermal activity)].

13. The processes that could occur in a particular area (e.g., "in the waste and EBS") may also occur elsewhere away from that area, without being explicitly called out. For instance, the description of FEP 2.1.08.08.00 states that "thermal, chemical, and mechanical processes related to the construction of the repository and the emplacement of waste may induce changes in the hydrologic behavior of the system." This definition is applied to the waste and EBS, but is equally relevant to areas away from the EBS.

3.5.2 More Specific Comments and Further Examples

1. FEP names are not always parallel in nature. For example, the presence of 2.1.09.07.00 (Reaction kinetics in waste and EBS) suggests that other entries will be included referring to reaction kinetics in the surrounding rock, the unsaturated zone, and the saturated zone. But such FEP names are not in the database.

2. The Yucca Mountain Project primary FEP description for primary entries does not reflect the scope of the secondary entries. For instance, the primary description for 1.1.12.01.00 (Accidents and unplanned events during operation) does not include the scope of 1.1.12.01.06, regarding spillage of oil or organic solvents.

3. An example of inconsistent screening among primary and secondary entries (item 7 in section 3.4.1) is as follows: 1.2.02.02.00 states that new faulting is excluded, yet four of the secondary entries under this primary entry describe new faulting and are listed as included (see 1.2.02.02.02, .03, .05, and .06).

4. Examples of primary FEPs that aggregate a number of distinct processes or features (see item 4 in section 3.4.1) are 2.1.04.02.00 (Features of and processes affecting backfill), 2.1.09.04.00 (Processes affecting radionuclide speciation and solubility), 2.1.11.04.00 (Temperature effects/coupled processes in waste and EBS), and 2.2.10.06.00 (Thermo-chemical alteration processes).

5. FEPs concerned with the drip shield (2.1.06.06.00) need to be better divided into the discrete features and processes necessary to describe the degradation of the drip shield. This cursory treatment stands in contrast, for example, with that for cladding degradation.

6. An example of redundancy among primary and apparently unrelated secondary entries is primary entry 2.1.09.10.00 (Secondary phase effects on dissolved radionuclide concentrations at the waste form). This entry is substantially the same in content as several of the secondary entries listed under 2.1.09.04.00.

7. An example of redundancy among primary FEPs is the coverage of degradation of cementitious materials found in both 2.1.06.01.00 and 2.1.06.03.00.

8. An example of inconsistency among secondary and primary entries is seen in 2.1.09.14.xx, concerning colloid formation. Some of the secondary entries (2.1.09.14.08, 2.1.09.14.09, and 2.1.09.14.10) concern colloid transport and would more appropriately be placed below primary entry 2.1.09.19.00. Likewise, the substance of secondary entries 2.1.04.01.02, 2.1.04.02.03, and 2.1.04.02.06 is more relevant to primary entry 2.1.04.05.00 (backfill evolution) than to their corresponding primary entries.

9. Entry 2.1.09.18.00 is described as microbial colloid transport, but it also addresses the separate process of microbial colloid formation. In addition, the formation of microbial colloids should perhaps be presented under the 2.1.10.00.00 category [Biological/biochemical processes and conditions (in wastes and EBS)].

10. The name of entry 2.1.09.19.00 may more appropriately only refer to colloid sorption, rather than colloid transport in general, because 2.1.09.20.00 concerns colloid filtration.

11 The FEP name for entry 2.1.11.07.00 (Thermally-induced stress changes in waste and EBS) does not match the processes described in the FEP description, namely, thermally-induced stress changes in the rock surrounding the EBS.

12. There are two further examples of primary entries that more appropriately may be considered categories containing other primary entries (comment 11 in section 3.4.1): (i) 2.1.12.01.00 (Gas generation)is a general category that includes the processes described in primary entries 2.1.12.02.00 through 2.1.12.05.00 and (ii) 2.1.14.01.00 (Criticality in waste and EBS) describes processes addressed in the subsequent seven primary entries 2.1.14.02.00 through 2.1.14.08.00.

13. Secondary entry 2.2.07.05.01 (Episodic infiltration enhances colloid transport) would more appropriately be entered below primary entry 2.2.07.06.00 because it describes radioactive release rather than simply episodic flow.

14. An example of FEPs that are too broadly defined, reducing transparency of how they might be implemented and dealt with in a performance assessment, is 2.2.08.09.00 (Sorption in the unsaturated and saturated zones). This entry incorporates sorption in the quite different unsaturated zone and saturated zone hydrologic regimes and includes sorption on soil, which could apply to the receptor location. Sorption at different locations (i.e., saturated zone, unsaturated zone, and receptor) should be described in separate FEPs. Another example is 2.1.11.08.00 (Thermal effects) chemical and microbiological changes in the waste and EBS. The description for this entry states, in broad terms, “Temperature changes may affect chemical and microbial processes in the waste and EBS,” and cites entries that do not entirely cover this description (see table 3-2).

15. Category entry 2.3.08.00.00 (Vegetation) describes the “possible effects of vegetation on the long-term performance of the disposal system,” and refers the reader to another entry (3.3.02.01.00) concerned with plant uptake. The description of this FEP and the cross-reference seem to imply that the only effect of vegetation on performance relates to plant uptake in the biosphere. However, the Unsaturated and Saturated Flow Under Isothermal Conditions IRSR (Nuclear Regulatory Commission, 1999c) has proposed that the invasion of Bromus sp. will likely increase infiltration in a manner that could influence repository performance.

16. The numbering of FEPs under entry 2.4.03.00.00 is in error. The database jumps from 2.4.03.00.02 to 2.4.03.01.03.

4 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The DOE database of FEPs is intended to provide transparency and traceability for the scenario selection and TSPA model disposition efforts. Review of a preliminary version of the database (Revision 00b) proved it be, in general, a comprehensive delineation of FEPs affecting repository performance. Entries relevant to the ENFE KTI make up over one third of the database, demonstrating the complexity, pervasiveness, and importance of coupled processes. Entries were distributed among ENFE subissues, helping direct ENFE efforts in assessing DOE TSPA model development and resolving outstanding technical issues. Critical review of the ENFE-relevant entries resulted in a list of 58 excluded primary and secondary entries for which the justification was unsatisfactory. This list will aid NRC/CNWRA staffs in identifying possible deficiencies in the DOE scenario development process. In fact, many of these deficiencies may be addressed in later versions of the database. More specific conclusions and recommendations are discussed in this section.

4.1 FINDINGS AND RECOMMENDATIONS TO U.S. DEPARTMENT OF ENERGY

NRC has described its review method process, including acceptance criteria, for scenario analysis in a total system performance assessment (Nuclear Regulatory Commission, 1998). The findings and recommendations to DOE presented in the following sections are organized according to the NRC scenario analysis review method process and acceptance criteria on transparency and traceability (TSPAI IRSR Revision 2, in preparation). The NRC review method (Nuclear Regulatory Commission, 1998) contains sequential steps for review in five areas: identification of an initial set of processes and events; classification of processes and events; screening of processes and events; formation of scenarios; and screening of scenario classes. The DOE FEP database (Revision 00b) addresses the first three steps in the review process, thus only findings on the first three steps of scenario analysis are presented. DOE's approach to scenario analysis (Swift et al., 1999) also contains five steps. However, the steps that DOE will use in their scenario analysis are not identical to those suggested by NRC in the TSPAI IRSR (Nuclear Regulatory Commission, 1998). For instance, the first step in DOE's approach combines identification of an initial set of processes and events with the classification of processes and events.

4.1.1 Identification of an Initial Set of Processes and Events

The relevant acceptance criterion from section 4.4.1 of the TSPAI IRSR Revision 1 (Nuclear Regulatory Commission, 1998) is

- DOE has identified a comprehensive list of processes and events that: (i) are present or might occur in the Yucca Mountain region, and (ii) includes those processes and events that have the potential to influence repository performance.

The "missing" FEPs of table 3-3, which are based on discussions in the ENFE IRSR Revision 2 (Nuclear Regulatory Commission 1999a), demonstrate that DOE's database (Revision 00b) is not comprehensive. Two of the missing FEPs address the natural setting and the other two reflect the repository design. The latter two may have been omitted from the FEP database because of the evolving repository design. All of these missing FEPs are relevant only to the proposed Yucca Mountain repository. This finding indicates the process to develop site-specific FEPs may be inadequate.

The process by which the database was constructed has been documented (Swift et al., 1999) and additional DOE documentation is forthcoming (Sandia National Laboratories, 1999). DOE has not identified

a specific technique as a preferred method of FEP identification (Swift et al., 1999). DOE has relied on a variety of methods, including expert judgment, informal elicitation, event tree analysis, stakeholder review, and regulatory stipulation to develop the Revision 00b FEP database (Swift et al., 1999). It has been suggested that final demonstration of the comprehensiveness would come through iterative review and comment (Sandia National Laboratories, 1999).

Review by DOE of its synthesis reports on the natural setting (e.g., Bish et al., 1996) and relevant design description documents for potential missing FEPs may help to ensure the comprehensiveness of the database. In addition, DOE should consider consulting the NRC IRSRs, including the ENFE IRSR (Nuclear Regulatory Commission, 1999a), for discussion of the range of FEPs that NRC considers potentially important to performance. Finally, additional documentation on database construction, as discussed in section 4.1.4 of this report, would also help address this deficiency.

4.1.2 Classification of Processes and Events

The relevant acceptance criteria from section 4.4.2 of the TSPAI IRSR Revision 1 (Nuclear Regulatory Commission, 1998) are

- DOE has provided adequate documentation identifying how its initial list of processes and events has been grouped into categories.

- Categorization of processes and events is compatible with the use of categories during the screening of processes and events.

DOE has not provided adequate documentation on the categorization of secondary entries into individual primary FEP entries. While Swift et al. (1999) describe the general approach used to categorize secondary entries into primary entries, this review found many occurrences of poor correspondence between primary and secondary entries. This observation indicates that categorization of secondary entries into primary entries may not have followed DOE guidance for categorization (Swift et al., 1999). The only site-specific categorization example cited in Swift et al., (1999), described a categorization based on regulatory requirements. Most of the criticisms noted in section 3.4 concern inappropriate categorization of technical FEPs. This finding also indicates additional documentation will be needed to identify how individual primary entries incorporate the secondary entries. This documentation should be incorporated in the FEP AMRs and in subsequent revisions of the database (see section 4.1.4).

DOE intends to screen FEPs at the primary level, requiring that the primary entries stand independent of the secondary entries. Thus, the poor correspondence between primary and secondary entries noted previously also indicates that the current categorization scheme may not be sufficient to ensure that categorization of processes and events is compatible with the use of categories during the screening of processes and events. Without additional documentation on the categorization of secondary entries into individual primary FEP entries, the current categorization scheme is not acceptable. However, DOE has indicated that additional documentation on the screening will be provided in FEP AMRs and with the FEP database (Revision 00). Thus, NRC will need to re-assess DOE's categorization of FEPs after the FEP AMRs and the FEP database (Revision 00) have been released.

4.1.3 Screening of Processes and Events

The relevant acceptance criteria from section 4.4.3 of the TSPAI IRSR Revision 1 (Nuclear Regulatory Commission, 1998) are

- Categories of processes and events that are not credible for the Yucca Mountain repository because of waste characteristics, repository design, or site characteristics are identified and sufficient justification is provided for DOE' s conclusions.

- The probability assigned to each category of processes and events is consistent with site information, well documented, and appropriately considers uncertainty.

- Processes and events may be screened from the performance assessment on the basis of their probability of occurrence, provided DOE has demonstrated that they have a probability of less than one chance in 10,000 of occurring over 10,000 yr.

- Categories of processes and events may be omitted from the performance assessment on the basis that their omission would not significantly change the calculated expected annual dose, provided DOE has demonstrated that excluded categories of processes and events would not significantly change the calculated expected annual dose.

Preliminary screening arguments have been presented in the DOE FEP database (Revision 00b). Table 3-2 documents ENFE-related database entries for which this review found an inadequate technical basis for screening FEPs. Due to the preliminary nature of the database, it is expected that screening arguments will have a stronger technical basis in the final version of the database and in the FEP AMRs. Table 3-2 provides DOE with a list of those technical issues that may require special attention in order to be resolved. DOE should consider reviewing the staff comments in table 3-2 to determine whether the deficiencies in the technical basis for exclusion noted by the staff are generic to the FEP database screening effort. If the findings are generic, then DOE should adjust its current screening analysis process to address the generic concern.

4.1.4 Transparency and Traceability

Revision 2 of the TSPAI IRSR (in preparation) will include new acceptance criteria regarding transparency and traceability. These are expected to focus on the need for full description by DOE of

- The FEPs screening process

- Relationships between relevant FEPs

Addressing transparency will improve NRC's ability to evaluate compliance with scenario analysis acceptance criteria discussed in sections 4.4.1, 4.4.2, and 4.4.3 of the TSPAI IRSR (Nuclear Regulatory Commission, 1998). This review revealed a number of obstacles to the desired level of transparency. Many were related to the structure of the database and the way in which FEPs were incorporated into and distributed among primary and secondary entries (i.e., categorization). Common themes in criticisms of the database were inappropriate FEP naming, poor correspondence between primary and secondary entries, inconsistencies in the specificity of coverage in primary entries, and screening inconsistencies. These concerns are important because DOE intends to screen FEPs at the primary level, requiring that the primary entries stand independent of the secondary entries. An overarching difficulty with using the database is the inadequate treatment and representation of FEP coupling—a concern particularly relevant for the ENFE KTI. DOE should review the grouping of FEPs in the database and should explore approaches to make more transparent both the interactions among FEPs and the screening process. This report does not necessarily recommend that all critiques of section 3.4 be directly addressed, but rather that they be considered in evaluating how to make the process more transparent.

The DOE database and the information presented at the Appendix 7 meeting on September 8, 1999, did not make clear how DOE intends to document assurance (i) that the database is comprehensive and (ii) that categorization and grouping of secondary entries will be transparent. Subsequently, NRC was informed about existing documentation (Swift et al., 1999) and additional, forthcoming, DOE documentation (Sandia National Laboratories, 1999) that address these subjects. These documents may not be sufficient because all of the deficiencies identified above were generated using the processes outlined in those documents. In order to meet the transparency and traceability criteria of Revision 2 of the TSPAI IRSR (in preparation), DOE should provide full documentation of the process of constructing the database. For instance, DOE should consider explicitly listing the documents that were used to generate the FEP database. Any additional references relied on to evaluate the comprehensiveness of the database subsequent to Revision 00b should be listed. In both the FEP database and in the FEP AMRs, the categorization of secondary FEPs into each of primary FEPs should be described. This information may help resolve many of the comments of section 3.4 regarding categorization and secondary FEP grouping. Finally, DOE should indicate whether the FEP database will be updated with each revision of the AMRs and when those revisions may occur.

4.2 GUIDANCE TO NUCLEAR REGULATORY COMMISSION AND THE CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

Analysis of the DOE FEP database comprises a key component of NRC issue resolution activities and future reviews of DOE's scenario development process. Revision 2 of the TSPAI IRSR (in preparation) will document parsing of FEPs among ISIs (section 2.3). Individual FEPs will than be assigned to KTI teams for reviews to be documented in IRSRs. Final integration of FEPs assessments is anticipated to be documented in Revision 3 of the TSPAI IRSR. This audit is therefore relevant to future NRC/CNWRA activities.

4.2.1 Evolution of the Near-Field Environment Key Technical Issue Activities

Outcomes of this analysis are improved direction and guidance for ENFE KTI activities and a tool for future reviews. Distributions of the DOE FEPs among the ENFE subissues (table 3-1) can be used to test the completeness of portions of the DOE site recommendation report and a potential DOE license application. As DOE refines and improves the FEP database, the sets compiled in this report can be used as a baseline to identify the changes. As discussed in section 1.2, the list of FEPs, their categorization by subissue (table 3-1), identification of "unresolved" screenings (table 3-2), and FEPs missing from the DOE database (table 3-3) should be used in preparation of ENFE FY2000 milestones that contribute to Revision 3 of the ENFE IRSR. In particular, review of relevant DOE FEP AMRs (listed in section 1.1) will be facilitated by reference to this report. Although DOE intends to roll up all secondary entries into primary FEPs for the purposes of screening, the results of this audit suggest that process is incomplete and secondary entries still need to be consulted. The comments from section 3.4 will guide identification of primary entries that may be affected by insufficiency of incorporation of secondary entries. Table 3-2 will provide guidance on those FEPs DOE intends to screen that may require special attention in establishing the status of subissue resolution.

Four FEPs potentially relevant to ENFE subissues were confirmed (table 3-3) absent from the DOE database: (i) dehydration of zeolites below the repository leading to large-scale volume changes affecting flow and/or drift stability, (ii) mineralogic dehydration reactions releasing water affecting hydrologic conditions, (iii) condensation of water on the underside of the drip shield affecting waste package hydrologic and chemical environment, and (iv) interaction with and degradation of drip shield affecting chemistry of the water contacting the waste package. (This list should not be considered final and may be augmented by further study by the ENFE team.) Staff working on each subissue should review the list of FEPs for their subissue to ensure that

DOE's FEP list is comprehensive. Staff should document the technical basis, including primary references, for each FEP that is missing from the DOE database.

4.2.2 Total System Performance Assessment And Integration Key Technical Issue, Yucca Mountain Review Plan, and Other Key Technical Issues

This audit has relevance to the acceptance criteria and review methods for scenario development outlined in the TSPAI IRSR (Nuclear Regulatory Commission, 1998) and to be incorporated into the Yucca Mountain Review Plan (see section 1.2). The findings discussed in section 4.1 demonstrate potential deficiencies in DOE's approach that could hinder resolution of the TSPAI subissues in the areas of transparency, traceability, and scenario analysis. Early focus on these areas may facilitate issue resolution.

The methods used and results of this audit have relevance to the applicability of review methods in the TSPAI IRSR Revision 2 (in preparation). With respect to the scenario development subissue, a review method is described for the acceptance criterion on comprehensiveness (section 4.2.1 of Revision 1; Nuclear Regulatory Commission, 1998). The approach to identification of ENFE-relevant entries and analysis of excluded entries described in sections 2.1 and 2.2 of this report should be evaluated for possible modification of the review methods. In particular, keyword searches informed by IRSR technical discussions may prove beneficial at identifying FEPs that (i) may not be categorized as suggested by the overall database structure or (ii) may be better described in secondary entries than in primary entries.

Categorization of FEPs is addressed in section 4.2.2, Revision 1, TSPAI IRSR (Nuclear Regulatory Commission, 1998). The findings of this audit suggest that the methods of sections 2.1 and 2.2 of this audit may also prove useful in assessing categorization. Inconsistencies in grouping of secondary entries and the level of detail apparent in primary entries may necessitate keyword searches to ensure that related FEPs are identified. In addition, the finding that roll up of secondary entries into primary entries is incomplete suggests that inspection of primary entries alone may be insufficient.

If other KTIs identify FEPs screening as integral to issue resolution, this report may serve as a guide on how to conduct a similar audit. Suggested aspects of such a review include

- Familiarization with overall database structure that will inform and supplement keyword searches
- Familiarization with critiques on database organization (section 3.4) that will help ensure completeness of review
- Adequate attention to secondary entries that may contain information absent in primary entries.

5 REFERENCES

Bish, D.L., et al. *Summary and Synthesis Report on Mineralogy and Petrology Studies for the Yucca Mountain Site Characterization Project*. WBS element 1.2.3.2.1.1 and 1.2.3.2.1.2. Studies 8.3.1.3.2.1, 8.3.1.3.2.2, and 8.3.1.3.3.2. Los Alamos New Mexico. Los Alamos National Laboratory. 1996.

Civilian Radioactive Waste Management System, Management and Operating Contractor. *Revise the Project Baseline to Add and Delete Work Scope, Budget, and Milestones for Process Models and Data Qualification (PMDQ) and Enhanced Design Alternative (EDA) II*. M&O-99-008. Las Vegas, NV: Civilian Radioactive Waste Management System, Management and Operating Contractor.

Cragnolino, G.A., D.S. Dunn, C.S. Brossia, V. Jain, and K.S. Chan. *Assessment of Performance Issues Related to Alternate Engineered Barrier System Materials and Design Options.* CNWRA 99-003. San Antonio, TX: Center for Nuclear Waste Regulatory Analyses. 1999.

Kozak, M., and W. Zhou. The use of interaction matrices to improve assessment of transparency. *Alternative Approaches to Assessing the Performance and Suitability of Yucca Mountain for Spent Fuel Disposal.* EPRI Report TR–108732. Palo Alto, CA: Electric Power Research Institute: 16-1–16-13. 1998.

Nuclear Energy Agency. *Safety Assessment of Radioactive Waste Repositories: An International Database of Features, Events and Processes. Draft 24/6/97*. SAM-J012-R1, Version 3. Paris: Nuclear Energy Agency, Organization for Economic Cooperation and Development. 1997.

Nuclear Regulatory Commission. *Issue Resolution Status Report. Key Technical Issue: Total System Performance Assessment and Integration. Revision 1*. Washington, DC: Nuclear Regulatory Commission. 1998.

Nuclear Regulatory Commission. *Issue Resolution Status Report. Key Technical Issue: Evolution of the Near-field Environment. Revision 2.* Letter and enclosure dated July 14, 1999, to S.J. Brocoum, U.S. Department of Energy. Washington, DC: Nuclear Regulatory Commission. 1999a.

Nuclear Regulatory Commission. *Issue Resolution Status Report. Key Technical Issue: Container Life and Source Term. Revision 2.* Washington, DC: Nuclear Regulatory Commission. 1999b.

Nuclear Regulatory Commission. *Issue Resolution Status Report. Key Technical Issue: Unsaturated and Saturated Flow Under Isothermal Conditions. Revision 2.* Washington, DC: Nuclear Regulatory Commission. 1999c.

Sandia National Laboratories. E-mail note dated December 1, 1999, concerning telephone conversation between Peter Swift and Bret Leslie. Sent to Bret Leslie (NRC). Washington, DC: Nuclear Regulatory Commission. 1999.

Swedish Nuclear Power Inspectorate. *SITE-94, Deep Repository Performance Assessment Project.* SKI Report 96:36. Stockholm: Swedish Nuclear Power Inspectorate. 1996.

Swift, P., G. Barr, R. Barnard, R. Rechard, A. Schenker, G. Freeze, and P. Burck. *Feature, Event, and Process Screening and Scenario Development for the Yucca Mountain Total System Performance Assessment*. SAND98-2831C. Albuquerque, NM: Sandia National Laboratories. 1999.

U.S. Department of Energy. *Disposal Criticality Analysis Methodology Topical Report.* YMP/TR-004Q. Revision 0. Washington, DC: U.S. Department of Energy. 1998a.

U.S. Department of Energy. Chapter 6. Waste form degradation, radionuclide mobilization, and transport through the engineered barrier system. *Total System Performance Assessment-Viability Assessment (TSPA-VA) Analyses Technical Basis Document*. B00000000-01717-4301-00006 Revision 01. Washington, DC: U.S. Department of Energy. 1998b.

U.S. Department of Energy. *Yucca Mountain Features, Events, and Processes Database. Revision 00b*. Washington, DC: Department of Energy. Preliminary Version, September 1999a.

U.S. Department of Energy. *AMR schedule.* E-mail note dated August 31, 1999, from April Gil to Chad Glenn. Washington, DC: Nuclear Regulatory Commission. 1999b.

Weldy, J.R., G.W. Wittmeyer, and D.R. Turner. *External Peer Review of the Total-System Performance Assessment Version 3.2 Code*. CNWRA 2000-01. San Antonio, TX: Center for Nuclear Waste Regulatory Analyses. 1999.

Appendix 1. Table of the number of U.S. Department of Energy features, events, and processes database (Revision 00b) entries resulting from evolution of the near-field environment filtering. Totals are redundant (i.e., they include entries that resulted from more than one filter). The number of unresolved entries is preliminary and does not reflect later refinement of that list (e.g., removal of secondary entries covered by included primaries). Boolean search operators are capitalized.

Filter Term(s)	Number of Hits	Excluded	Evolution of the Near-Field Environment-Relevant Excluded	Unresolved (Preliminary)
actinide	10	2	1	1
anion	2	1	1	0
backfill	103	56	49	21
calcite	6	3	0	0
cement	111	58	31	8
cladding AND corrosion	26	13	12	9
cladding AND crack	16	6	6	4
clay	61	30	23	8
colloid	84	28	18	10
colloid AND chemi	22	7	4	4
concrete AND water	14	7	5	5
coprecipitat	5	3	3	2
corrosion AND chemi	39	17	16	11
corrosion AND rate	41	21	19	13
corrosion AND release	11	4	4	3
corrosion AND transport	26	15	11	10
corrosion AND water	36	16	11	7
critical AND heat	7	3	3	3
critical AND thermal	3	3	2	2
criticality	59	24	17	17
dissol AND fracture	18	7	5	2
drift AND flow	46	11	8	3
filtration AND NOT infil	14	7	3	2

Appendix 1. Table of the number of U.S. Department of Energy features, events, and processes database (Revision 00b) entries resulting from evolution of the near-field environment filtering. Totals are redundant (i.e., they include entries that resulted from more than one filter). The number of unresolved entries is preliminary and does not reflect later refinement of that list (e.g., removal of secondary entries covered by included primaries). Boolean search operators are capitalized. (cont'd)

Filter Term(s)	Number of Hits	Excluded	Evolution of the Near-Field Environment-Relevant Excluded	Unresolved (Preliminary)
fissile	30	9	4	4
fissile AND reduc	6	3	1	1
fission product	6	1	1	1
flux	37	23	4	4
fracture AND mineral	12	4	2	1
gas	141	109	48	26
glass AND alter	19	9	8	4
glass AND corro	10	6	6	4
glass AND dissol	15	10	10	6
heat	159	68	38	19
hydroxide	7	1	1	1
hyperalk	17	4	3	2
illit OR smectit OR kaolinit	5	5	5	0
invert	16	4	3	3
ionic	7	2	2	1
iron[space]	17	9	8	4
liner	27	9	9	7
matrix diffusion	18	2	1	0
microb	59	26	21	10
natural colloid	2	0	0	0
neutron absorber	9	3	3	3
open AND fracture	17	5	4	2
organic AND complex	12	4	4	0
organic AND ligand	2	1	1	0

Appendix 1. Table of the number of U.S. Department of Energy features, events, and processes database (Revision 00b) entries resulting from evolution of the near-field environment filtering. Totals are redundant (i.e., they include entries that resulted from more than one filter). The number of unresolved entries is preliminary and does not reflect later refinement of that list (e.g., removal of secondary entries covered by included primaries). Boolean search operators are capitalized. (cont'd)

Filter Term(s)	Number of Hits	Excluded	Evolution of the Near-Field Environment-Relevant Excluded	Unresolved (Preliminary)
oxide	31	18	9	5
oxidizing OR oxidation	29	10	6	3
permeability AND dissol	11	7	5	4
permeability AND precipitat	9	4	3	3
pH. OR pH[space]	27	16	12	10
plutonium	5	1	1	0
porosity AND dissol	3	1	1	0
porosity AND precipitat	3	0	0	0
precipitat	114	38	14	10
precipitat AND fracture	12	4	3	2
pseudo	14	0	0	0
radioly	33	12	12	5
reducing OR reduction	48	27	11	6
release AND radionuclide	62	32	16	8
secondary AND mineral	6	3	3	1
secondary AND phase	6	0	0	0
secondary AND solid	6	3	3	3
seep	22	14	8	5
shield	30	14	7	6
silica	28	11	9	4
solubility AND corrosion	2	1	0	0
solubility AND radionuclide	22	10	5	1
sorpti AND dissol	17	5	3	2
sorpti AND precipitat	13	3	3	3

Appendix 1. Table of the number of U.S. Department of Energy features, events, and processes database (Revision 00b) entries resulting from evolution of the near-field environment filtering. Totals are redundant (i.e., they include entries that resulted from more than one filter). The number of unresolved entries is preliminary and does not reflect later refinement of that list (e.g., removal of secondary entries covered by included primaries). Boolean search operators are capitalized. (cont'd)

Filter Term(s)	Number of Hits	Excluded	Evolution of the Near-Field Environment-Relevant Excluded	Unresolved (Preliminary)
sorption AND alteration	7	1	1	0
sorption AND corrosion	9	4	4	3
spent fuel	27	10	6	1
temperature	185	90	54	29
thermal	210	71	46	27
thermo	70	22	12	4
unsaturated zone AND flow	11	1	0	0
UO_2	11	2	1	0
uranium	24	6	3	2
ventilation	13	5	4	1
vitrophyre	12	4	2	1
waste AND oxid	15	6	4	2
waste form AND pH	18	8	6	4
water AND chemi	146	68	34	23
water chemistry	66	31	15	9
zeolit	34	15	12	7