SRR-CWDA-2012-00011
Revision 0

Features, Events, and Processes for Liquid Waste Performance Assessments

February 14, 2012

Prepared by: Savannah River Remediation LLC
Closure and Waste Disposal Authority
Aiken, SC 29808

Prepared for U.S. Department of Energy Under Contract No. DE-AC09-09SR22505

APPROVALS

Author/FEPs Team Lead:

______________________________ 2/13/2012
Steve Hommel Date
C&WDA Closure Assessments
Navarro Research and Engineering, Inc.

FEPs Screening Team Member:

______________________________ 02/14/2012
Gerald Eide Date
Nuclear Safety Engineering
Savannah River Remediation

FEPs Screening Team Member:

______________________________ FOR 2/13/2012
Anthony Knepp — APPROVED VIA EMAIL Date
Environmental Consultant

FEPs Screening Team Member:

______________________________ 2/14/2012
Mark Layton Date
C&WDA Closure Assessments
Savannah River Remediation

FEPs Screening Team Member:

______________________________ 2/14/12
Mark Phifer Date
Senior Fellow Engineer
Savannah River National Laboratory

APPROVALS (Continued)

FEPs Screening Team Member:

Maria Rios-Armstrong
Engineering Technology Integration
Savannah River Remediation

2/14/2012
Date

FEPs Screening Team Member:

James Rush
Waste Removal and Tank Closures
Savannah River Remediation

2/13/2012
Date

FEPs Screening Team Member:

Richard Sheppard
C&WDA Closure Assessments
Savannah River Remediation

2/13/2012
Date

Technical Review:

Leslie E. Safely
C&WDA Closure Assessments
Portage Inc.

2/14/2012
Date

Management Review:

Kent Rosenberger
C&WDA Closure Assessments
Savannah River Remediation

2/14/2012
Date

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS/ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
C&WDA	Closure and Waste Disposal Authority
CA	Composite Analysis
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CHAP	Consolidated Hazard Analysis Process
DGR	Deep Geologic Repository
DOE	U.S. Department of Energy
DWPF	Defense Waste Processing Facility
E_h	Oxidation Potential
FEPs	Features, Events, and Processes
FTF	F-Area Tank Farm
HDPE	High Density Polyethylene
HLW	High Level Waste
HRR	Highly Radioactive Radionuclide
HTF	H-Area Tank Farm
IHI	Inadvertent Human Intruder
ISAM	Improvement of Safety Assessment Methodologies for Near Surface Disposal Facilities
K_d	Distribution Coefficient
LLW	Low Level Waste
LW	Liquid Waste
MEP	Maximum Extent Practical
MOP	Member of the Public
NDAA	National Defense Authorization Act
NRC	U.S. Nuclear Regulatory Commission
NWMO	[Canadian] Nuclear Waste Management Organization
OPG	Ontario Power Generation
PA	Performance Assessment
pH	The measure of the acidity or basicity of an aqueous solution
QA	Quality Assurance
RCRA	Resource Conservation and Recovery Act
SDF	Saltstone Disposal Facility
SKI	Swedish Nuclear Power Inspectorate [Statens Kärnkraftinspektion]
SRNL	Savannah River National Laboratory
SRR	Savannah River Remediation
SRS	Savannah River Site
TSPA	Total System Performance Assessment
UFD	Used Fuel Disposal
YMP	Yucca Mountain Project

1.0 INTRODUCTION

Performance Assessment (PA) models simulate the release and transport of radionuclides and chemical contaminants from disposal sites and estimate exposure and consequence to potential receptors. At the Savannah River Site (SRS), PAs have been developed to support the closure of liquid waste (LW) facilities and to provide the technical basis for demonstrating compliance with performance objectives as defined in Department of Energy (DOE) Order 435.1-1 and 10 Code of Federal Regulations (CFR) 61.

These PAs inform decisions related to facility designs and the methods of disposal to ensure compliance with the performance objectives, as related to protection of public health and safety. PAs provide understanding of the facilities' capabilities to limit contaminant exposure to members of the public (MOPs) and to hypothetical inadvertent human intruders (IHIs).

Due to the complex nature of these models, a structured methodology is necessary to ensure that relevant components are adequately addressed during model development. Therefore, PA models must be developed within defined boundaries and with appropriate consideration of the relevant features, events, and processes (FEPs), as derived from a complete set of FEPs.

1.1 Purpose and Scope

The purpose of this report is to document: (1) the methods used in the development of a comprehensive (or "initial") FEPs list identifying all of the FEPs that could potentially affect the performance of the SRS LW closure facilities; and (2) the criteria used to screen FEPs for inclusion or exclusion from PAs to develop a screened (or "final") FEPs list.

For the purpose of this report, FEPs are defined as follows [SAND2010-3348 P]:

- A **feature** is an object, structure, or condition that has a potential to affect disposal system performance;
- An **event** is a natural or human-caused phenomenon that has a potential to affect disposal system performance and that occurs during an interval that is short relative to the period of performance; and
- A **process** is a natural or human-caused phenomenon that has a potential to affect disposal system performance and that operates during all or a significant part of the period of performance.

The intended uses for this report are as follows:

- Promote transparency, traceability, and reproducibility of the FEPs analysis process for SRS LW PAs;
- Provide a description of the process followed in the FEPs analysis (i.e., FEPs identification and screening); and
- Identify a final list of FEPs that are potentially relevant to SRS LW disposal.

The final list of FEPs generated by this report will be used in future documentation to evaluate existing LW PAs and/or for the development of future PAs.

Section 2 of this report discusses the FEPs methodology, as it was applied for this analysis. Sections 3 and 4 provide details regarding the development of the initial FEPs list and FEPs

screening, respectively. Finally, Section 5 summarizes the qualifications of the members of the FEPs Screening Team.

This FEPs report is considered a living document. As additional information becomes available (such as from new scientific or engineering studies), this report shall be reviewed to verify that it accurately represents the best available information with respect to FEPs for the LW PAs.

1.2 Quality Assurance

Development of this report and supporting analyses are subject to the quality assurance (QA) program and requirements as defined in Manual 1Q – *Quality Assurance Manual*. Consistent with this QA program, the information provided herein shall undergo technical and management review prior to approval and release.

2.0 FEPs METHODOLOGY

FEPs analyses typically consist of three steps [SAND2010-3348 P]:

1. **FEPs Identification** – Identify and define a list of all potentially relevant FEPs, no matter how improbable or inconsequential.
2. **FEPs Screening** – Evaluate the potentially relevant FEPs using specific criteria to determine which FEPs should be included (screened in) or excluded (screened out) from PA modeling or analyses.
3. **PA Model Implementation** – Develop PA models (Base Case and alternate scenarios or sensitivity cases) and analyses that incorporate consideration for the included (screened in) FEPs.

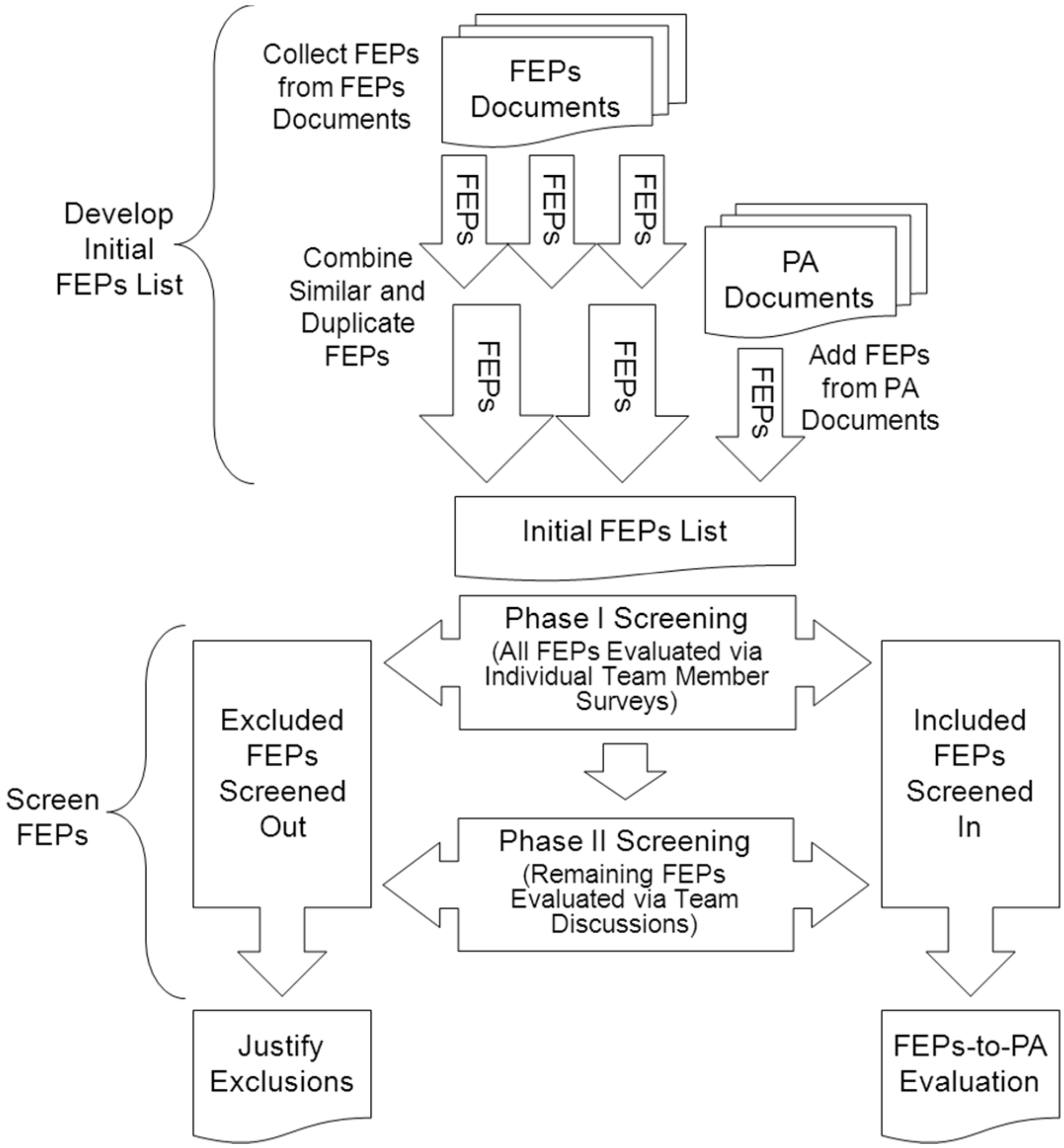
Typical FEPs analyses call for the analyses to be performed prior to the development of PA models and modeling scenarios. However, the U.S. Department of Energy (DOE) has developed three LW PAs prior to any *formal* FEPs analyses: the F-Area Tank Farm (FTF) PA, the H-Area Tank Farm (HTF) PA, and the Saltstone Disposal Facility (SDF) PA. [SRR-CWDA-2009-00017, SRR-CWDA-2010-00128, and SRS-REG-2007-00002] In other words, Step 3 (PA Model Implementation) has already been completed.

This report documents the first two steps of an *ex post facto* FEPs analysis: identifying and screening FEPs (Steps 1 and 2). Future documentation shall complete the FEPs process by evaluating the LW FEPs against PA-related documentation to ensure that these PAs appropriately considered the LW FEPs.

Note that screening FEPs "in" does not necessarily constitute a requirement for the FEPs to be explicitly modeled, rather it indicates that the FEPs warrant consideration. During PA development and/or analyses, these FEPs should be researched and handled on a case-by-case basis as appropriate for the specific waste closure facility and conditions.

Figure 2.0-1 provides an overview of the FEPs methodology as applied in this report.

Figure 2.0-1: FEPs Methodology



Note: The FEPs-to-PA Evaluation represents future work; it is not documented within this report.

3.0 DEVELOPMENT OF THE INITIAL FEPs LIST

During the first step in the development of the initial FEPs list, FEPs lists were collected from several domestic and international sources. These sources were:

- Improvement of Safety Assessment Methodologies for Near Surface Disposal Facilities (ISAM) FEPs;
- Used Fuel Disposition (UFD) Campaign Low Level Waste (LLW) FEPs;
- Yucca Mountain Project (YMP) FEPs;
- Deep Geologic Repository (DGR) FEPs; and
- Swedish Nuclear Power Inspectorate (Statens Kärnkraftinspektion [SKI]) FEPs.

Table 3.0-1 describes each of these sources. The total number of FEPs collected, including any duplicates, was 1,383 FEPs.

The second step in the development of the initial FEPs list was the removal of duplicate FEPs and the combining of similar FEPs. To accomplish this, members of the Closure & Waste Disposal Authority (C&WDA) Closure Assessments team tabulated and organized the FEPs from these five lists based on groups (shown in Table 3.0-2), then dispositioned as either unique or duplicate. The resulting draft FEPs list included 245 FEPs.

Table 3.0-1: FEPs Lists Reviewed for the Development of the Initial FEPs List

FEPs List - Source Document	Total FEPs	Discussion
ISAM FEPs List – *Safety Assessment Methodologies for Near Surface Disposal Facilities, Results of a Co-ordinated Research Project*, Volume 1 [ISBN 92-0-104004-0]	141	The ISAM FEPs list consists "of high level FEPs that could influence the behaviour [*sic*] of a near surface disposal system" and "is considered to be a useful tool when generating and comparing FEP lists for specific safety cases." [p. 6, ISBN 92-0-104004-0]
UFD FEPs List – *Features, Events and Processes for the Disposal of Low Level Radioactive Waste FY 2011 Status Report*, [FCRD-USED-2011-000297]	449	The UFD Campaign LLW FEPs list supports "research and development for the storage, transportation and disposal of used nuclear fuel and wastes generated by existing and future nuclear fuel cycles." [FCRD-USED-2011-000297] **Note:** The author of this report provided the FEPs list via an Access database. The list in the database varies from the list provided in Appendix A.1 of the referenced document. The database includes a greater number of individual FEPs; therefore, the database was used in lieu of the FEPs list in this document.
YMP FEPs List – *Features, Events, and Processes for the Total System Performance Assessment: Analyses* [ANL-WIS-MD-000027 REV 00]	374	This list of FEPs was developed in support of the YMP's Total System Performance Assessment (TSPA), a model to support DOE's proposed high level waste repository.
DGR FEPs List – *Deep Geologic Repository for OPG's Low & Intermediate Level Waste, Postclosure Safety Assessment (V1): Features, Events and Processes* [NWMO DGR-TR-2009-05]	299	This report was prepared by the Nuclear Waste Management Organization (NWMO) in Canada on behalf of Ontario Power Generation (OPG) for a DGR. This FEPs list was selected because it includes detailed FEPs descriptions.
SKI FEPs List – *Encyclopaedia of Features, Events and Processes (FEPs) for the Swedish SFR and Spent Fuel Repositories* [SKI Report 02:35]	120	This report was deliberately prepared as a FEPs encyclopedia. As such, the document includes a number of general FEPs that have broad implications.

Table 3.0-2: FEPs Groups

Group	Sub-Group
1.0 Assessment Basis	1.1 General
	1.2 Regulations and Controls
	1.3 Models and Calculations
	1.4 Other Assessment Factors
2.0 External Factors	2.1 Human Characteristics
	2.2 Land and Water Management
	2.3 Future Human Activity
	2.4 Biological Factors
	2.5 Geologic Features
	2.6 Geologic Processes
	2.7 Climate
	2.8 Water Cycle
3.0 Closure System	3.1 General Closure System
	3.2 Pre-Closure Activities
	3.3 Closure System Components
	3.4 Closure System Hydrology
	3.5 Chemical Processes
	3.6 Thermal Processes
	3.7 Material Degradation
	3.8 Other Closure System Factors
4.0 Contaminant Factors	4.1 Contaminant Description
	4.2 Contaminant Properties
	4.3 Concentrations
	4.4 Exposure Factors
	4.5 Other Contaminant Factors
5.0 Flow and Transport	5.1 Flow Factors
	5.2 Hydraulic Effects on Flow
	5.3 Release and Transport
6.0 Disruptive Events	6.1 Intrusions
	6.2 Seismic Events
	6.3 Igneous Events
	6.4 Other Events

Finally, the draft FEPs list was reviewed against the existing PAs to identify and define any potential FEPs that may be missing. This activity resulted in 17 FEPs being added to the initial FEPs list for a total of 262 initial FEPs.

Table 3.0-3 summarizes the development of the initial FEPs list, as described above.

Table 3.0-3: Summary of the Development of the Initial FEP List

Step	Activity	Result
1	Collected FEPs from FEP Documents (ISAM, UFD, YMP, DGR, and SKI)	1,383 FEPs
2	Combined duplicate/similar FEPs	1,383 − 1,138 = 245 FEPs
3	Added additional FEPs from PAs (FTF, HTF, and SDF)	245 + 17 = 262 FEPs
	Initial FEP List	**262 FEPs**

The complete initial FEPs list is provided in Table 3.0-4. This list was used to perform the screenings for SRS LW FEPs, as described in Section 4. Additional details about this data are available in the associated Excel file: "SRS_LW_FEPs_Rev0.xlsx".

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs

FEP ID	FEP Name	FEP Description
1.1.01	Assessment Context Factors	Factors related to determining the scope or boundary conditions for the performance assessment of a waste closure facility. These include: a) factors related to the purpose for which the assessment is being performed, b) the regulatory requirements and criteria, c) the assessment philosophy that will be followed, and d) the overall framework within which the assessment will be performed.
1.1.02	Assessment Purpose	Consideration for the purpose of the performance assessment of a waste closure facility.
1.1.03	Assessment Conditions	Factors related to the conditions (or framework) under which the performance assessment of the waste closure facility and closure system will be performed.
1.1.04	Documentation and Presentation of Results	The effective documentation, presentation and communication of the performance assessment using a variety of techniques (such as written material, videos, presentations, CD-ROM, web pages) tailored to the needs of the various stakeholders.
1.1.05	Transparency of Assessment Approach	A transparent assessment approach ensures that all assumptions, constraints, and conditions imposed on the assessment and made within the assessment, are communicated or documented to all stakeholders. Such documentation includes scenario development and handling of expert judgment; model development decisions and justifications; input parameter values; and approaches with respect to the treatment of subjective uncertainties.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
1.1.06	Assessment Timeframe (Phases of Disposal)	Factors related to the timeframe over which the waste closure facility may present human health or environmental hazards and be considered for the performance assessment. Examples of time periods to consider include: from closure to the end of institutional control; institutional control to 10,000 years; beyond 10,000 years; and the timing of the peak impact.
1.1.07	Safety Effects Beyond Periods of Control	Consideration for the effects of waste releases beyond the periods of facility controls. The continued isolation of the contaminants should not depend on actions by future generations to maintain the integrity of the closure system. The assessment should consider impacts on the health of future generations with respect to the relevant levels of impact that are acceptable today.
1.1.08	Spatial Domain of Concern	Factors related to the spatial domain over which the contaminants and the waste closure facility may present significant human health or environmental hazard and that will be considered in the post-closure performance assessment. This includes consideration for the level discretization to apply to the spatial domain.
1.1.09	Assessment Endpoints	Concentration, flux, or health impact (risk/dose) criteria used to quantify the impact of the contaminants released from the waste closure facility. The endpoints may include: a) the concentration in disposed material, b) the contaminant flux from the waste closure facility, c) contaminant concentration in environmental media (e.g., soil, sediment, groundwater, surface water, fauna and flora, and the atmosphere), and d) risks to human health.
1.2.01	Regulatory Compliance	Factors related to the compliance of regulatory requirements, conditions, and criteria associated with all stages of the development, operation, and closure of the facility with respect to influences on the post-closure performance assessment or the permitting and/or licensing of the closure facility. This includes consideration for Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements.
1.2.02	Protection of Human Health and the Environment	Factors related to the regulatory requirements, criteria, and standards for the protection of human health and the environment during the lifetime of the waste closure facility and that would have an influence on the post-closure performance assessment and the assessment endpoints.
1.2.03	Performance Requirements and Criteria	Factors related to performance requirements and criteria to be considered in the development of waste closure facility and the associated performance assessment. Closure systems are designed to satisfy a number of requirements to ensure the long-term safety of the closure facility. Criteria specific to closure system design can be performance driven (derived from site and facility-specific models) or prescriptive (i.e. regulatory criteria that apply to an entire class of facility).
1.2.04	Functional and Technical Requirements and Criteria	Factors related to functional and technical requirements to be considered in the development of a safety case for the waste closure facility. Examples of such factors include: a) minimizing infiltration of water into disposal units, b) ensuring the integrity of disposal unit covers, c) providing the structural stability of system components, d) minimizing contact of waste with standing water, e) providing adequate drainage, minimizing the need for long-term maintenance, and f) providing barriers against intrusion.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
1.2.05	ALARA	Factors related to "As Low As Reasonably Achievable" (ALARA) requirements and goals. This is a requirement to ensure risks are minimized with respect to the radiological detriment to members of the public that may result from the disposal of wastes.
1.2.06	Administrative Control of the Waste Closure Facility	Factors related to failure of administrative control measures and responsibilities for these measures during the pre-operational, operational, and post-closure (institutional control) periods. Measures applicable for the institutional control period can be divided into: active institutional control measures (such as monitoring, surveillance and remedial work) and passive institutional control measures (such as land use controls, site markers, and record keeping).
1.2.07	Waste Acceptance Requirements and Criteria	Factors related to defining waste acceptance requirements and criteria and ensuring that waste(s) accepted for disposal or closure meet specific requirements and criteria, such that the waste(s) is/are consistent with the operational and long-term safety cases for the waste closure facility.
1.3.01	Model and Data Issues	Factors related to modeling of the disposal system. Model and data issues are general (i.e., methodological) issues affecting the modeling process and data usage. Model issues include: a) the approach and assumptions associated with the selection of conceptual models, b) the mathematical implementation of conceptual models, c) spatial and temporal discretization, d) models of coupled processes, and e) boundary and initial conditions. Data issues include the derivation of data values, correlations, and dependence of parameter selection on model scale.
1.3.02	Software Codes	Factors related to software selection and software quality assurance practices for codes important to the performance and safety of the waste closure facility as they apply to modeling, model validation, calibration, and benchmarking.
1.3.03	Model Approaches	Factors related to the modeling approaches applied in the performance assessment. Some examples include: a) simple scoping calculations that can be computed using a hand calculator or spreadsheet, b) worst case (or bounding) calculations that deal with uncertainty, and c) conceptual and mathematical models. This also includes consideration for deterministic modeling versus probabilistic modeling approaches.
1.3.04	Systematic Assessment Approach	Different systematic or structured approaches can be followed to perform performance assessments of waste closure facilities, all aimed at improving the confidence in the assessment results. Factors to be considered in a systematic approach include: a) the necessary level of appropriate documentation, b) rigor and technical justification for decisions and methods used, c) use of multiple lines of reasoning to broaden result sets, d) use of iterations, e) development of system understanding and expertise, and f) demonstration of performance.
1.3.05	Iterative Assessment Approach	Performance Assessments, by their nature, require an iterative approach, aiming at continual improvement of the safety case. This implies that a performance assessment process will have to go through two or more consecutive iterations. The advantage of such an approach is that it allows one to use information from the previous assessment to refine the design of the system and the collection of additional data.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
1.3.06	Realistic Assessment Approach	A realistic, or equitable, approach applies assumptions with respect to physical reality (including what is possible and likely to occur). This approach is typically used when some knowledge of the actual system or conditions are available. The disadvantage of applying realistic assumptions in the assessment is that results might be underestimated. Therefore, it is necessary to document and justify the nature of each assumption in the assessment.
1.3.07	Conservative Assessment Approach	Using a conservative, or cautious, approach applies assumptions that will not result in the end-point(s) being underestimated. In applying this approach, there is a danger that aggregation of conservative assumptions, each of which may be appropriate in its own right, may result in an unrealistic estimate of potential impacts. Therefore, it is necessary to document and justify the nature of each assumption in the assessment.
1.3.08	Reasonable Assurance Assessment Approach	The reasonable assurance approach emphasizes that performance assessments are not exact reflections of reality. As such, the goal of a performance assessment is to determine the conditions for which reasonable assurance of regulatory compliance can be achieved. This approach is a more of a decision tool, rather than a method to predict the actual behavior of a disposal system into the future. The results are a function of the data, design, and assumptions used in the analysis.
1.3.09	Prospective Evaluation Assessment Approach	A prospective evaluation approach emphasizes that the intent of the performance assessment is not to predict actual system behavior but to improve system understanding such that appropriate emphasis may be directed towards specific system components (i.e., those with the greatest potential impact on regulatory compliance).
1.3.10	Uncertainties	Factors related to the identification and treatment of model/future uncertainties in the performance assessment. Such factors include: a) conceptual model uncertainty, b) mathematical model uncertainty, c) computer model uncertainty d) parameter/data uncertainty, and e) subjective uncertainties.
1.3.11	Sensitivity Analyses	Factors related to the performance of sensitivity analyses of the post-closure performance assessment. Sensitivity analyses help to establish a comprehensive and defensible safety case and provide insights into system behavior that may lead to design improvements.
1.3.12	Model Confidence	Factors related to activities that build confidence in the performance assessment modeling. Activities include verification of performance, calibration of performance, and validation of performance.
1.3.13	Alternative Simplified Modeling Approach	Supplement the sophisticated model with a less complex model for explanatory purposes and as a confidence-building tool. A well-designed simplified model may help foster public understanding and acceptance of the waste closure facility. While simplification may cause loss of detail, demonstration of equivalence of simple and complex methods may be possible if it can be shown that the simplifications focus on the critical factors related to system performance and safety.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
1.3.14	Evaluate Multiple Endpoints	The use of multiple lines of reasoning and the calculation of multiple endpoints helps ensure that the varied interests of stakeholders are addressed and understood. Demonstration of the performance of individual system components and their expected time evolution increases confidence in the performance of the whole system. Presentation of a number of safety indicators over a range of timeframes allows stakeholders to focus attention on indicators and timeframes of the greatest interest.
1.3.15	Processing Limitations to Modeling	Factors related to the processing (computing) limitations to running the performance assessment models.
1.4.01	Development of Expertise	Develop expertise and understanding of the performance assessment process and determination of related strategic issues.
1.4.02	Monitoring and Surveillance	Factors related to the monitoring and surveillance that is carried out during operations or following closure of individual disposal units or total the waste closure facility. This includes monitoring and surveillance for operational safety and parameters related to long-term safety and performance. Regulations, confidence building activities, or public pressure may determine the extent and requirement for such a monitoring and surveillance program.
1.4.03	Retrievability	Factors related to any design, emplacement, operational or administrative measures that might be applied or considered in order to enable or ease retrieval of radioactive wastes from the waste closure facility. An interim period might be planned between waste emplacement and final tank farm closure, during which time retrieval is possible.
1.4.04	Regulatory and Peer Reviews	A requirement that the performance assessment should be subject to a rigorous regulatory and peer review processes as part of developing a comprehensive and defensible safety case for a waste closure facility. Reviewers should be satisfied that good engineering practices are used in design, construction, operation, and closure of the facility and that good science has been applied in investigating and researching the site and related FEPS, and in evaluating and interpreting the resulting data and methodologies used.
1.4.05	Confidence Building (External to Modeling)	Activities, other than modeling, to address the concerns of stakeholders. Such as validation and analogue studies, as well as public hearings to maintain an open dialogue.
1.4.06	Target Audience (Stakeholders Involvement)	Factors related to the definition of the target audience and their involvement in the post-closure safety assessment process of the waste closure facility.
2.1.01	Definition of the Exposed Member of the Public	Factors related to the determination of the "Member of the Public" (MOP), the representative and reasonably or conservatively exposed individual for whom doses and results shall be evaluated. Defining the MOP shall consider regulatory stipulations, conservatisms, and group homogeneity (in terms of diet and habits, location).
2.1.02	Human Physiology (Metabolism, Diet, and Fluid Intake)	Factors related to intake human consumption and ingestion. Human diets can vary greatly, both qualitatively and quantitatively. In addition to food and fluid intake, humans may also consume other things such as medicines, drugs, soils, and minerals. Consideration could also be given to vegetarian and other special diets, and to changes in diet due to external factors.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
2.1.03	Human Behavior and Habits (Non-Diet Related)	Factors related to non-diet related behavior and habits of humans to whom exposures from the waste closure facility are calculated. These factors include time spent in various environments, activities, and uses of materials and may be influenced by agricultural practices, technology, and societal factors (e.g., culture, religion, economics). Examples include: a) outdoor activities (e.g., fishing, logging, swimming, etc.), b) keeping of pets that could become contaminated, and c) agricultural practices (e.g., plowing, cultivation, harvesting, etc.).
2.1.04	Human Dwellings	The characteristics of the houses or other structures or shelters in which humans spend time. The dwelling location, materials used in construction, design elements (e.g., for improved energy efficiency and air tightness), dwelling size, heating sources, the likelihood of infiltration of water or gases, and the introduction of other contaminants into the dwelling may all affect human exposure to contaminants.
2.1.05	Demographics and Community	Factors related to demographic features and assumed urban development in the vicinity of the waste closure facility. In addition to population density and location, consideration should be given to the types of communities: hunter-gatherer/nomadic communities; agricultural communities; self-sufficient rural communities; other rural communities; and urban communities. Changes in any of these conditions may influence the performance of the facility.
2.2.01	Natural and Geological Resources and Land Use	Factors related to natural resources and land use, particularly those that might encourage investigation or excavation at or near the waste closure facility. Examples of natural resources include: water, lumber, oil and gas (such as methane), minerals, and geothermal energy. Examples of land use include: reclamation/extension, logging, agricultural activity, urbanization, and waste disposal.
2.2.02	Water Management	Factors related to groundwater and surface water management. Water management is accomplished through a combination of dams, reservoirs, canals, pipelines, and collection and storage facilities. Water management activities could have a major influence on the behavior and transport of contaminants.
2.2.03	Natural/Semi-Natural Land and Water Use	The use of natural or semi-natural tracts of land and water such as forest, bush and lakes. Uses include the gathering of special foodstuffs and resources (e.g., picking wild blueberries and gathering of peat and wood for household heating).
2.2.04	Rural and Agricultural Land and Water Use	The use of land and water for agriculture, fisheries, game ranching and similar practices. Practices include: a) fish hatcheries and fish farming, b) ranching of indigenous and imported animals, c) draining of wetlands for farming use, d) gardening, e) irrigation, f) plowing, g) other farming practices such as greenhouses or hydroponics, fertilization, and the use of herbicides, pesticides, fungicides and related products, h) recycling and composting, i) crop storage, and j) outdoor spraying of water to cool buildings and control dust. Consideration for the duration of land use may need to be considered.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
2.2.05	Urban and Industrial Land and Water Use	The use of land and water for urban or industrial purposes. Water has a variety of industrial uses: mining, the pulp and paper industry, food preparation, and electricity generation. Establishment of large water-use systems could influence the behavior and transport of contaminants in the environment and introduce remote sources of contaminants to a large community (such as the concentration of effluent sewage at a single point of discharge). Additionally, produce from hobby gardens in urban areas might be more contaminated than agricultural crops because the amateur gardener might over-irrigate.
2.2.06	Leisure and Other Uses of the Environment	Leisure activities, their effects on the surface environment, and implications for contaminant exposure pathways. Examples include: a) swimming and boating, b) hiking, c) camping, d) skiing, and e) sports activities. Many of these activities might influence which exposure pathways have significant impacts.
2.2.07	Pollution (Soil, Groundwater, Air, etc.)	Factors related to any type of human activities associated with pollution of the surface environmental at or near waste closure facility site that can potentially affect the performance of the system, or the exposure pathways at or near the waste closure facility. Pollution (air, soil, and groundwater) is possible from various sources (e.g., agricultural, industrial, and urban development). These pollution conditions may alter a) the chemical composition of the soil or groundwater, b) the contaminant migration properties, c) vegetation, and d) human health.
2.3.01	Future Human Actions (Active)	Factors related to human actions and regional practices associated with the post-closure period (future), which may affect the performance of the natural (geological) and/or engineered barriers, and consequently the waste closure facility.
2.3.02	Future Knowledge of the Facility	Factors related to the degree of knowledge of the existence, location and/or nature of the waste closure facility, including the retention of related records and the construction of markers to inform future humans of the location and contents of the facility. The loss of such records and markers may increase the likelihood of inadvertent intrusion.
2.3.03	Social and Institutional Developments	Factors related to changes in future social patterns and degree of local government, planning and regulation. Specific factors include: a) changes in planning controls and environmental legislation, b) demographic change and urban development, c) changes in land use, and d) loss of records or societal memory of the waste closure facility location and hazards.
2.3.04	Technological Developments	Factors related to future developments in human technology and changes in the capacity and motivation to implement technologies (i.e., research and development). Technological developments may affect the long-term performance of the waste closure facility. These include changes in the ability of humans to intrude the site, and changes that might affect contaminant exposure and its health implications. For example: Scientific and technological advances may lead to a total cure for cancer, thereby reducing the risks from radiation exposure.
2.3.05	No Technological Development	The conservative assumption that technological development will not occur, on the basis of uncertainty as to what types of developments may or may not occur. In these cases it is assumed that the past and present technological developments are a sufficient indication for future developments.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
2.3.06	Retrograde Developments	The conservative assumption that technological capacities may be lost due to degradation of society or failure to pass on generational expertise.
2.3.07	Ozone Layer Failure	Human actions (i.e., the use of certain industrial chemicals) may lead to destruction or damage to the earth's ozone layer. This may lead to significant changes to the climate locally and globally, affecting properties of the geosphere such as groundwater flow patterns.
2.4.01	Biomes	Factors related to the characteristics of biomes found on earth, and their evolution. A biome is a mixed community of plants and animals (a biotic community) occupying a major geographical area on a continental scale. Usually applied to terrestrial environments, each biome is characterized by similarity of structure or physiology rather than by species composition. Within a particular biome, plants and animals are regarded as being well adapted to each other and to broadly similar environmental conditions, especially climate. Important factors influencing biomes (excluding human activity) include temperature, precipitation, latitude, and altitude.
2.4.02	Microbial Activity	Microbes exist naturally in soils and groundwater. Other microbes may be introduced on construction materials and in the air during excavation, operation and closure procedures. These microbes may affect chemical conditions and can affect the rates of some reactions. They may also directly affect contaminant transport by acting as organic colloids or by affecting redox potential and pH.
2.4.03	Vegetation	Factors related to the characteristics of terrestrial and aquatic vegetation both as individual plants and in mass, and their evolution.
2.4.04	Animal Populations	Factors related to the characteristics of the terrestrial and aquatic animals both as individual animals and as populations, and their evolution.
2.4.05	Species Evolution	Factors related to the possibility of biological evolution or genetic manipulation of humans, microbial, animal and plant species, and related consequences. Over the times scales considered natural evolution may be possible. The rate varies between organisms. Humans are subject to biological evolution, although perhaps to a lesser degree. Evolution may affect anatomical features and physiological processes and the effects of contaminant exposure.
2.5.01	Geological Environment and Processes	Factors related to features and processes of the geological environment surrounding the waste closure facility.
2.5.02	Topography and Landforms	Factors related to the topography and surface morphology (relief and shape of the surface) of the waste closure facility region and its evolution over time. Topographical features include outcrops and hills, water-filled depressions, wetlands, recharge areas and discharge areas. Topography, precipitation, and surficial permeability distribution in the system will determine the flow boundary conditions (i.e., location and amount of recharge and discharge in the system).

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
2.5.03	Depositional Environments and Landforms	Factors related to landforms formed from the deposition of weathered and eroded surface materials. On occasion, these deposits can be compressed and/or altered by pressure, heat and chemical processes to become sedimentary rocks. This includes landforms with some of the following geomorphic features: beaches, deltas, flood plains, and glacial moraines.
2.5.04	Stratigraphy and Host Lithology	Factors related to the properties and evolution of the local stratigraphy and lithology. Stratigraphy is the succession of geological formations and rock structures and types that make up the region. The various units may help isolate the waste and influence where surface water infiltrates and where ground-waters eventually discharge. Lithology describes the relevant properties of the geological units, including: thermal and hydraulic conductivity, compressive and shear strength, porosity, tortuosity, thickness, etc. The inhomogeneity and uncertainty of these properties is also part of their characterization. These properties could change with time and temperature.
2.5.05	Geologic Discontinuities and Boundary Conditions (Fractures, Faults, and Cracks)	Factors related to the properties and characteristics of large scale discontinuities in the geosphere, such as faults, fractures, dykes, and folds. These geological discontinuities often form the boundaries of an aquifer.
2.5.06	Near-Surface Aquifers and Water-Bearing Features	Factors related to the characteristics and formation of aquifers and water-bearing features within a few meters of the land surface and their evolution. Aquifers are formed by the gathering of water between alternating layering of permeable and impermeable rock on a local or regional scale.
2.5.07	Unconsolidated Soft Zones	The presence of soft zones (e.g., the calcareous zone in the Santee Formation of the SRS) may influence stability of the waste closure facility and have an effect on flow.
2.5.08	Undetected Geologic Features	Natural or man-made features that are not detected during site investigation, or even during excavation, construction, or operation. Examples of possible features are a) faults, b) fracture zones, c) induced fractures caused by excavation, and d) other discontinuities. These features could play a significant role in the transport of groundwater to and from the waste closure facility.
2.5.09	Stress Regimes	Geological media deforms according to the acting stress field and its inherent strength. Changes in the groundwater flow and changes in the temperature field will change the active stress acting on the rock, which in turn will change fracture properties and groundwater flow. Stress regimes can change due to: coupled thermal-hydro-mechanical effects; swelling of materials; isostatic rebound (such as when glaciers recede); and salt creep.
2.5.10	Soils and Sediment	The soils and sediments that overlie the rock of the geosphere, including their evolution in time. Soil type is determined by many different factors (e.g., formative process, geology, climate, vegetation, land use). The physical and chemical attributes of the surficial soils (such as organic matter content and pH) may influence the mobility of radionuclides. Feature includes overburden and aquatic and marine sediments.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
2.5.11	Hydraulic Properties	Properties of the host rock and other rock units that affect the migration of fluids, including a) hydraulic conductivity in the context of flow through a porous medium, b) the presence of open fractures, c) capillary suction, and d) the gas-entry pressure. Changes of hydraulic properties due to changes in rock stress or fault movements.
2.6.01	Mechanical Effects on Geologic Features	Factors related to the mechanical processes and conditions that affect the geosphere and the overall evolution of conditions of the natural system with time. This includes the effects of changes due to the seismicity, excavation, and the long-term presence of the closure system.
2.6.02	Tectonic Activity and Processes	Factors related to tectonic movement at plate boundaries, the potential for tectonic movement, and its effects on the performance of the waste closure facility. Large-scale tectonic activity, such as regional uplift, subsidence, folding, mountain building, or other processes related to plate movements, could affect performance by altering the physical and thermohydrologic properties of the geosphere.
2.6.03	Orogeny	Factors related to the formation of mountains (orogeny), the potential for orogeny and its effects on the performance of the waste closure facility.
2.6.04	Deformation and Metamorphism	Factors related to the physical deformation (elastic, plastic, or brittle) or metamorphism of geological structures in response to geological forces such as tectonic movement and orogeny or in response to stress fields generated either at plate margins or in regions of anomalous stress. This includes a) faulting, b) fracturing, c) extrusion and, d) compression and folding of rocks. A fault is a large-scale discontinuity or fracture in the Earth's crust accompanied by displacement of one side of the fracture relative to the other. Fractures may be caused by compressional or tensional forces in the Earth's crust.
2.6.05	Diagenesis and Pedogenesis	Diagenesis refers to processes that take place in rocks after formation but before eventual metamorphism or weathering. Pedogenesis is the conversion of rock materials into soils. These processes may affect biosphere uptake and near-surface system evolution as it involves geohydrologic, atmospheric and biological processes (burrowing animals, plant roots activity/invasion) at or near the surface on time scales of a few hundred to thousands of years.
2.6.06	Sedimentation	The processes by which deposited sediments at or near the Earth's surface are formed into rocks by compaction, cementation and crystallization, i.e. under conditions of temperature and pressure normal to the upper few kilometers of the Earth's crust.
2.6.07	Deposition	Deposition is the geological process by which material is added to a landform or land mass. The process may change topography and thus affects local and regional hydrology. Deposition of surficial materials can occur by a variety of means, including fluvial, eolian, and lacustrine deposition and redistribution of soil through weathering and mass wasting processes.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
2.6.08	Erosion and Weathering	Erosion and weathering are processes which lead to the denudation of the land surface and a reduction in topography. Erosion and weathering may cause changes to the present day topography through denudation and are thus capable of affecting both local and regional hydrology. Weathering refers to physical and chemical processes that alter and degrade rocks and soil at and near the land surface. Erosion involves the transport of surficial material away from the site by various mechanisms including glacial, fluvial, eolian (involving wind), and chemical processes. Surficial materials, including weathering products, are also subject to gravity, and erosion can take place by mass wastage processes (e.g., landslides). The extent of denudation depends to a large extent on climate and the rate of local uplift.
2.6.09	Mass Wasting	Mass wasting is the geomorphic process by which materials move downslope under the force of gravity. Types of mass wasting include creep, slides, flow, topples, and falls, each with its own characteristic features, and taking place over timescales from seconds to years. Mass wasting occurs on both terrestrial and submarine slopes, and the largest and most disastrous mass wasting events may be related to some extraordinary activity or occurrences, including: a) earthquakes, b) slope modification (e.g., human activity), c) undercutting (typically along stream banks or by surf action along the coast), d) exceptional precipitation, and e) volcanic eruptions.
2.6.10	Creeping of the Rock Mass	Creeping of the rock mass is the slow movement of the rock along pre-existing discontinuities or in the rock matrix due to differential stress fields at a very slow rate. Creep of the rock mass may affect the hydraulic properties of the rock and may have a mechanical impact on the backfill.
2.6.11	Large Scale Salt Processes (Diapirism, Dissolution, and Creep)	Salt diapirism is the intrusion or upwelling of a salt formation into overlying strata (such as salt domes). Salt dissolution can occur when any soluble mineral is removed by flowing water. Large-scale dissolution is a potentially important process in rocks that are composed predominantly of water-soluble evaporite minerals. Salt creep is the continuous deformation of a salt formation as a response to an applied stress such as overburden pressure.
2.6.12	Hydrogeological Processes and Conditions	Factors related to the hydraulic and hydrogeological processes that affect the geosphere and the overall evolution of conditions due to the excavation, construction, and long-term presence of the closure facility. During hydrogeological investigations, efforts should describe the existing and projected water uses; location, extent and interrelationship of the important hydrogeological units in the region; recharge and discharge of the major hydrogeological units; regional and local water tables and their gradients and seasonal fluctuations; an estimate of groundwater flow velocities and direction; radionuclides travel times along most likely flow paths from the closure facility to the biosphere.
2.7.01	Atmosphere	The transport of radionuclides and chemical contaminants in the atmosphere as gas, vapor, or suspended fine particulate or aerosol. Contaminants may enter the atmosphere as a result of water evaporation, degassing from soils or water, transpiration from plants, suspension due to wind erosion, plowing, or fires. The atmosphere may provide a significant mechanism to transport, dilute, or remove these contaminants by advection and dispersion. This category provides for specific human and animal exposure pathways.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
2.7.02	Climate and Weather	The characteristics of climate and weather including precipitation, temperature, pressure, and wind speed and direction, and their evolution. Climate and weather may have a major influence on transport of contaminants in the environment through recharging of surface-water bodies and leaching of soils, and affect human behavior of irrigation requirements for agricultural crops and the source of drinking water. The variability in the climate and weather (such as drought, flooding, storms, and duration of snow melt and their potential effects) can influence erosion, the accumulation and release of contaminants, and potential human exposure.
2.7.03	Precipitation	Precipitation depends on climate and is an important control on the amount of runoff and infiltration, flow in the unsaturated zone, and groundwater recharge. It transports solutes with it as it flows downward through the subsurface or escapes as runoff. Precipitation influences agricultural practices of the receptor.
2.7.04	Acid Rain	Acid rain refers to precipitation on a local to regional scale containing higher than normal amounts of nitric and sulfuric acids. This can result from man-made sources such as emissions produced from the burning of fossil fuels. Acid rain can influence the behavior and transport of contaminants in the biosphere by affecting surface water and soil chemistry and detrimentally affect aquatic and terrestrial life by interfering with the growth, reproduction, and thus survival of affected organisms.
2.7.05	Warm Weather Effects	Factors related to warm tropical and desert climates and their effect on the performance of the waste closure facility. For example, warm weather may increase evapotranspiration thus reducing infiltration and eventual transport.
2.7.06	Cold Weather Effects	Factors related to cold weather effects (i.e., physical processes) and associated landforms. Permafrost and seasonal freeze/thaw cycles are characteristic of periglacial environments that may impact erosional processes. This FEP includes the effects of glaciers and ice sheets within the region of the waste closure facility. For example, frost heaving pushes the ground surface up and causes a downslope movement of rocks. Gelifluction occurs when the thawed layer becomes saturated with melt water and slowly moves downslope forming distinctive lobes and sheets of debris. Rock glaciers form as a tongue or lobe of ice-cemented rock debris that moves slowly downslope in a manner similar to glaciers.
2.7.07	Climate Change	Climate change includes the effects of long-term change in global climate (e.g., glacial/interglacial cycles) and shorter-term change in regional and local climate. Climate is typically characterized by temporal variations in precipitation and temperature and may affect the long-term performance of the waste closure facility. This includes the effects of greenhouse gases and potential for global warming.
2.7.08	Solar Radiation	Solar radiation is used in ecosystems to heat the atmosphere and to evaporate and transpire water into the atmosphere. Sunlight is also necessary for photosynthesis, which provides the energy for plant growth and metabolism, and the organic food for other forms of life.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
2.8.01	Water	The characteristics of water, and its evolution. Water is the medium by which mineral nutrients enter and are translocated in plants and is required for photosynthetic chemical reactions. The original source of this water is precipitation from the atmosphere and plants and animals receive their water from the Earth's surface and soil.
2.8.02	Surface-Water Bodies	The characteristics of surface-water bodies such as rivers, lakes, wetlands and springs, and their evolution in time. These water bodies can indicate watershed boundaries and act as recharge zones for groundwater and, as such, can influence groundwater chemistry and contaminant transport. Contaminant transport and mixing can occur within the surface water bodies (such as dilution, sedimentation, aeration, stream flow, and river meander).
2.8.03	Evapotranspiration	Evapotranspiration removes water from soil and rock by evaporation and transpiration via plant root water uptake. Surface water runoff and evapotranspiration are components in the water balance, together with precipitation, infiltration, and change in soil water storage.
2.8.04	Surface Runoff	Surface runoff produces erosion, and can feed washes, arroyos, and impoundments, where flooding may lead to increased recharge. Surface water runoff and evapotranspiration are components in the water balance, together with precipitation, infiltration, and change in soil water storage.
2.8.05	Capillary Rise	Capillary rise, or wicking, involves the drawing up of water, above the water table or above locally saturated zones through continuous pores, due to a net upward force produced by the attraction of the water molecules to a solid surface until the suction gradient is balanced by the gravitational pull downward.
2.8.06	Infiltration and Recharge	Infiltration into the subsurface provides a boundary condition for groundwater flow in the unsaturated zone. The amount and location of the infiltration influences the amount of seepage through the closure cap, and the amount and location of recharge influences the height of the water table, the hydraulic gradient, and the specific discharge. Mixing of these waters could result in mineral precipitation, dissolution, and altered chemical gradients in the subsurface.
2.8.07	Discharge Zones Within the Assessment Domain	Locations (within the assessment domain) where the water table intersects the surface allow ground waters to flow out onto the surface as springs, seepage lines, streams, wetlands or lakes. Discharge zones are often low-lying areas such as at the margin or bottoms of lakes and wetlands. Springs may also be found at various elevations depending on factors such as the lithology and stratigraphy of the geosphere and the location of outcropping geological units.
2.8.08	Discharge Zones Outside the Assessment Domain	Some contaminants could be released and discharged to the surface environment at locations beyond the assessment domain (or the reference biosphere). Radionuclides transported in groundwater as solutes or solid materials (colloids) from the far-field may discharge at specific "outcrops" that are outside the reference biosphere.
2.8.09	Hydrological Regime and Water Balance (Near-Surface)	Factors related to near-surface hydrology at a catchment scale and also soil water balance, runoff, the flushing rate of surface-water bodies, and their evolution. Extremes such as drought, flooding, storms and snow melt may be relevant. Changes to the hydrological regime could also induce changes in the behavior of the critical group.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
3.1.01	Site Characterization and Investigations	Factors related to site characterization. Such factors include: a) determining which site investigations are needed (both prior and during construction and operation), b) evaluations of related assessments, c) defining the level of detail required (to support both a general understanding of the site, its past evolution, and likely future natural evolution over a period of time), and d) a specific understanding of the impact on safety of associated FEPs. These activities establish baseline conditions and data.
3.1.02	Site Development	Factors related to any type of human activities during site development that can potentially affect the performance of the waste closure facility or the exposure pathways after closure. Examples of site development include the following: construction of roads, residential buildings (urban), or industries. This includes earthmoving works such as leveling of the site, modifications of natural site drainage, and construction of dams).
3.1.03	Facility Factors	Factors related to decisions taken and events occurring during the life cycle of the waste closure facility that may influence the performance of the facility. These include those features, events, and processes occurring during pre-operational, operational, and post-closure periods of the waste closure facility whose principal effect is to determine the evolution of the physical, chemical, biological, and human conditions of the waste closure facility with the purpose to estimate the release and migration of contaminants and the consequent exposure to human beings and the environment.
3.1.04	Multi-Barrier Safety Function	Consideration for applying a multi-barrier closure system (using both natural and engineered barriers) that is designed to ensure long-term safety by means of multiple safety functions.
3.2.01	Design Basis for Engineered Components	Factors related to the design of the waste closure facility and facility components (and associated design documentation) and the ways in which the design contributes to long-term performance. The performance assessment must account for design features, material characteristics, design influences on the environment, and assumptions regarding the design of the waste closure facility (i.e., the safety concept and the engineering specifications for excavation, construction, operation and closure). Design should ensure that the functional requirements and criteria are met.
3.2.02	Schedule and Planning	A detailed description of the major activities associated with the construction, the operation, the closure of the waste closure facility, and the schedule and resources required for that purpose. Relevant events may include monitoring activities to provide data on the transient behavior of the system or to provide input to the final assessment. The sequence of events and time between events may have implications for long-term performance.
3.2.03	Procurement of Items and Services	Factors related to quality assurance that will be applied during the procurement of items and services important to the safety of the waste closure facility.
3.2.04	Costs of Construction, Operation, Closure	Factors related to the costs of constructing, operating, and closing the waste closure facility.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
3.2.05	Construction	Factors related to the excavation, stabilization, and the installation and assembly of structural elements according to the assessed design and approved schedule and planning. The major tasks of construction of waste closure facility include: a) excavation, testing, and preparation of soil material, b) placement of monitoring systems, c) placement of engineered barrier systems, d) installation of drainage control features, e) revegetation, and f) quality control.
3.2.06	Operation	Factors related to the operation (waste emplacement, backfilling, monitoring and surveillance, remedial activities) of the waste closure facility, according to the approved schedule and planning for the facility.
3.2.07	Removal or Stabilization of Waste	Factors related to the waste storage, removal, and stabilization of waste tanks and disposal units at the waste closure facility. Distinction can be made between qualitative and quantitative requirements for the removal and stabilization of radioactive waste from waste tanks at the waste closure facility.
3.2.08	Disposal Unit and/or Facility Closure	Factors related to the end of waste disposal operations and the closure of individual waste tanks. These closure activities are undertaken mainly to prevent human access into and limit the migration of contaminants from the individual waste tanks. This includes planning, preparation, decommissioning of components, and confirmation activities.
3.3.01	Closure System Features and Materials	Features related to the closure operations of the waste closure facility and the materials used for that purpose, according to the approved schedule and planning for the facility. A wide variety of materials can be used in combination to provide the overall system with the required properties to prevent human access into and limit the migration of contaminants from the waste closure facility.
3.3.02	Manufacturing and Commissioning of Components	Factors related to the commissioning and manufacturing of components and subcomponents activities important to the safety of a waste closure facility (such as the possibility and impacts of manufacturing defects).
3.3.03	Consolidation of System Components	Factors related to the consolidation of engineered barrier system components. Such consolidation may affect the development of the chemical environment and, therefore, the radionuclide transport out of the closure system.
3.3.04	Waste Tank, Container, or Package Characteristics	**Physical characteristics** of the container include: a) dimensions and geometry, b) permeability and porosity, c) density, d) void space, e) surface finish and level of cleanliness, and f) external or internal coatings or linings. **Chemical characteristics** of the container include: a) chemical composition of container, b) chemical stability and confinement in the near-field, c) reactivity, and d) gas generation. **Mechanical characteristics** of the container include: a) tensile and compressive strengths, b) abrasion resistance, and c) ductility. Considers materials that may have been used, such as: a) carbon steel, b) stainless steel, c) polymers and polymer impregnated concrete, d) asbestos cement, e) reinforced concrete, f) cast steel, g) modular cast iron, h) spheroidal graphite cast iron, i) polyethylene, j) lead, k) titanium, l) ceramics, m) stainless steel, and n) High Density Polyethylene (HDPE). Considers function (the role of the waste container) and repackaging capabilities.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
3.3.05	Closure System Buffer (Closure Cap, Backfill, and Near-Field Soil) Properties	The backfill and other soil mineralogy will affect the buffering of geochemical conditions in response to perturbation by the cementitious materials and residual wastes, and provide a substrate for sorption of contaminants. Used to inform the selection of distribution coefficients that describe contaminant mobility. Mineralogical dehydration reactions release water affecting hydrologic conditions. Dehydration of zeolites may lead to large-scale volume changes affecting flow and/or waste tank stability. The likelihood of geothermal fluids might cause changes in mineralogical composition.
3.3.06	Bentonite and Vermiculite Effects	Bentonite/Vermiculite layers provide a barrier to groundwater flow and act as a mechanical barrier to protect the waste tank. The material will degrade over time by physical and chemical processes and thus its barrier functions will diminish. This will have an impact on radionuclide release processes and rate. For example, in a ground or pore water containing suspended bentonite/vermiculite clay particles, there is sometimes a tendency for the bentonite/vermiculite clay particles to coagulate and form larger aggregates, and may settle to form clay-rich sediment. This process is promoted by an increase in the salinity of the solution.
3.3.07	Closure Cap Thickness and Material Properties	The vertical distance between the top of the closure cap and the top of the waste closure facility.
3.3.08	Disposal Unit and/or Facility Wall and Roof Thicknesses	The thicknesses of the walls and roof of the disposal unit or closure facility.
3.3.09	Disposal Unit or Facility Floor Thickness	The thickness of the floor of the disposal unit or closure facility.
3.3.10	Ancillary Equipment and Piping/Transfer Lines	Factors related to ancillary equipment and transfer lines (including evaporators, mixers, robotics, cooling coils, etc.) and their effects on other system components and processes.
3.4.01	Hydrological Processes and Conditions	The hydrological and hydrogeological processes (including coupled effects) that affect the wastes, tanks, and other engineered features, and the overall hydrological evolution of the closure system with time.
3.4.02	Hydrostatic Pressure on the Closure System	Waste and system components within the saturated zone will be subjected to hydrostatic pressure (or suction head) in addition to stresses associated with the evolution of the waste and cementitious materials.
3.4.03	Condensation on Closure System Surfaces	Condensation of water on engineered system components may affect the hydrologic and chemical environment. Emplacement of waste can create thermal gradients that can lead to cold traps (locations characterized by transferal of latent heat). This can create condensation, leading to enhanced moisture at the site of engineered system components. Waste emplacement geometry and thermal loading may affect the scale at which condensation occurs.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
3.4.04	Resaturation and Desaturation	After closure, groundwater may flow from the near-field into the engineered system and from far-field materials into near-field materials causing these environments to hydraulically saturate or resaturate. Groundwater may cause materials to expand, resulting in a general homogenization of physical and chemical characteristics. This resaturation will impact thermal, hydraulic, mechanical, and chemical properties. For example, metals may corrode and temperatures may cool.
3.5.01	Chemical/Geochemical Processes and Conditions	The chemical and longer-term geochemical processes that affect the system and the overall chemical evolution over time. This includes the effects of chemical and geochemical influences on and degradation of a) wastes, b) containers and engineered components, c) backfill, and d) host material by groundwater entering from the surrounding geology. Properties that may be affected include permeability and sorption.
3.5.02	Evolving Water Chemistry in the Engineered System and Waste Form	Factors related to the chemical properties of water in the engineered system components and the waste form. Chemistry of water flowing into the engineered system components and the waste form is affected by initial water chemistry in the rock, mineral and gas composition in the rock, and thermal-hydrological-chemical processes in the rock. Chemical effects on the engineered system components and the waste form (e.g., dissolution) may be enhanced or altered in a system where metals, waste, rock minerals, and water are all in physical contact with one another. This water will react with the various metals and cementitious materials (e.g., grout) causing considerable changes to the chemistry of the intruding water. When radionuclides are released, this will result in further changes to the water chemistry.
3.5.03	Evolving Water Chemistry in the Near-Field	Factors related to the chemical properties of water in the backfill and near-field environment. The water chemistry in the near-field materials is controlled by the composition of the ambient natural groundwater and the composition of waters leaving the engineered system. The water chemistry in the near-field controls transport and retardation processes related to contaminants released from the engineered system.
3.5.04	Evolving Water Chemistry in the Far-Field	Factors related to the chemical properties of water in the backfill and far-field environment. The initial chemistry of the far-field environment reflects the natural, present-day system. This far-field groundwater chemistry is controlled largely by rock- and soil-water interactions and by mixing with waters from the near-field and from the surface. However, perturbations can occur due to climate change which can cause infiltration of sea-water or glacial melt waters.
3.5.05	pH Conditions	The pH conditions in water owing to interactions between the water and the cementitious materials. pH (along with Eh and chloride and sulphate conditions) is an important determinant in the chemical behavior, which in turn affects the release and transport of contaminants in groundwater and gas.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
3.5.06	Eh Conditions	The Eh conditions in water owing to interactions between the water and the cementitious materials. Eh (along with pH and chloride and sulphate conditions) is an important determinant in the chemical behavior of any waste closure facility, which in turn affects the release and transport of contaminants in groundwater and gas. An oxygen-deficient environment (anaerobic) promotes the formation of lower, and often less soluble, oxidation states of radioelements, promotes relatively slow corrosion and microbial processes, and minimizes the rate of gas generation.
3.5.07	Colloid Generation	Colloids may be generated by chemical, physical, and microbiological processes. Contaminants can sorb onto these colloids which may affect their subsequent transport through the system.
3.5.08	Chemical Effects of Waste-Rock Contact	Waste and rock may be placed in direct contact by mechanical failure of the waste packages. Chemical effects on the waste (e.g., dissolution) may be enhanced or altered in a system where waste, rock minerals, and water are all in physical contact with one another, relative to a system where only waste and water are in physical contact.
3.5.09	Rind (Chemically Altered Zone) Forms in the Near-Field	Thermal-chemical processes involving precipitation, condensation, and re-dissolution could alter the properties of the adjacent materials. These alterations may form a rind, or altered zone with hydrological, thermal, and mineralogical properties different from the initial conditions.
3.5.10	Complexation in the Natural System	Effects on the physical and chemical environment due to complexing agents such as carbonate, fluoride, and humic and fulvic acids present in natural ground waters could affect radionuclide transport in the natural system.
3.5.11	Reaction Kinetics	Chemical reactions, such as radionuclide dissolution/precipitation reactions and reactions controlling the reduction-oxidation state, may not be at equilibrium within the closure system.
3.5.12	Chelating Agent Effects	The effect of chelating agents derived from the pore water on the performance of a closure system. Chelating agents are organic compounds, usually carboxylic acids, which have a number of locations in each molecule that can bind metal ions to form soluble species. The resulting complexes are usually highly stable, a factor that can increase can: increase (or decrease) the solubility of the complexed element significantly. The chief concern is that these complexing agents can chemically bond with a radionuclide, metallic elements, or other contaminant to form another stable species.
3.5.13	Osmotic Effects	Osmosis is the flow of water through a semi-permeable membrane so that the molecular concentration solutions on either side of the membrane become equal. Water deposited on the surface of concrete (by condensation or through incoming groundwater) and the pore water would eventually have the same ionic compositions, with osmosis playing a role in achieving this if the pore structure of the concrete acted like a semi-permeable membrane.
3.5.14	Leaching	Leaching is the removal by water of minerals from the solid materials (i.e., concrete, bentonite and asphalt) that could affect waste closure facility performance.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
3.6.01	Thermal Processes and Conditions the Engineered System	Factors related to the thermal processes that affect the wastes, packaging and engineering features in the closure system and the overall evolution of the thermal conditions over time. A range of processes could potentially give off heat including: a) concrete hydration, radioactive decay, b) chemical reactions (such as corrosion and uranium oxidation), and c) microbiological processes. Thermal processes affect the integrity of the engineered system components and the release and transport of contaminants in groundwater and gases.
3.6.02	Thermal Processes and Conditions the Natural System	Factors related to the thermal processes that affect the backfill and the near-field and far-field natural environments and the overall evolution of the thermal conditions over time. A range of processes could potentially give off heat including: a) the effects of seasonal and global climate change, b) excavation activities, c) geothermal activity, d) convective heat transport, and e) the long-term presence of the waste closure facility. The thermal properties of the soils and host rock affect the migration of contaminants from the disposal system.
3.6.03	Thermo-Chemical Alteration, Near-Field	Thermal effects may influence chemical alterations and radionuclide transport directly (such as radionuclide speciation and solubility in the natural system) or indirectly (such as changes in the mineralogy along the flow path). Relevant processes include: a) volume effects associated with silica phase changes, b) precipitation and dissolution of fracture-filling minerals (such as silica and calcite), and c) alteration of zeolites and other minerals to clays.
3.6.04	Thermo-Mechanical Stresses Alter Characteristics of Engineered Barrier System Components	Heat from the waste causes thermal expansion of the surrounding materials, generating changes to the stress field that may change the properties (both hydrologic and mechanical) in and along faults, fractures, and solid materials (such as the grouted monolith). Cooling as the radioactive material decays will also change the stress field, further affecting material properties.
3.6.05	Recrystallization of Vitrified Wastes	Recrystallization is a slow process and typically occurs only if a high glass temperature is maintained over a prolonged period. Recrystallization of vitrified (glass) wastes could occur under high heat and/or pressure, leading to a less corrosion-resistant waste form.
3.6.06	Effects of System Heat on the Biosphere	Heat released from radioactive decay of the waste may increase the temperatures at the surface above the system. This could result in local or extensive changes in the ecological characteristics.
3.6.07	Temperature and Thermal Gradient Effects on the Geosphere	Factors related to the thermal processes that affect the geosphere and the overall evolution of conditions with time due to the long-term presence of the closure facility. The variety of materials in the near-field barriers will have different thermal expansion coefficients. Thus, if the temperature of the near-field changes, the barriers may expand or contract at different rates, causing changes to the stresses acting on them, and may cause minor physical effects on some barriers. The temperature of the far-field is largely controlled by the natural geothermal gradient, although it may be influenced by changing climate at the surface. The temperature in the far-field will be a control on the rates of chemical and microbiological processes, and can influence the stress field, groundwater flow, diffusion rates, and radionuclide transport.
3.7.01	Chemical Degradation of Engineered System Metals	Degradation of the metal materials used in the engineered system may occur by chemical or microbial processes, and may affect long-term system performance.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
3.7.02	Corrosion	The corrosive effect of water on metals in the engineered barrier system. Corrosion includes generalized, localized, and galvanic processes. This also includes chemical interactions related to corrosion products and processes related to corrosion enhanced by microbial influences and radiolysis.
3.7.03	Stress-Corrosion Cracking and Hydride Cracking of Engineered System Metals	Stress-corrosion cracking, or hydride embrittlement and cracking, may mechanically weaken the container and promote subsequent failure or other corrosion mechanisms. The process might be accelerated if hydrogen is attracted to and accumulates at a defect or crack site, forming metal hydrides that promote degradation.
3.7.04	Creep of Metallic Materials in the Engineered System	As a result of exposure to high temperatures (>400°C) and pressures for long periods of time, metal components of the engineered system may experience 'creep', a slow but continuous plastic deformation, often in response to stresses or internal void space. In extreme cases creep may lead to a breach in the metals, releasing waste.
3.7.05	Oxygen Embrittlement of Engineered System Metals	A potential failure mechanism for engineered system metals is oxygen embrittlement, resulting from the diffusion of interstitial oxygen in the metals at high temperatures.
3.7.06	Waste Container, Package, or Over-Pack Failure	The outer shell of the waste canister provides long lifetimes because of the very slow corrosion rate in the waste closure facility environment. However, corrosion will eventually cause the canister to fail, although early failure could be caused by manufacturing defects, mechanical impacts or creep. The mechanical strength of the waste canister is largely provided by the type of metal alloy and a reduction of the mechanical strength can occur due to a number of physical and chemical processes. The effect will be to limit the canister's resistance to failure by mechanical impact. Waste packages may fail prematurely because of manufacturing defects, improper sealing, or other factors related to quality control during manufacture and emplacement.
3.7.07	Degradation of Non-Metal Solids: Backfill, Rock, Grout, Cement, etc.	Factors related to the degradation of non-metal solids within the engineered closure system (e.g., backfill, rock, grout, cementitious materials, etc.). These will be affected by physical and chemical degradation processes. These processes will affect the pore water chemistry, the solubility and sorption of radionuclides, and the mechanical stability of the waste tanks. Degradation of backfill by flowing groundwater, either by erosion of particulate matter or by dissolution, may occur by a combination of physical and chemical processes, and their degradation may impact on other parts of the closure system.
3.7.08	Swelling of Backfill and Emplacement Materials	The backfill may be a mixture of partially dried bentonite and an inert filler material. The bentonite or vermiculite will take-up water during the resaturation phase and swell as the clay minerals adsorb water into their lattice structure. Swelling of the bentonite will affect properties which are important for water and gas transport through the backfill and for radionuclide transport and release.
3.7.09	Concrete Shrinkage/Expansion	Concrete shows volume changes during the curing phase and during aging which can impact the integrity and hydraulic properties of the material.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
3.7.10	Sulfate and Chloride Attack	Sulfate attack and chloride attack: The chloride and sulphate conditions and chemical processes owing to interactions between the water and the cementitious materials and engineered features. Chloride and sulphate concentrations, along with pH and Eh, are important in affecting the chemical behavior of any cementitious material, which in turn affects the release and transport of contaminants in groundwater and gas. The presence of organic complexants could augment radionuclide transport by providing a transport mechanism in addition to simple diffusion and advection of dissolved material. Chemical complexing agents include inorganic ions such as the chloride, fluoride and sulphate anions, and organic-based species such as humic and fulvic acids which occur naturally in soils and in the geosphere.
3.7.11	Carbonation	The carbonate conditions and chemical processes owing to interactions between the water and the cementitious materials and engineered features. Carbonate and carbon dioxide concentrations, along with pH and Eh, are important in affecting the chemical behavior of any cementitious material, which in turn affects the release and transport of contaminants in groundwater and gas.
3.7.12	Polymer Degradation	The chemical effect of water in the waste closure facility on polymeric materials.
3.8.01	Alternatives to Pre-Closure Activities	Factors related to alternative waste closure facility design, construction, operation, and closure conditions rather than those in the approved schedule and planning. Included are the poor design, construction, operation, and closure conditions and the effects on long-term safety and performance.
3.8.02	Incomplete Closure	Factors related to incomplete filling, construction, and/or closure (premature abandonment) of the waste closure facility.
3.8.03	Error in Waste Removal and Stabilization	Deviations from the design and/or errors in waste removal and stabilization that could affect long-term performance of the waste closure facility.
3.8.04	Inadequate Quality Assurance/Control and Deviations from Design	Quality assurance and control procedures and tests during the design, construction, operation, and closure of the waste closure facility. Factors related to the failure or poor implementation of quality assurance and quality control procedures during the life cycle of the waste closure facility.
3.8.05	Remedial Actions	Factors related to actions taken to remediate problems or issues related to the performance of the waste closure facility. This FEP addresses the concern that remedial actions may worsen the situation, possibly because it was incorrectly determined that performance was impaired, or because remedial actions are improperly undertaken or unknowingly defeat important barriers. Another possibility is that contaminated materials from remedial activities may not be adequately stored or disposed.
3.8.06	Void Space Formation	If waste packages and/or canisters are not completely filled, then the unfilled inert gas or air-filled volume could influence water-chemistry calculations. Diffusion-controlled cavity growth is a possible creep rupture mechanism that could occur under the temperature and pressure conditions that prevail during dry storage of spent fuel. It might also occur during disposal.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
3.8.07	Material Volume Changes	The effects of volume changes in materials used in the waste closure facility. This includes the effects of volume growth from corrosion products, which have a higher molar volume than the intact, non-corroded material. Increases in volume could change the stress state in the material leading to additional system degradation.
3.8.08	Electrochemical Effects in the Closure System (Including Anion Exclusion)	Electrochemical effects (or gradients) may establish an electric potential within or between closure system materials, particularly where two different metals occur close together in saturated conditions or in response to natural electrical currents in far-field rock. Migration of ions within such an electric field could affect corrosion of metals and could also have a direct effect on the dissolution and transport of radionuclides as charged ions. Anion exclusion refers to the overlapping of electrical double layers within a pore and the subsequent exclusion (full or partial) of anions and cations from the pore. Neutral species and water itself may migrate through such a pore unimpeded.
3.8.09	Mechanical Effects at EBS Component Interfaces	Factors related to the mechanical effects that occur at the interfaces between the engineered components of the closure system and the near-field environment. These factors include: a) the physical effects of steady-state contact (such as mechanical and static loading) at these interfaces, b) the effects of backfill and grouting for resisting to rockfall and structure collapse, c) the effects of physical impacts to the backfill and grout itself, and d) the effects of drilling and excavating at or near the closure facility. These factors may also be caused by forces such as rockfall and seismic-induced impacts, and internal and external stresses. These stresses will act on the engineered components and can be partially responsible for failure of the engineered barriers.
4.1.01	Waste Type Classification	Classification of the radioactive waste into exempt waste, low and intermediate level waste (short lived and long lived) or any other country-specific waste classification scheme. A variety of waste forms and waste types may be disposed of within the closure system. Some of types may have initial degradation characteristics. Therefore, the effectiveness of each waste form as a barrier to radionuclide mobilization should be considered.
4.1.02	Waste Form Characteristics	Contaminant characteristics are related to the physical, chemical (organic and inorganic) and radiological properties of the contaminant(s) contained in the residual waste of the closure facility. Chemical characteristics of the waste form include: a) chemical composition, b) chemical stability and confinement in the near-field, c) reactivity, d) gas generation, e) toxicity, and f) decomposition of organic wastes Physical characteristics of the waste form include: a) permeability and porosity, b) homogeneity (distribution of waste and matrix constituents within the waste form, c) density, d) voidage, e) preferential pathways in waste form.
4.1.03	Waste Inventory	A description of the total radionuclide content in the waste (total activity in units of curies, or mass in grams) and a description of the content of individual radionuclides (radionuclide composition) and chemicals (chemical composition, typically in units of density or concentration) in the waste. A description of the physical content of the waste material in its untreated form (i.e. as generated). A description of the physical size of the waste and/or waste containers used to dispose the waste material in its untreated or treated (stabilized) form.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
4.1.04	Waste Allocation and Emplacement	Describes the assumptions regarding the allocation of wastes (i.e. variance between waste tanks), including waste type(s) and amount(s). Some waste types and inventories may require special waste emplacement arrangements to simplify the disposal practice, to ensure safety, or to ensure structure stability in the disposal zone.
4.1.05	Waste Homogeneity	A description of the homogeneity of the waste in the closure facility. Different categories of heterogeneity are possible in a waste closure facility: a) heterogeneity in the disposal concepts, b) heterogeneity in the waste stream, and c) heterogeneity in the distribution of the radionuclides in the waste or waste form.
4.1.06	Highly Radioactive Radionuclides (HRRs)	Identification of HRRs, selection of radionuclides characterized in residual waste, selection of treatment technologies to remove HRRs to the Maximum Extent Practical (MEP), and screening of radionuclides for the purpose of performance assessment calculations.
4.1.07	Metallic Wastes	The physical, chemical, and biological characteristics of the metallic wastes and any conditioning material at the time of disposal are important for the definition of contaminant release rates (source term); gas generation rate; and geochemical conditions in the waste closure facility.
4.1.08	Non-Metallic, Inorganic Wastes	The physical, chemical and biological characteristics of non-metallic, inorganic wastes and solutes at the time of disposal are important for the definition of: contaminant release rates (source term); gas generation rate; and geochemical conditions in the waste closure facility.
4.1.09	Organic Wastes	Factors related to the characteristics of radionuclides or chemical contaminants that are organic or have the potential to form organics under prevailing waste closure facility and environmental conditions. Organic compounds may include stable organic complexes which may form compounds with other contaminants (usually metals). The resulting organic forms may be more or less mobile or toxic than the original form. Conditioning material at the time of disposal are important for defining contaminant release rates (source term), gas generation rates, and geochemical conditions in the waste closure facility
4.1.10	Volatiles and Potential for Volatility	Factors related to the characteristics of radiotoxic and chemotoxic species that are volatile or have the potential for volatility under prevailing waste closure facility and environmental conditions.
4.2.01	Radioactive Decay and In-Growth	Radioactive decay is a fundamental process that affects all radioactive (unstable) nuclides. Radioactive decay will change the inventory of radionuclides in the waste, and the heat generation will affect the temperature in the near-field and the stability of the wasteform and other cementitious materials.
4.2.02	Activity Limits in Disposed Waste	The radionuclide specific activity limits that can be disposed in a waste closure facility to ensure that human health and the environment are not adversely affected by the disposal waste material. As part of defining waste acceptance criteria for a waste closure facility, quantitative nuclide specific activity limits can be derived to ensure adequate protection to human health and the environment as a function of time. These activity limits can be expressed as total activity limits (Bq of waste disposed) or activity concentration limits (Bq per kg of waste material). In addition, activity limits for each waste package can also be defined.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
4.2.03	Contaminant Solubility, Solubility Limits, and Speciation	Speciation and solubility processes, including their evolution in time, occurring in the accessible environment that effect the dissolution/precipitation of contaminants. Large solubility limits increase the mobility of contaminants, but low solubility limits may lead to larger exposures when precipitation occurs. Small concentrations of complexing agents could form stable dissolved species, enhancing the dissolution of contaminants from the waste form and increasing their solubility. Conversely, solubility limits will be smaller when complexing agents have low concentrations or where the chemical environment decreases the stability of dissolved species or enhances the stability of a solid phase.
4.2.04	Reduction-Oxidation Potential (Redox Fronts)	The generation and propagation of a redox front influence contaminant transport due to variations in solubilities and concentrations at the interfaces between waters with varying redox potentials. This geochemical instability may also result in the generation of colloids.
4.2.05	Localized Interactions Between Emplaced Wastes	Co-location refers to the disposal of various types of wastes in close proximity. Co-disposal refers to the disposal of different waste types within the same waste package. Co-location and co-disposal might affect thermal outputs, chemical interactions, or radionuclide mobilization.
4.2.06	Degradation of the Inorganic Waste	Degradation and failure processes: The waste form type and associated characteristics will determine the dominant waste form degradation processes including: a) physical degradation processes (e.g., physical stress), b) chemical degradation processes (e.g., sulfate attack), and c) biological degradation processes (e.g., notifying bacteria and heterotrophic organisms), together with the physical, chemical, hydrological and biological conditions in the waste closure facility and environment. Consequently, degradation of inorganic wastes may impact on the release and transport of radionuclides from the near-field.
4.2.07	Degradation of the Organic Waste	Degradation and failure processes: The waste form type and associated characteristics will determine the dominant waste form degradation processes including: a) physical degradation processes (e.g., physical stress), b) chemical degradation processes (e.g., sulfate attack), and c) biological degradation processes (e.g., notifying bacteria and heterotrophic organisms), together with the physical, chemical, hydrological and biological conditions in the waste closure facility and environment. Consequently, degradation of organic wastes may impact on the release and transport of radionuclides from the near-field.
4.3.01	Contaminant Concentrations in Water and Other Media	Factors related to the concentrations of contaminants in: a) environmental media; b) drinking water, foodstuffs or drugs that may be consumed by humans; c) environmental media other than drinking water, foodstuffs or drugs; and d) human manufactured materials or environmental materials used by humans for special uses, e.g., clothing, building materials, peat. This includes groundwater concentrations.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
4.3.02	Dissolution and Precipitation	Dissolution and precipitation processes, including their evolution in time. Most contaminants are released from the residual waste when they dissolve into the groundwater that has entered the waste tank, and many contaminants could re-precipitate as different compounds. Precipitation could also occur if there is an abrupt change in the chemical environment (including groundwater composition and pH) or if ingrowth from radioactive decay produces a local increase in concentration.
4.3.03	Solubility and Sorption Changes From Chemical and Temperature Interactions	Factors related to release of the various contaminants, by desorption and solubility influences, into the invading pore waters. For example, radionuclides in secondary uranium mineral phases, such as neptunium in schoepite and uranium silicates, could affect radionuclide concentrations (during radionuclide alteration, the radionuclides could be chemically bound to immobile compounds and result in a reduction of available radionuclides for mobilization).
4.3.04	Dilution of Radionuclides in Groundwater	Dilution due to mixing of contaminated and uncontaminated water may affect radionuclide concentrations in groundwater during transport in the saturated zone and during pumping at a withdrawal well. For example: Mixing or dilution of the radioactive species from the waste with species of the same element from other sources (i.e., stable and/or naturally occurring isotopes of the same element) could lead to a reduction of the radiological consequences.
4.3.05	Radionuclide Accumulation (Recycling) in Soils	Radionuclide accumulation in soils may occur as a result of upwelling of contaminated groundwater (leaching, evaporation at discharge location), deposition of contaminated water or particulates (irrigation water, runoff), and/or atmospheric deposition. Radionuclides that have accumulated in soils (e.g., from deposition of contaminated irrigation water) may leach out of the soil and be recycled back into the groundwater as a result of recharge (either from natural or agriculturally induced infiltration). The recycled radionuclides may lead to enhanced radionuclide exposure at the receptor.
4.4.01	Human Exposure Pathways	Ingestion, inhalation, and external exposure pathways.
4.4.02	Food Preparation and Water Processing	Factors related to human diet and fluid intake of dietary foodstuffs and water between its original (raw) form and consumption by human beings and animals. Other influences include water filtration, diet of uncontaminated food, and food preparation techniques.
4.4.03	Radon and Radon Daughter Exposure (Noble Gas Contamination)	Radon and radon progeny exposure is considered separately from exposure to other radionuclides because the behavior of radon and its progeny, and their modes of exposure, are somewhat different. Radon is mobile and readily enters different components of the biosphere. Exposure to radon almost always implies exposure to its progeny which are relatively immobile and reactive. The principal mode of exposure to humans is inhalation of radon progeny attached to dust particles.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
4.4.04	Animal, Plant, and Microbe Uptake and Migration of Contaminants	Factors related to migration of radionuclides and chemical contaminants as a result of animal, plant and microbial activity. Radionuclides may be transported and transferred through and between different compartments of the biosphere. Temporally and spatially dependent physical and chemical environments in the biosphere may lead to alteration of both the physical and chemical properties of the radionuclides as they move through or between the different compartments of the biosphere. Uptake and accumulation of contaminants by plants could affect potential exposure pathways. Uptake and bioaccumulation of contaminants in aquatic organisms could affect potential exposure pathways. These plants and aquatic organisms may be used as feed for livestock and/or consumed directly by humans.
4.4.05	Radiological Dose Effects/Risks	The radiation dose is calculated from exposure rates (external, inhalation, and ingestion) and dose coefficients. The latter are based upon radiation type, human metabolism, metabolism of the element of concern in the human body, and duration of exposure. Includes consideration of annual, lifetime, individual, and collective doses. Also includes sensitization to radiation so that its effects are more severe.
4.4.06	Radiological and Chemical Toxicity/Effects	A description of the total toxic content in the waste (organic, inorganic, chemical), and a description of the content of individual toxic elements in the waste. The effects of radiation and chemical contaminants on man and other organisms can be classified in several different ways: somatic or genetic, occurring in the exposed individual or in the offspring of the exposed individual, respectively; and stochastic or non-stochastic, where the probability of the effect is a function of dose received, or the severity of the effect is a function of dose received and no effect may be observed below some threshold, respectively.
4.5.01	Nuclear Criticality	Factors related to possibility and effects of spontaneous nuclear chain reactions within the system (e.g., near-field, far-field, within the waste form, etc.) A chain reaction is the self-sustaining process of nuclear fission in which each neutron released from fission triggers, on average, at least one other nuclear fission. Nuclear criticality requires a sufficient concentration and localized mass (critical mass) of fissile isotopes and also presence of neutron moderating materials in a suitable geometry; a chain reaction will be damped by the presence of neutron absorbing isotopes.
4.5.02	Radiation Effects on the Waste Closure System	When radionuclides decay, the emitted high-energy particle could result in the production of radicals in the water or air and they may then enhance the degradation/corrosion rate of the cementitious materials. Strong radiation fields could lead to radiation damage to the residual waste and surrounding waste tank. This effect would increase the dissolution rate and transport of radionuclides from the residual waste into the groundwater.
4.5.03	Radionuclide Interaction with Corrosion Products	Corrosion of materials will generate a range of possible solid secondary alteration products which depend on the groundwater chemistry. Radionuclides released from the source term may interact with these alteration products by a range of processes such as sorption/desorption or (co-)precipitation/dissolution reactions. These interactions have the potential for significantly controlling radionuclide release rates from the near-field.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
4.5.04	Natural or Background Radiation	Factors related to radiation exposure and risks due to naturally occurring or background radiation.
4.5.05	Medical Radiation	Factors related to radiation exposure and risks due to medical procedures.
4.5.06	Contaminants from Other Man-Made Sources or Facilities	Factors related to radiation exposure and risks due to interactions or cumulative effects from man-made sources (such as other burial grounds or waste closure facilities) in the vicinity of the waste closure facility.
4.5.07	Radiolysis Effects	Alpha, beta, gamma, and neutron irradiation of water can cause disassociation of molecules, leading to gas production and changes in chemical conditions (potential, pH, and concentration of reactive radicals). Radiation emitted during radioactive decay of unstable nuclides can cause radiolysis of the groundwater and of water-bearing solid materials. This radiolysis can lead to the formation of oxidants and free hydrogen gas which will impact on the redox conditions in the near-field, leading to a change in radionuclide solubilities.
5.1.01	Groundwater Flow and Movement (Near-Field)	Unsaturated and saturated flow may occur along preferential pathways in and surrounding the waste tanks. Physical and chemical properties of the cementitious materials, in both intact and degraded states, should be considered in evaluating pathways. Preferential pathways for groundwater flow and diffusion may exist within the transfer lines. Backfill, plugs, and seals may not preclude hydrological, chemical, and thermal interactions between the various system components. Water outflows are responsible for the transport of dissolved radionuclides away from the waste tanks and ancillary equipment.
5.1.02	Groundwater Flow and Movement (Far-Field)	Groundwater flow in the saturated zone below the water table may affect long-term performance of the closure system. The location, magnitude, and direction of flow under present and future conditions and the hydraulic properties of the rock are all relevant.
5.1.03	Episodic Or Pulse Flow and Release	Episodic flow could occur as a result of episodic infiltration. Episodic or pulse release of radionuclides from the waste tanks and radionuclide transport in the groundwater may occur both because of episodic flow into the waste tanks, and because of pulse releases from failed waste tanks.
5.1.04	Water Influx at the Closure Facility	An increase in the water flux at the tank closure facilities may affect thermal, hydrologic, chemical, and mechanical behavior of the system. The cause of the increase is not an essential part of the FEP.
5.1.05	Focusing of Flow Along Preferred Flow Paths (Fingers, Weeps, Faults, Fractures, etc.)	Development of preferential flow paths and/or the alteration of preferential flow paths. Heterogeneities in rock properties, including fractures and faults, may contribute to focusing of unsaturated flow into zones of greater and lower saturation that may persist as preferential flow paths. Fractures or other analogous channels may act as conduits for fluids to move into the subsurface to interact with the waste tanks and as conduits for fluids to leave the vicinity of the waste tanks and be conducted to the saturated zone. Water may flow through only a portion of the fracture network, including flow through a restricted portion of a given fracture plane.
5.1.06	Chemically-Induced Density Effects on Groundwater Flow	Chemically-induced spatial variation in groundwater density may affect groundwater flow.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
5.1.07	Flow Diversion and Bypass Flow	Flow in unsaturated rock tends to be diverted by the closure cap. The resulting diversion of flow could have an effect on seepage into the waste tanks. Flow diversion could also lead to the development of a zone of lower flow rates and low saturation beneath the closure cap. The movement of water through the soil along a pathway other than that provided by the microscopic pore spaces within the soil matrix (such as shrinkage cracks, faunal burrows, and voids left following the decay of plant roots). Bypass flow can transmit water through soils whose matrix is not saturated faster than under laminar flow.
5.1.08	Film/Laminar Flow	Water may enter the waste tanks by a film flow process. This differs from the traditional view of flow in a capillary network where the wetting phase exclusively occupies capillaries with apertures smaller than some level defined by the capillary pressure. A film flow process could allow water to enter a waste tank at non-zero capillary pressure.
5.1.09	External Flow Boundaries	The external flow boundary conditions of the hydrogeological system control the location and amount of recharge and discharge, and are a control on the geometry of the flow system. The external flow boundary conditions are, thus, important to define for modeling groundwater flow and radionuclide transport in the far-field.
5.1.10	Alteration and Chemical Weathering Along Flow Paths	Chemical (water-rock) reactions between groundwater and the rock and any fracture minerals will lead to progressive changes to the solid phases along the flow path and to its hydraulic properties. Ongoing chemical reactions (precipitation and dissolution) between groundwater and rock and fracture minerals lead to weathering of the migration path resulting in increased groundwater flow and channeling. Weathering may alter the mineral composition and physical composition of the fractures and pores, as well as the groundwater chemistry and generation of colloids. These water-rock reactions can impede or enhance radionuclide transport depending on their nature.
5.2.01	Hydrological Response to Geological Changes	Effects on regional groundwater flow and pressures arising from large-scale geological changes. Effects include changes in groundwater flow and pressures caused by erosion, and changes to hydraulic properties of geological units caused by changes in rock stress or fault movements. Within and underlying low-permeability geological formations, the hydrogeological conditions may have characteristics that reflect past geological conditions and are in a state of disequilibrium.
5.2.02	Hydrothermal Activity	Naturally occurring high-temperature groundwater may induce hydrothermal alteration of minerals in the rocks through which the high-temperature groundwater flows. Factors related to hydrothermal activity, the potential for hydrothermal activity and its effects on the performance of the waste closure facility.
5.2.03	Hydraulic Potentials and Gradients	Hydraulic gradients drive fluid flow through the host rock and other rock units. The near-surface hydraulic gradients are topographically controlled and are in equilibrium with the current surface conditions. Hydraulic gradients will evolve with time due to changes in climate and landform, but more significantly due to glacial cycles.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
5.2.04	Interfaces Between Different Waters	There is potential for the development of interfaces between ground waters of different composition in the near and far-field rock. At these interfaces, changes may occur in radionuclide solubilities and groundwater flow which could affect radionuclide transport and release.
5.2.05	Effects related to air and vapor flow and evaporation within the system	FEP addresses the effects of dry-out within the rocks. Natural convective air circulation transfers energy between a hot and a cold region (source and sink, respectively) using the heat of vaporization and movement of the vapor as the transfer mechanism. Two phase circulation continues until the heat source is too weak to provide the thermal gradients required to drive it. Alteration of the rock may include dissolution that maintains the permeability necessary to support the circulation.
5.2.06	Perched Water Develops	Zones of perched water may develop above the water table which may affect flow between the surface and the waste tanks. If these zones develop within the disposal units, a "bath tub" effect may occur (i.e., water "pooling" and possibly filling the unit prior to degradation of the disposal unit walls and/or liner). If they develop below the waste tanks, they may affect flow pathways and radionuclide transport between the waste tanks and the saturated zone.
5.3.01	Contaminant Release and Migration Factors	The Contaminant Release and Migration category is related to the physical, chemical, and radiological processes that directly affect the release (i.e. that will result in the contaminants being available for migration into the environment) and migration of contaminants in the disposal system domain that will result in a contaminant concentration in environmental media.
5.3.02	Contaminant Release Pathways	Factors related to the pathways as well as the associated processes and conditions for the release of radiotoxic and chemotoxic species from its physical state of the waste closure facility. Factors related to the properties and characteristics of smaller discontinuities and features within the geosphere (saturated and unsaturated) that are expected to be the main paths for contaminant migration, and as they may evolve after closure.
5.3.03	Multiphase Transport Processes	Contaminant migration in the disturbed zone could be influenced by: a) the development of a fractured/cracked system caused by the construction of the waste closure facility, b) an alteration of the flow regime caused by a changes in porosity or permeability, c) changes in the sorption properties of the disturbed zone, or d) gaseous (or diffusive) release of contaminants generated in the near-field. Pore water may flow into, and gas out of, the waste tanks in a complex process governed by hydraulic gradients, geosphere gas and liquid flow parameters, gas pressure, and relative saturations in the geosphere.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
5.3.04	Contaminant Release from the Waste Form and Engineered Barrier System	Radionuclides will be released from the waste forms by a variety of mechanisms either into solution, to secondary solid alteration phases, as colloids, or in the gaseous phase. The nature and abundance of the released species will depend on the chemistry of the near-field pore-waters and the degradation rate of the wasteform. Radionuclides in the form of solutes or colloids released from the residual waste can migrate by diffusion or by water exchange from inside the waste tank to the groundwater, after the waste tank has been breached. Radionuclides can also migrate in the gas phase. Release and transport of radionuclides and other solute species from the waste tank will affect the groundwater chemistry (radionuclide content) inside the waste tank and in the surrounding soil. Radionuclides released from the waste tank can be transported through the backfill in solution or as a gas, and possibly also in colloidal form. The mechanisms and rate of radionuclide transport through the backfill are determined largely by the physical properties of the backfill materials. Transport through the backfill controls the release rate to the near-field environment.
5.3.05	Solid-Mediated Migration of Contaminants	The transport of radionuclides and chemical contaminants in large-scale solid phase movement (such as large-scale erosion processes) or smaller-scale processes (such as rinse mechanisms or colloidal transport) can also occur, leading to movement of contaminants.
5.3.06	Gas-Mediated Migration of Contaminants	The transport of radionuclides and chemical contaminants in gas or vapor phase, or as fine particulate or aerosols suspended in gas or vapor. Radioactive and chemically toxic gases may be generated by degradation of waste closure facility components, generated from the wastes, microbial degradation of organic material, or naturally occurring, and transported in the gas phase into the geosphere. The gas generated may form a free gas phase that could impact on the transport and release of radionuclides. In some cases, radionuclides may be directly associated with the gas molecules whilst, in other cases, the gas phase will impact on the movement of ground waters containing dissolved radionuclides. Pressure variations due to gas generation may affect flow patterns and contaminant transport in the natural system. Issues such as dwelling location, which could affect seepage of gases such as radon into basements, and heating source, could involve biogas production.
5.3.07	Water-Mediated Migration of Contaminants	Transport of radionuclides and chemical contaminants in groundwater and surface water. Water-mediated transport processes include: a) advection or movement with the bulk movement of the fluid, b) percolation or convection, where the movement of the fluid is driven by gravity and heat, respectively, c) dispersion, or the spread in the spatial distribution of contaminants with time because of differential rates of advective or convective transport, d) molecular diffusion, or the random movement of individual atoms or molecules within the fluid; matrix diffusion or diffusion into stagnant pores, and e) multiphase transport processes including unsaturated flow.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
5.3.08	Diffusion (Molecular Diffusion and Matric)	Diffusion is the process whereby chemical species move through water-filled cracks and voids under the influence of a chemical potential gradient (usually a concentration gradient). Radionuclides can migrate by diffusion from inside the tank to the backfill, after the tank has been breached. In addition, dissolved species in the ground waters outside the tank can be transported into the tank by diffusion. Both inward and outward diffusion of species will affect the groundwater chemistry and the release of solubility controlled species. Matrix diffusion is the process by which radionuclides and other species in the water flowing along fractures migrate into the non-flowing micro-fractures and into the micro-porosity of the surrounding rock mass. Matrix diffusion can provide an efficient retardation mechanism for both sorbing and non-sorbing contaminants.
5.3.09	Dispersion and Imbibition	Dispersion is the collective name for the consequences of a number of processes that cause 'spreading-out' of a contaminant plume in all directions, superimposed on the bulk movement predicted by a simple advection model. It results in a spatially distributed contaminant plume. Water flowing in fractures or other channels in the unsaturated zone may be imbibed into the surrounding rock matrix. This may occur during steady flow, episodic flow, or into matrix pores that have been dried out during the thermal period.
5.3.10	Advection	Transport of fluids and dissolved contaminants by advection with the flowing groundwater may occur. Physical and chemical properties of the system and system components, in both intact and degraded states, should be considered in evaluating advective transport.
5.3.11	Sorption and Desorption of Dissolved Contaminants (Kd Retardation)	Sorption and desorption of radionuclides and chemical contaminants describes the physicochemical interactions of a dissolved species with a solid phase to remove the species from solution. Desorption is the opposite process. Sorption and desorption are often described by a simple partition coefficient (Kd), also called the distribution constant. Sorption of radionuclides from the waste occurring on the cementitious materials, their degradation products, and on surfaces of fractures and matrix in rock or soil will retard the migration of those species. Sorption may be reversible or irreversible, and it may occur as a linear or nonlinear process.
5.3.12	Radionuclide Fluxes to the Biosphere	Radionuclide fluxes from the closure facility into environmental media as an indicator of barrier performance. Care should be taken to define appropriate areas and volumes over which the fluxes are to be defined in order to make comparisons between those derived from the waste closure facility and fluxes of naturally occurring radionuclides.
5.3.13	Fast Transport Pathways	Fast pathways for water and radionuclide transport between the surface and depth can occur in the form of highly transmissive natural features (such as large fractures) or as poorly sealed shafts and boreholes. The presence of such fast pathways could potentially bypass large regions of the far-field rock and lead to early and large releases to the surface.
5.3.14	Long-Term Release of Radionuclides	The release of radionuclides to the environment may occur over a long period of time, as a result of the timing and magnitude of the waste tanks/waste packages degradation, and radionuclide transport.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
5.3.15	Radionuclide Release Outside The Reference Biosphere	Radionuclide releases and accumulations outside the reference biosphere can occur. This could include: a) areas surrounding distant springs and surface water bodies, b) remote natural outfalls, and c) discharge areas such as playas, forests, grasslands, or wetlands that occur in isolated areas in the region. This might also include withdrawal from wells in remote areas. Sediment transport and redistribution may cause concentration or dilution of radionuclides. Flora and fauna in these areas may be exposed and radionuclides be bioaccumulated and enter the food chain. Intermittent use of these areas by humans may also lead to exposure.
5.3.16	Vadose Zone Depth	The vertical distance between the bottom of the floor of the disposal unit or closure facility and the top of the saturated zone.
5.3.17	Saturated Zone Depth	The vertical distance between the top of the saturated zone and the bottom point (or intake) of the assessment well.
5.3.18	Depth of Assessment Well	The depth from which the assessment well draws water.
5.3.19	Horizontal Distance to Points of Assessment	The horizontal distance between the waste closure facility and the assessment well or stream.
6.1.01	Inadvertent Human Intrusion	Humans without knowledge or awareness of the existence of the waste closure facility could accidentally intrude into the system and experience exposures to contaminants. In addition, activities may result in damage to containment, increasing contaminant release rates. An example of an inadvertent action includes an archeological or scientific study of the site. Note: other intrusions (such as meteorite impacts, drilling, and excavating) are discussed in other FEPs.
6.1.02	Deliberate Human Intrusion	Humans could deliberately intrude into the waste closure facility although without appropriate precautions, and experience exposures to contaminants. In addition, activities may result in damage to containment, increasing contaminant release rates. Motivation for deliberate human intrusion includes: a) mining and waste retrieval, b) site remediation/improvement activities, c) facility sabotage, and d) acts of war. Note that other intrusions (such as meteorite impacts, drilling, and excavating) are discussed in other FEPs.
6.1.03	Drilling Activities	Factors related to any drilling activities in the vicinity of the waste closure facility. This includes: a) exploratory boreholes (for minerals or natural gas and oil), b) boreholes drilled for water-supply wells, c) boreholes drilled before construction of the facility, and d) boreholes drilled after the existence or the purpose of the closure facility has been forgotten. Other drilling activities might include: a) the production of geothermal energy, b) the injection of liquid wastes, and c) other scientific studies.
6.1.04	Excavating and Mining Activities	Factors related to any excavation and mining activities in the vicinity of the waste closure facility (excluding drilling). This includes: a) mining for natural resources (ore, oil, gas, etc.), b) mining to retrieve or extract components of the waste or of the closure facility, c) tunneling for the purpose of constructing subterranean dwellings, and d) tunneling for the purpose of additional waste storage or disposal. Activities may include: a) open excavation, b) tunneling, c) solution mining, d) digging, e) blasting, f) breaking, and g) loading and hauling of material. Some of these activating may result in the production of tailings, which may subsequently release contaminants.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
6.1.05	Animal/Plant Intrusion	Factors related to the intrusion of animal and plant into the waste closure facility, leading to the disruption in performance.
6.1.06	Igneous or Seismic Event Precedes Human Intrusion	An igneous or seismic event (e.g., a dyke) could intersect the waste closure facility and alter the material and structural properties of the closure system (engineered and natural barriers). Because of the change in properties of these materials resulting from an igneous intrusion, an intruder using groundwater exploration drilling techniques may not be able to recognize that something other than naturally-occurring material has been encountered.
6.2.01	Seismicity	Factors related to the effects of seismic events on the closure system. Such factors include: a) liquefaction of the backfill materials and soils, b) shaking and damage to the waste form or engineered components, c) rockfalls, and d) extension or creation of fractures or faults. External effects also include: a) tidal waves (tsunamis), b) liquefaction of soil, c) formation of new discharge areas, d) alteration of river courses, and e) destruction of dams. Multiple events occurring close together in time might have effects that are not simply additive.
6.2.02	Seismic-Induced Damage or Changes to System Components	Factors related to physical damage or property changes to components of the waste closure system due to seismic events. Types of damage include: a) damage from repeated vibration, b) damage from physical contact between components, c) damage from rockfall, d) damage from stress resulting in dynamic or static loading, and e) damages related to movement or displacement of components or materials. Such damage mechanisms could lead to degraded performance. This includes changes to system chemistry, hydrology, and thermo-hydrology. Consider effects on porosity and permeability, fault and fractures, and effects to perched water and aquifers.
6.2.03	Effects of Subsidence	Subsidence at or near the closure facility may affect the properties of the natural system materials and surface topography. Changes in rock and soil properties, such as enhanced permeability, may alter flow paths from the surface to the waste closure facility. Changes in surface topography may alter run-off and infiltration, and may create impoundments.
6.2.04	Seismicity Associated with Igneous Activity	Seismicity associated with future igneous activity that may affect disposal and closure system performance.
6.3.01	Igneous Intrusion Into the Closure Facility	Igneous activity at or near the waste closure facility may cause change the backfill and rock and soil properties (e.g., stress fields, thermal regimes, permeabilities, etc.). This may alter the hydrology, mineralogy, or the overall integrity of the waste closure facility. Magma from an igneous intrusion may flow into the facility, forming a sill, dike, or dike swarm. This could result in magma, pyroclastic debris, and volcanic gases entering the facility and interacting with the engineered components and the waste forms. This could lead to accelerated system failure (e.g., attack by magmatic volatiles, damage by flowing or fragmented magma, thermal effects) and dissolution or volatilization of waste. Igneous activity may change the infiltration rates, groundwater flow directions, water level, water chemistry, and temperature.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
6.3.02	Volcanic Eruptions and Magmatic Activity	Factors related to volcanic eruptions and magmatic activities, including changes to topography or surface drainage patterns (via effusive lava flows or development of a volcanic cone). Specifically, magmatic vents could pass directly through the waste closure system, interacting with the waste. Some of the waste (entrained, dissolved, or volatized) could then be transported away from the waste closure facility. Of most concern is transport directly along the land surface to the MOP. Additionally, large-scale volcanic activity has the potential to influence short-term climatic change that could alter rainfall and infiltration.
6.3.03	Ashfall	Following a volcanic event, finely divided waste particles may be carried up a volcanic vent and deposited on the land surface from an ash cloud. Deposited contaminants may leach out of the ash and be transported through the subsurface or redistributed on the surface via aeolian and fluvial processes.
6.4.01	Releases Prior to Closure	Factors related to release of contaminants after waste emplacement but prior to closure of the waste closure facility.
6.4.02	Flooding or Drainage System Failure	Factors related to flooding (or drainage system failures) of the site or facilities during construction, operation, or post-closure that could introduce additional water into the system, which could affect the long-term performance of the waste closure facility.
6.4.03	Movement of the Waste Form	Backfill provides a stable physical and chemical environment for the wasteform, and isolates the engineered system components from the near-field natural environment and flowing ground waters. The effectiveness may be diminished if the waste moves within the backfill. This could occur as a result of sinking, uneven swelling of clays and backfill materials, expansion of engineered system materials, or movement of the near-field geosphere via slumping or stresses.
6.4.04	Cave-In, Collapse, or Rockfall	Partial or complete collapse or cave-in of the engineered components or discrete rockfall could occur as a result of thermal effects, stresses related to excavation, or other mechanisms (including seismic activity). Cave-ins and rockfalls could affect the stability of the engineered components or result in static loading from rock overburden, as well as altering flow paths.
6.4.05	Accidents and Unplanned Events	Factors related to accidents and unplanned events, which might have an impact on long-term performance or safety of the waste closure facility.
6.4.06	Explosions and Crashes	Factors related to deliberate or accidental explosions and crashes that might impact the waste closure facility. Examples include: a) underground nuclear testing, b) aircraft crash on the site, c) acts of war or sabotage, and d) accidental equipment or chemical explosions.
6.4.07	Impacts from Meteorites or Space Debris	Factors related to impacts from meteorites or space debris (natural or man-made) occurring at or near the waste closure system. Such impacts could create a crater, damage system components, or cause physical and chemical changes in materials.
6.4.08	Extraterrestrial Events	Factors related to extraterrestrial events (e.g., supernova, solar flare, gamma-ray burster, and events associated with alien life forms) may affect long-term performance of the disposal system.
6.4.09	Changes in the Earth's Magnetic Field	Changes in the earth's magnetic field could affect the long-term performance of the waste closure facility.

Table 3.0-4: Initial (Unscreened) FEPs List for SRS LW PAs (Continued)

FEP ID	FEP Name	FEP Description
6.4.10	Changes to Earth's Tidal Processes	Earth tides are small pressure variations in the groundwater flow system caused by changes to the gravitational field due to the relative movements of the Earth, the Sun and the Moon. Earth tides may have an influence on the transport and retardation of radionuclides in the far field.

Source: "SRS_LW_FEPs_Rev0.xlsx" (in the sheet: "Initial_List").

4.0 FEPs SCREENING

The scope of PA modeling is limited by the extent that observed phenomena may influence modeling results and by the computing resources that are available (i.e., it is not practical to develop PA models that simulate *every* FEP). Therefore, each FEP needs to be screened to determine whether or not it should be considered within PA modeling or analyses.

The FEPs Screening Team was assembled from subject matter experts (see Section 6.0) to screen FEPs from the initial FEPs list (Table 3.0-4). This team applied a two-phased screening process as shown in Figures 4.0-1 and 4.0-2. During the first phase, team members independently applied the FEPs screening criteria, as defined in Section 4.1, to each FEP, via a survey. These independent survey results were collected and FEPs were screened based on the initial responses, as described below. During the second phase of the screening process, the team discussed the FEPs and dispositioned them as either "screened in" or "screened out" based upon their discussions. Phases I and II are both discussed in greater detail below.

Figure 4.0-1: Phase I FEPs Screening: Team Survey

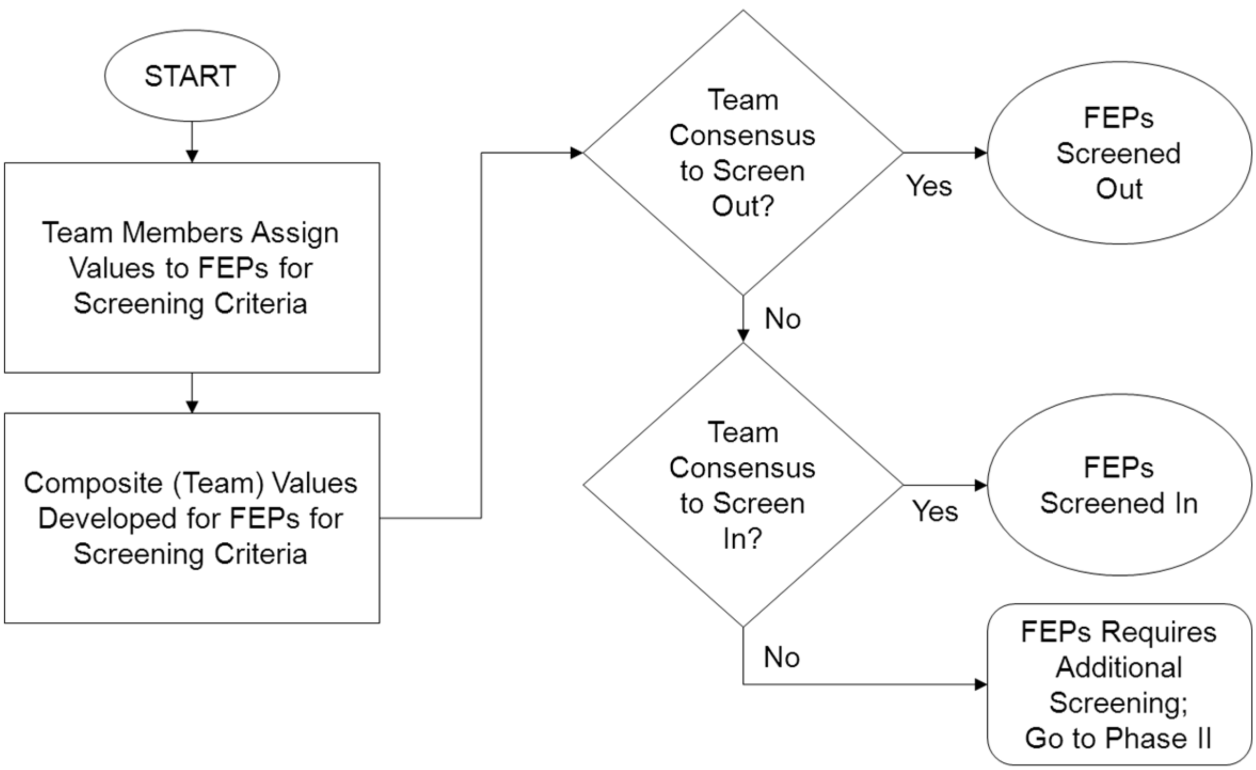
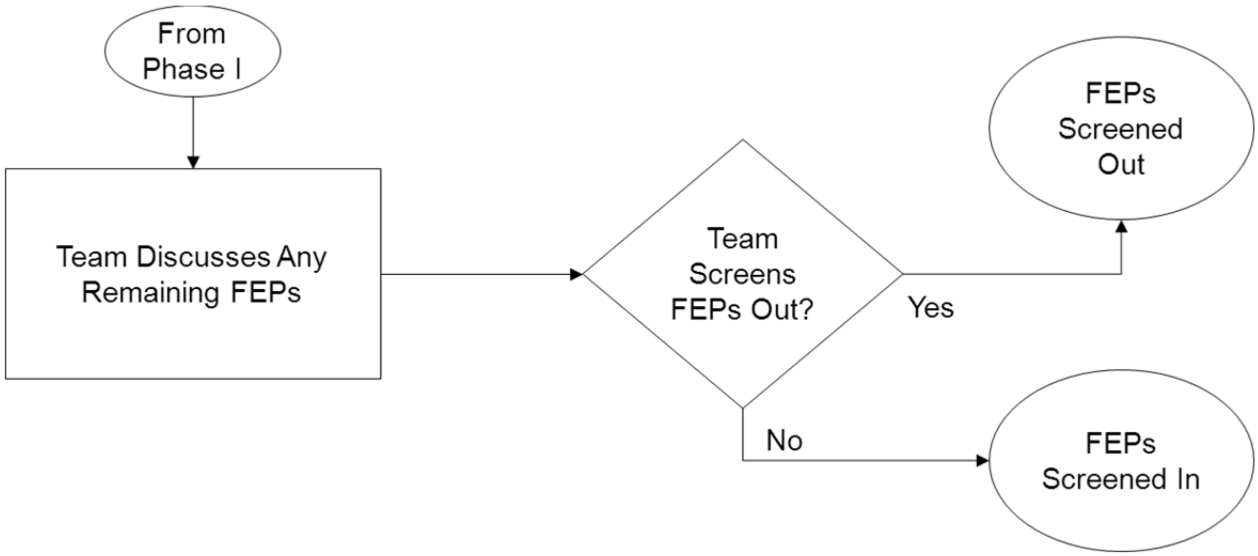


Figure 4.0-2: Phase II FEPs Screening: Team Discussion



All included (screened in) FEPs will be considered and/or evaluated with respect to each LW PA. As noted in Section 2.0, “screening in” does not require the FEPs to be explicitly modeled. Consideration for these FEPs may be given through a variety of methods. These methods include, but are not limited to: explicit modeling, implicit modeling using bounding conditions, secondary analysis, design consideration, administrative procedures, PA maintenance processes, etc.

Note that prior to Phase I, the initial FEPs list was reviewed by members of C&WDA Closure Assessments to identify FEPs that required inclusion into the final FEPs list for programmatic purposes. C&WDA Closure Assessments identified 46 FEPs for initial inclusion into the final FEPs list. Table 4.0-1 identifies the 46 FEPs that were initially screened in by C&WDA Closure Assessments to programmatically support PA functionality.

Table 4.0-1: FEPs Programmatically Screened In

FEP ID	FEP Name
1.1.01	Assessment Context Factors
1.1.02	Assessment Purpose
1.1.03	Assessment Conditions
1.1.04	Documentation and Presentation of Results
1.1.05	Transparency of Assessment Approach
1.1.06	Assessment Timeframe (Phases of Disposal)
1.1.07	Safety Effects Beyond Periods of Control
1.1.08	Spatial Domain of Concern
1.1.09	Assessment Endpoints
1.2.01	Regulatory Compliance
1.2.02	Protection of Human Health and the Environment
1.2.03	Performance Requirements and Criteria
1.2.04	Functional and Technical Requirements and Criteria
1.2.05	ALARA
1.2.06	Administrative Control of the Waste Closure Facility
1.2.07	Waste Acceptance Requirements and Criteria
1.3.01	Model and Data Issues
1.3.02	Software Codes
1.3.03	Model Approaches
1.3.04	Systematic Assessment Approach
1.3.05	Iterative Assessment Approach
1.3.06	Realistic Assessment Approach
1.3.07	Conservative Assessment Approach
1.3.08	Reasonable Assurance Assessment Approach
1.3.09	Prospective Evaluation Assessment Approach
1.3.10	Uncertainties
1.3.11	Sensitivity Analyses
1.3.12	Model Confidence
1.3.13	Alternative Simplified Modeling Approach
1.3.14	Evaluate Multiple Endpoints
1.3.15	Processing Limitations to Modeling
1.4.01	Development of Expertise
1.4.02	Monitoring and Surveillance
1.4.03	Retrievability
1.4.04	Regulatory and Peer Reviews
1.4.05	Confidence Building (External to Modeling)
1.4.06	Target Audience (Stakeholders Involvement)
2.1.01	Definition of the Exposed Member of the Public
3.1.01	Site Characterization and Investigations
3.1.02	Site Development
3.1.03	Facility Factors
3.1.04	Multi-Barrier Safety Function
3.2.01	Design Basis for Engineered Components
3.2.02	Schedule and Planning
5.3.01	Contaminant Release and Migration Factors
5.3.02	Contaminant Release Pathways

Source: “SRS_LW_FEPs_Rev0.xlsx” (in the sheet: “Screening”).

4.1 FEPs Screening Criteria

Each FEP was screened by the FEPs Screening Team based on (1) the perceived probability of occurrence (or frequency) within 10,000 years and (2) the perceived consequence (or impact) relative to final PA results and expected compliance. This screening approach was modeled after the Savannah River Site's Consolidated Hazard Analysis Process (CHAP). The CHAP approach is defined in Sections 7.2, 7.3 and 7.4 of *Consolidated Hazard Analysis Process*. [Manual SCD-11, Rev. 9]

Due to the complexity of the waste closure facilities and related flow and transport processes reflected in PA modeling, and due to the relatively long time frames considered for PAs, the frequencies and consequences for many FEPs are often difficult to quantify. Recognizing these limitations, screening criteria were established based on the ISAM and TSPA FEP screening methodologies. The ISAM and TSPA FEPs screening methodologies are described in Section 4.3.4 of *Safety Assessment Methodologies for Near Surface Disposal Facilities, Results of a Co-ordinated Research Project*, Volume 1 and in Section 6.2 of *Features, Events, and Processes for the Total System Performance Assessment: Methods*, respectively. [ISBN 92-0-104004-0; ANL-WIS-MD-000026 REV 00]

The initial screening criteria used by the FEPs Screening Team, and the associated screening matrix, are defined in Tables 4.1-1, 4.1-2, and 4.1-3. These tables include ordinal values for each criterion.

Table 4.1-1: FEPs Screening Criteria for Perceived Frequency

Description	Perceived Frequency	Score
Anticipated, Expected, or Already Known to Exist or Occur	Will Occur in 10,000 Years	2
Unlikely or Extremely Unlikely	May Occur in 10,000 Years	1
Beyond Extremely Unlikely	Not Expected to Occur in 10,000 Years	0

Table 4.1-2: FEPs Screening Criteria for Perceived Impact

Description	Perceived Impact to Member of Public	Score
High	Significant Impact on Release or Dose	2
Moderate	Moderate Impact on Release or Dose	1
Negligible	No or Negligible Impact on Release or Dose	0

Table 4.1-3: FEPs Screening Criteria Matrix

Frequency / **Impact**		Beyond Extremely Unlikely	Unlikely or Extremely Unlikely	Anticipated, Expected, or Already Known to Exist or Occur
		0	1	2
High	2	*Considered*	Screened In	Screened In
Moderate	1	Screened Out	*Considered*	*Considered*
Negligible	0	Screened Out	Screened Out	Screened Out

4.2 Phase I: Team Survey Screening

Each member of the FEPs Screening Team was provided with the initial FEPs list and instructed to use their professional judgment to assign the most appropriate ordinal values for each FEP, much like completing a survey. They reviewed each FEP and assigned an ordinal score for each screening criterion (shown in Tables 4.1-1 and 4.1-2). If they were undecided as to which value to assign to a specific FEP, they were instructed to conservatively assign the highest applicable value. Note that this approach relies on the qualitative perceptions (based on knowledge and professional expertise) of the subject matter experts rather than on some measured or quantified set of values.

Each team member initially performed this scoring independently to ensure that members scored each FEP based upon their own expertise and did not bias their decisions based on group influences. The values from each survey were then mapped to the screening matrix (shown in Table 4.1-3). Given the wide variety of backgrounds among the team members, if the team members agreed to screen a FEP in or out, prior to any discussion, then it is assumed that the FEP is well understood and further discussion or evaluation of the FEP is not necessary. Any FEPs that were not initially screened during this first phase advanced to the second phase.

The results of the initial screening survey are provided in the following tables. Table 4.2-1 shows the FEPs that were screened out by the survey results. These were FEPs in which *none* of the Screening Team Members' surveys resulted in a decision to screen the FEP in (i.e., all of the surveys indicated that the FEP should either be "screened out" or "considered"). Table 4.2-2 shows the FEPs that were screened in by the survey results. These were FEPs in which *none* of the Screening Team Members' surveys resulted in a decision to screen the FEP out (i.e., all of the surveys indicated that the FEP should either be "screened in" or "considered").

The remaining FEPs were not screened in or out during Phase I (i.e., the survey results included some combination of "screen in", "screen out", and "consider"). These FEPs advanced to Phase II of the screening process for additional consideration, as described in Section 4.3. Note that the one FEP in which all responses resulted in "considered" (FEP 6.4.07) was discussed during Phase II.

Table 4.2-1: FEPs Screened Out During Phase I

FEP ID	FEP Name	Phase I Results	Discussion
2.6.11	Large Scale Salt Processes (Diapirism, Dissolution, and Creep)	Screen Out	Screened out by the frequency criteria: this FEP is beyond extremely unlikely.
6.3.03	Ashfall	Screen Out	Screened out by the frequency criteria: this FEP is beyond extremely unlikely.
6.4.08	Extraterrestrial Events	Screen Out	Screened out by the impact criteria: this FEP would have a negligible impact on PA results.
6.4.09	Changes in the Earth's Magnetic Field	Screen Out	Screened out by the Impact criteria: This FEP would have a negligible impact on PA results.
6.4.10	Changes to Earth's Tidal Processes	Screen Out	Screened out by the Impact criteria: This FEP would have a negligible impact on PA results.

Source: “SRS_LW_FEPs_Rev0.xlsx” (in the sheet: “Screening”).

Table 4.2-2: FEPs Screened In During Phase I

FEP ID	FEP Name	Phase I Results	Discussion
2.3.02	Future Knowledge of the Facility	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
2.6.01	Mechanical Effects on Geologic Features	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
2.6.08	Erosion and Weathering	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
2.6.12	Hydrogeological Processes and Conditions	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
2.7.02	Climate and Weather	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
2.8.04	Surface Runoff	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
2.8.07	Discharge Zones Within the Assessment Domain	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
2.8.09	Hydrological Regime and Water Balance (Near-Surface)	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.3.04	Waste Tank, Container, or Package Characteristics	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.3.08	Disposal Unit and/or Facility Wall and Roof Thicknesses	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.3.09	Disposal Unit or Facility Floor Thickness	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.4.01	Hydrological Processes and Conditions	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.4.02	Hydrostatic Pressure on the Closure System	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.5.01	Chemical/Geochemical Processes and Conditions	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.5.02	Evolving Water Chemistry in the Engineered System and Waste Form	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.

Table 4.2-2: FEPs Screened In During Phase I (Continued)

FEP ID	FEP Name	Phase I Results	Discussion
3.5.03	Evolving Water Chemistry in the Near-Field	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.5.07	Colloid Generation	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.5.10	Complexation in the Natural System	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.7.02	Corrosion	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.7.03	Stress-Corrosion Cracking and Hydride Cracking of Engineered System Metals	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.7.06	Waste Container, Package, or Over-Pack Failure	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.7.07	Degradation of Non-Metal Solids: Backfill, Rock, Grout, Cement, etc.	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.7.09	Concrete Shrinkage/Expansion	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.7.10	Sulfate and Chloride Attack	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.7.11	Carbonation	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.8.01	Alternatives to Pre-Closure Activities	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.8.02	Incomplete Closure	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.8.03	Error in Waste Removal and Stabilization	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.8.07	Material Volume Changes	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.8.08	Electrochemical Effects in the Closure System (Including Anion Exclusion)	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
3.8.09	Mechanical Effects at EBS Component Interfaces	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.1.02	Waste Form Characteristics	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.1.03	Waste Inventory	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.1.06	Highly Radioactive Radionuclides (HRRs)	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.1.09	Organic Wastes	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.2.01	Radioactive Decay and In-Growth	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.2.02	Activity Limits in Disposed Waste	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.2.03	Contaminant Solubility, Solubility Limits, and Speciation	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.

Table 4.2-2: FEPs Screened In During Phase I (Continued)

FEP ID	FEP Name	Phase I Results	Discussion
4.2.06	Degradation of the Inorganic Waste	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.2.07	Degradation of the Organic Waste	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.3.01	Contaminant Concentrations in Water and Other Media	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.3.02	Dissolution and Precipitation	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.3.03	Solubility and Sorption Changes From Chemical and Temperature Interactions	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.3.04	Dilution of Radionuclides in Groundwater	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.3.05	Radionuclide Accumulation (Recycling) in Soils	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.4.01	Human Exposure Pathways	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.4.04	Animal, Plant, and Microbe Uptake and Migration of Contaminants	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.5.03	Radionuclide Interaction with Corrosion Products	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
4.5.07	Radiolysis Effects	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.1.01	Groundwater Flow and Movement (Near-Field)	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.1.03	Episodic Or Pulse Flow and Release	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.1.04	Water Influx at the Closure Facility	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.1.05	Focusing of Flow Along Preferred Flow Paths (Fingers, Weeps, Faults, Fractures, etc.)	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.1.07	Flow Diversion and Bypass Flow	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.1.08	Film/Laminar Flow	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.1.09	External Flow Boundaries	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.2.04	Interfaces Between Different Waters	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.2.06	Perched Water Develops	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.3.04	Contaminant Release from the Waste Form and Engineered Barrier System	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.3.07	Water-Mediated Migration of Contaminants	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.

Table 4.2-2: FEPs Screened In During Phase I (Continued)

FEP ID	FEP Name	Phase I Results	Discussion
5.3.08	Diffusion (Molecular Diffusion and Matric)	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.3.09	Dispersion and Imbibition	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.3.10	Advection	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.3.11	Sorption and Desorption of Dissolved Contaminants (Kd Retardation)	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.3.14	Long-Term Release of Radionuclides	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.3.16	Vadose Zone Depth	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
5.3.19	Horizontal Distance to Points of Assessment	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
6.1.05	Animal/Plant Intrusion	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
6.4.06	Explosions and Crashes	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.
6.4.07	Impacts from Meteorites or Space Debris	Screen In	Screened in based on survey results: no team members identified this FEP for screen out.

Source: "SRS_LW_FEPs_Rev0.xlsx" (in the sheet: "Screening").

4.3 Phase II: Team Discussion Screening

Tables 4.0-1, 4.2-1, and 4.2-2 (above) showed the screening dispositions for 116 of the 262 initial FEPs. The FEPs Screening Team met and discussed the remaining 146 FEPs. In addition to the probability and impact values for each FEP, these discussions also considered available knowledge (or uncertainty) and synergism with other FEPs. These FEPs were carefully evaluated and dispositioned (screened in or out) by the team and a justification was determined for any FEP that was screened out. No justification is required for FEPs that are screened in.

Table 4.3-1 provides the final screening disposition for all of the FEPs screened during Phase II.

Table 4.3-1: Phase II FEPs Screening Results

FEP ID	FEP Name	Screening Decision	Justification for Screening Out
2.1.02	Human Physiology (Metabolism, Diet, and Fluid Intake)	Screen In	N/A
2.1.03	Human Behavior and Habits (Non-Diet Related)	Screen In	N/A
2.1.04	Human Dwellings	Screen In	N/A
2.1.05	Demographics and Community	Screen In	N/A
2.2.01	Natural and Geological Resources and Land Use	Screen In	N/A
2.2.02	Water Management	Screen In	N/A

Table 4.3-1: Phase II FEPs Screening Results (Continued)

FEP ID	FEP Name	Screening Decision	Justification for Screening Out
2.2.03	Natural/Semi-Natural Land and Water Use	Screen In	N/A
2.2.04	Rural and Agricultural Land and Water Use	Screen In	N/A
2.2.05	Urban and Industrial Land and Water Use	Screen In	N/A
2.2.06	Leisure and Other Uses of the Environment	Screen In	N/A
2.2.07	Pollution (Soil, Groundwater, Air, etc.)	Screen Out	This FEP is screened out as it is considered outside the scope of a PA (per DOE Order 435.1 and an NRC 10 CFR part 61).
2.3.01	Future Human Actions (Active)	Screen In	N/A
2.3.03	Social and Institutional Developments	Screen In	N/A
2.3.04	Technological Developments	Screen In	N/A
2.3.05	No Technological Development	Screen In	N/A
2.3.06	Retrograde Developments	Screen In	N/A
2.3.07	Ozone Layer Failure	Screen Out	This FEP is screened out as it is considered outside the scope of a PA (per DOE Order 435.1 and an NRC 10 CFR part 61).
2.4.01	Biomes	Screen In	N/A
2.4.02	Microbial Activity	Screen In	N/A
2.4.03	Vegetation	Screen In	N/A
2.4.04	Animal Populations	Screen In	N/A
2.4.05	Species Evolution	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that it would be beyond extremely unlikely for this to affect PA results.
2.5.01	Geological Environment and Processes	Screen In	N/A
2.5.02	Topography and Landforms	Screen In	N/A
2.5.03	Depositional Environments and Landforms	Screen In	N/A
2.5.04	Stratigraphy and Host Lithology	Screen In	N/A
2.5.05	Geologic Discontinuities and Boundary Conditions (Fractures, Faults, and Cracks)	Screen In	N/A
2.5.06	Near-Surface Aquifers and Water-Bearing Features	Screen In	N/A
2.5.07	Unconsolidated Soft Zones	Screen In	N/A
2.5.08	Undetected Geologic Features	Screen In	N/A
2.5.09	Stress Regimes	Screen Out	This FEP is screened out because the environment considered for LW PAs is too shallow for this feature to result in any significant impact.
2.5.10	Soils and Sediment	Screen In	N/A
2.5.11	Hydraulic Properties	Screen In	N/A
2.6.02	Tectonic Activity and Processes	Screen In	N/A

Table 4.3-1: Phase II FEPs Screening Results (Continued)

FEP ID	FEP Name	Screening Decision	Justification for Screening Out
2.6.03	Orogeny	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that it would be beyond extremely unlikely for this to affect PA results.
2.6.04	Deformation and Metamorphism	Screen In	N/A
2.6.05	Diagenesis and Pedogenesis	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that it would be beyond extremely unlikely for this to affect PA results.
2.6.06	Sedimentation	Screen Out	This FEP is screened out because the environment considered for LW PAs is too shallow for this process to result in any significant impact.
2.6.07	Deposition	Screen In	N/A
2.6.09	Mass Wasting	Screen In	N/A
2.6.10	Creeping of the Rock Mass	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that it would be beyond extremely unlikely for this to affect PA results.
2.7.01	Atmosphere	Screen In	N/A
2.7.03	Precipitation	Screen In	N/A
2.7.04	Acid Rain	Screen Out	This FEP is screened out as it is considered outside the scope of a PA (per DOE Order 435.1 and an NRC 10 CFR part 61).
2.7.05	Warm Weather Effects	Screen In	N/A
2.7.06	Cold Weather Effects	Screen In	N/A
2.7.07	Climate Change	Screen In	N/A
2.7.08	Solar Radiation	Screen In	N/A
2.8.01	Water	Screen In	N/A
2.8.02	Surface-Water Bodies	Screen In	N/A
2.8.03	Evapotranspiration	Screen In	N/A
2.8.05	Capillary Rise	Screen In	N/A
2.8.06	Infiltration and Recharge	Screen In	N/A
2.8.08	Discharge Zones Outside the Assessment Domain	Screen In	N/A
3.2.03	Procurement of Items and Services	Screen In	N/A
3.2.04	Costs of Construction, Operation, Closure	Screen Out	This FEP is screened out as it is considered outside the scope of a PA (per DOE Order 435.1 and an NRC 10 CFR part 61).
3.2.05	Construction	Screen In	N/A
3.2.06	Operation	Screen In	N/A
3.2.07	Removal or Stabilization of Waste	Screen In	N/A
3.2.08	Disposal Unit and/or Facility Closure	Screen In	N/A
3.3.01	Closure System Features and Materials	Screen In	N/A

Table 4.3-1: Phase II FEPs Screening Results (Continued)

FEP ID	FEP Name	Screening Decision	Justification for Screening Out
3.3.02	Manufacturing and Commissioning of Components	Screen In	N/A
3.3.03	Consolidation of System Components	Screen In	N/A
3.3.05	Closure System Buffer (Closure Cap, Backfill, and Near-Field Soil) Properties	Screen In	N/A
3.3.06	Bentonite and Vermiculite Effects	Screen In	N/A
3.3.07	Closure Cap Thickness and Material Properties	Screen In	N/A
3.3.10	Ancillary Equipment and Piping/Transfer Lines	Screen In	N/A
3.4.03	Condensation on Closure System Surfaces	Screen In	N/A
3.4.04	Resaturation and Desaturation	Screen In	N/A
3.5.04	Evolving Water Chemistry in the Far-Field	Screen In	N/A
3.5.05	pH Conditions	Screen In	N/A
3.5.06	Eh Conditions	Screen In	N/A
3.5.08	Chemical Effects of Waste-Rock Contact	Screen In	N/A
3.5.09	Rind (Chemically Altered Zone) Forms in the Near-Field	Screen In	N/A
3.5.11	Reaction Kinetics	Screen In	N/A
3.5.12	Chelating Agent Effects	Screen Out	This FEP is screened out because the LW closure systems are not affected by any chelating agents.
3.5.13	Osmotic Effects	Screen In	N/A
3.5.14	Leaching	Screen In	N/A
3.6.01	Thermal Processes and Conditions the Engineered System	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that the environment of the SRS LW closure system does not have enough heat to significantly impact PA results.
3.6.02	Thermal Processes and Conditions the Natural System	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that the environment of the SRS LW closure system does not have enough heat to significantly impact PA results.
3.6.03	Thermo-Chemical Alteration, Near-Field	Screen In	N/A
3.6.04	Thermo-Mechanical Stresses Alter Characteristics of Engineered Barrier System Components	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that the environment of the SRS LW closure system does not have a significant thermal gradient to significantly impact PA results.
3.6.05	Recrystallization of Vitrified Wastes	Screen Out	This FEP is screened out as the LW PAs do not include any vitrified wastes as source terms.

Table 4.3-1: Phase II FEPs Screening Results (Continued)

FEP ID	FEP Name	Screening Decision	Justification for Screening Out
3.6.06	Effects of System Heat on the Biosphere	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that the environment of the SRS LW closure system does not have enough heat to significantly impact PA results.
3.6.07	Temperature and Thermal Gradient Effects on the Geosphere	Screen In	N/A
3.7.01	Chemical Degradation of Engineered System Metals	Screen In	N/A
3.7.04	Creep of Metallic Materials in the Engineered System	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that the environment of the SRS LW closure system does not have enough heat to significantly impact PA results.
3.7.05	Oxygen Embrittlement of Engineered System Metals	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that the environment of the SRS LW closure system does not have enough heat to significantly impact PA results.
3.7.08	Swelling of Backfill and Emplacement Materials	Screen In	N/A
3.7.12	Polymer Degradation	Screen In	N/A
3.8.04	Inadequate Quality Assurance/Control and Deviations from Design	Screen In	N/A
3.8.05	Remedial Actions	Screen In	N/A
3.8.06	Void Space Formation	Screen In	N/A
4.1.01	Waste Type Classification	Screen In	N/A
4.1.04	Waste Allocation and Emplacement	Screen In	N/A
4.1.05	Waste Homogeneity	Screen In	N/A
4.1.07	Metallic Wastes	Screen In	N/A
4.1.08	Non-Metallic, Inorganic Wastes	Screen In	N/A
4.1.10	Volatiles and Potential for Volatility	Screen In	N/A
4.2.04	Reduction-Oxidation Potential (Redox Fronts)	Screen In	N/A
4.2.05	Localized Interactions Between Emplaced Wastes	Screen Out	This FEP is screened out as LW disposal plans for the residual waste within the tank to be characterized as homogenous.
4.4.02	Food Preparation and Water Processing	Screen In	N/A
4.4.03	Radon and Radon Daughter Exposure (Noble Gas Contamination)	Screen In	N/A
4.4.05	Radiological Dose Effects/Risks	Screen In	N/A
4.4.06	Radiological and Chemical Toxicity/Effects	Screen In	N/A
4.5.01	Nuclear Criticality	Screen Out	This FEP is screened out as the LW closure systems will not include wastes profiles that are susceptible to criticality.

Table 4.3-1: Phase II FEPs Screening Results (Continued)

FEP ID	FEP Name	Screening Decision	Justification for Screening Out
4.5.02	Radiation Effects on the Waste Closure System	Screen In	N/A
4.5.04	Natural or Background Radiation	Screen In	N/A
4.5.05	Medical Radiation	Screen In	N/A
4.5.06	Contaminants from Other Man-Made Sources or Facilities	Screen In	N/A
5.1.02	Groundwater Flow and Movement (Far-Field)	Screen In	N/A
5.1.06	Chemically-Induced Density Effects on Groundwater Flow	Screen Out	This FEP is screened out as there is very little variability in SRS chemical density in SRS groundwater.
5.1.10	Alteration and Chemical Weathering Along Flow Paths	Screen In	N/A
5.2.01	Hydrological Response to Geological Changes	Screen In	N/A
5.2.02	Hydrothermal Activity	Screen Out	This FEP is screened out as SRS does not have any significant hydrothermal activity.
5.2.03	Hydraulic Potentials and Gradients	Screen In	N/A
5.2.05	Effects related to air and vapor flow and evaporation within the system	Screen In	N/A
5.3.03	Multiphase Transport Processes	Screen In	N/A
5.3.05	Solid-Mediated Migration of Contaminants	Screen In	N/A
5.3.06	Gas-Mediated Migration of Contaminants	Screen In	N/A
5.3.12	Radionuclide Fluxes to the Biosphere	Screen In	N/A
5.3.13	Fast Transport Pathways	Screen In	N/A
5.3.15	Radionuclide Release Outside The Reference Biosphere	Screen In	N/A
5.3.17	Saturated Zone Depth	Screen In	N/A
5.3.18	Depth of Assessment Well	Screen In	N/A
6.1.01	Inadvertent Human Intrusion	Screen In	N/A
6.1.02	Deliberate Human Intrusion	Screen In	N/A
6.1.03	Drilling Activities	Screen In	N/A
6.1.04	Excavating and Mining Activities	Screen In	N/A
6.1.06	Igneous or Seismic Event Precedes Human Intrusion	Screen In	N/A
6.2.01	Seismicity	Screen In	N/A
6.2.02	Seismic-Induced Damage or Changes to System Components	Screen In	N/A
6.2.03	Effects of Subsidence	Screen In	N/A
6.2.04	Seismicity Associated with Igneous Activity	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that the environment of the SRS LW closure system does not have enough heat to significantly impact PA results.

Table 4.3-1: Phase II FEPs Screening Results (Continued)

FEP ID	FEP Name	Screening Decision	Justification for Screening Out
6.3.01	Igneous Intrusion Into the Closure Facility	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that it would be beyond extremely unlikely for this to affect PA results.
6.3.02	Volcanic Eruptions and Magmatic Activity	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that it would be beyond extremely unlikely for this to affect PA results.
6.4.01	Releases Prior to Closure	Screen Out	This FEP is screened out because such releases would be considered under CERCLA area processes and are outside the scope of a DOE Order 435.1 and an NRC 10 CFR part 61 PA..
6.4.02	Flooding or Drainage System Failure	Screen In	N/A
6.4.03	Movement of the Waste Form	Screen In	N/A
6.4.04	Cave-In, Collapse, or Rockfall	Screen In	N/A
6.4.05	Accidents and Unplanned Events	Screen In	N/A
6.4.07	Impacts from Meteorites or Space Debris	Screen Out[a]	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that it would be beyond extremely unlikely for this to affect PA results.
6.4.08	Extraterrestrial Events	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that it would be beyond extremely unlikely for this to affect PA results.
6.4.09	Changes in the Earth's Magnetic Field	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that it would be beyond extremely unlikely for this to affect PA results.
6.4.10	Changes to Earth's Tidal Processes	Screen Out	This FEP is screened out based on the professional judgment of the FEPs Screening Team members that it would be beyond extremely unlikely for this to affect PA results.

Source: “SRS_LW_FEPs_Rev0.xlsx” (in the sheet: “Screening”).
Note: (a) FEP 6.4.07, Impacts from Meteorites or Space Debris, was initially screened in (as shown in Table 4.2-2); however, the FEPs Screening Team discussed this FEP and determined it would be more appropriate to screen it out on the basis that it would be beyond extremely unlikely for this FEP to impact PA results.

4.4 Summary of FEPs Screening Results

Table 4.4-1 summarizes the overall results of the screening process.

Table 4.4-1: FEPs Screening Results

	In	**Out**
Prior to Phase I (C&WDA)	46	0
Phase I	69	5
Phase II	115	27
Total	**230**	**32**

5.0 FEPs SCREENING TEAM

The screening described in Section 4 of this report relies on the experience and professional expertise of the individual members of the screening team. The following provides a brief summary of the qualifications for each team member. These team members represent a wide range of backgrounds, providing the breadth of knowledge necessary for evaluating FEPs. The following individuals contributed to the development of the final LW FEPs List.

EIDE, GERALD, Savannah River Remediation (SRR)/Nuclear Safety Engineering

M.S. Mechanical Engineering - Georgia Institute of Technology
B.S. Mechanical Engineering - United States Naval Academy

Mr. Eide has over 20 years of experience at SRS within various engineering organizations. The majority of his time has been spent working within the Liquid Waste Tank Farms. He also has experience working in the Nuclear Safety organization supporting Liquid Waste Operations. Prior to arriving at SRS, he worked in the Commercial Nuclear industry and the Nuclear Navy.

HOMMEL, STEVE, Navarro Research and Engineering, Inc./C&WDA

M.S. Information Systems – University of Phoenix
B.S. Earth Science – University of Nevada, Las Vegas

Mr. Hommel is a PA analyst with over eight years of experience working on PAs for DOE projects. Prior to coming to SRS, he used GoldSim and other quantitative tools to develop validation models for the Total System PA of the DOE's Yucca Mountain Project. In addition to modeling work, his expertise includes technical writing (such as responding to technical comments from regulators), statistical and data analyses, software development, and technical checking.

Mr. Hommel is currently the FEPs Lead and prepared the FEPs documentation.

KNEPP, ANTHONY, Consultant

M.S. Environmental Engineering – Clemson University
B.S. Computer Sciences – Johns Hopkins University
Registered Professional Engineer, Commonwealth of Virginia (No. 009254)

Mr. Knepp is an environmental engineer and former manager who has worked on various nuclear waste planning, design and cleanup projects for the DOE. He directed the Single Shell Tank Performance Assessment for the Richland Office of DOE, evaluated the environmental cleanup program at Los Alamos for the National Academy of Sciences, and provided technical direction to soil and groundwater cleanup of radioactive waste for the DOE. Mr. Knepp managed the investigation of the impact of leaking radioactive waste from single shell tanks at the Hanford Site.

<u>LAYTON, MARK, SRR/C&WDA</u>

B.S. Nuclear Engineering – University of Cincinnati

Mr. Layton has over 20 years of experience at SRS in various regulatory compliance organizations. The majority of this time was spent working on High Level Waste (HLW) regulatory compliance assignments and supporting various Safety Basis activities. Mr. Layton also provided safety basis support for numerous other facilities at SRS and across the DOE complex, including Sandia, Pantex, and Oak Ridge.

<u>PHIFER, MARK, Savannah River National Laboratory (SRNL)</u>

M.S. Civil Engineering (Environmental and Geotechnical) - University of Tennessee
B.S. Civil Engineering - Tennessee Tech
Registered Professional Engineer, South Carolina (No. 12310)

Mr. Phifer is a Senior Fellow Engineer with the SRNL. He has 28 years of environmental and geotechnical experience at SRS. The first 10 years included environmental regulatory compliance, civil/environmental design, project engineering (closure of a mixed waste landfill and basins (80 acres)), and management (environmental remediation technology). The subsequent 18 years have been at the SRNL with two primary areas of technical focus. The first technical focus area involves the development, deployment, and evaluation of waste site closure, groundwater characterization, groundwater remediation, and radioactive waste disposal technologies. These technologies include horizontal and vertical barrier systems, diffusion barriers, closure caps (including their degradation), waste subsidence and its treatment, low-level radioactive waste disposal facilities, Saltstone, permeable reactive barriers, GeoSiphon / GeoFlow groundwater treatment systems, sulfate reduction remediation, reductive dechlorination, vadose zone and aquifer characterization and testing, and material (soil, cementitious, and geosynthetic) testing. The second technical focus area involves development of and technical support for closure plans, PAs, and Composite Analyses (CA) in association with DOE and Nuclear Regulatory Commission (NRC) regulations. Primary efforts in this area include technical lead for development of the SRS CA, development of closure cap configuration, degradation, and infiltration estimates associated with SRS PAs (two low-level waste facilities and two high level waste tank farms), work on the update of the DOE Radioactive Waste Management Order, and technical assistance to other DOE sites.

<u>RIOS-ARMSTRONG, MARIA, SRR/ENGINEERING TECHNOLOGY INTEGRATION</u>

B.S. Chemical Engineering – University of Puerto Rico

With over 20 years of experience at SRS, Ms. Rios-Armstrong has worked at the Tank Farms and the Defense Waste Processing Facility (DWPF) in roles of increasing responsibility: engineering, planning lead, and salt flowsheet technical advisor. She has many years of experience in the areas of Tank Farm and DWPF processing and sludge and salt batch preparation and qualification. Maria is a certified Six Sigma Black Belt. Her current role is Engineering Technology Integration DWPF/Saltstone Processing Facility Interface Lead.

ROSENBERGER, KENT, SRR/C&WDA

B.S. Nuclear Engineering – Pennsylvania State University

Mr. Rosenberger has over 21 years of experience at SRS primarily in the area of radiological controls. He has spent the last seven years supporting tank closure and Saltstone regulatory documents including PA and National Defense Authorization Act (NDAA) Section 3116 Waste Determination development. He has previously held positions in radiological engineering project and operations support and facility operational radiological control management. Mr. Rosenberger has considerable experience with the SRS HLW processes and facilities, in addition to experience with reactor, chemical separations, plutonium processing, and storage, and laboratory facilities.

Mr. Rosenberger is currently the Manager of C&WDA Assessments and provided overall technical direction, coordination, and review.

RUSH, JAMES, SRR/Waste Removal & Tank Closure, Projects

B.S. Civil Engineering - Clemson University

Mr. Rush has over 15 years of experience. In his two years at SRS, Mr. Rush has primarily worked on projects related to waste removal and tank closure within the tank farms. He was involved with the isolation efforts and the grout modifications for Tanks 18 and 19 in F-Area Tank Farm. Prior to joining SRR, Mr. Rush spent 13 years in the water/wastewater industry (CH2M HILL and Augusta, Georgia) with experience in planning, design, construction, operations, and regulatory compliance.

SHEPPARD, RICHARD, SRR/C&WDA

M.S. Nuclear Science - University of Michigan
B.S. Mathematics - Michigan Technological University

Mr. Sheppard has over 35 years of experience within the nuclear industry. During his period of commercial nuclear industry experience his emphasis was on accident analyses and dose assessments for various commercial nuclear power plants and regulatory and licensing activities associated with construction and operation. During his period at SRS, Mr. Sheppard coordinated hazard and safety analyses for design projects at various SRS nuclear facilities. He has spent the past six years supporting the waste determination and PA efforts associated with Saltstone and the closure of SRS Tank Farms.

6.0 REFERENCES

10 CFR 61, *Licensing Requirements for Land Disposal of Radioactive Waste*, U.S. Nuclear Regulatory Commission, Washington DC, January 5, 2010, http://www.nrc.gov/reading-rm/doc-collections/cfr/part061/, Accessed January 20, 2011.

ANL-WIS-MD-000026, Sandia National Laboratories, *Features, Events, and Processes for the Total System Performance Assessment: Methods*, Rev 00, Las Vegas, NV, February 2008.

ANL-WIS-MD-000027, Sandia National Laboratories, *Features, Events, and Processes for the Total System Performance Assessment: Analyses*, Rev 00, Las Vegas, NV, March 2008.

DOE G 435.1-1, *Implementation Guide for use with DOE M 435.1-1*, U.S. Department of Energy, Washington DC, July 9, 1999, https://www.directives.doe.gov/directives/current-directives/435.1-EGuide-1ch1/view?searchterm=doe+g+435, Accessed January 20, 2011.

DOE O 435.1 Chg 1, *Radioactive Waste Management*, U.S. Department of Energy, Washington DC, January 9, 2007, https://www.directives.doe.gov/directives/current-directives/435.1-BOrderc1/view?searchterm=doe+o+435.1, Accessed January 20, 2011.

FCRD-USED-2011-000297, Jones, R. H., *Features, Events and Processes for the Disposal of Low Level Radioactive Waste FY 2011 Status Report*, Fuel Cycle Research and Development, Revision 0, September 2011.

ISBN 92-0-104004-0. International Atomic Energy Agency 2004, *Safety Assessment Methodologies for Near Surface Disposal Facilities, Results of a Co-ordinated Research Project*, Volume 1, Vienna, Austria, July, 2004.

Manual 1Q, *Quality Assurance Manual*, Savannah River Site, Aiken, SC, Rev. 11, March 8, 2011.

Manual SCD-11, *Consolidated Hazard Analysis Process (CHAP) Program and Methods Manual*, Savannah River Site, Aiken, SC, Rev. 9, June 30, 2011.

NWMO DGR-TR-2009-05¸ Ontario Power Generation, *Deep Geologic Repository for OPG's Low & Intermediate Level Waste, Postclosure Safety Assessment (V1): Features, Events and Processes*, Toronto, OT, Canada, July 2009.

SAND2010-3348 P, Freeze, G., *Features, Events, and Processes (FEPs) for Nuclear Waste Repository Systems*. Sandia National Laboratories, Albuquerque, New Mexico, June 21, 2010.

SKI Report 02:35, Miller, B., Savage, D., McEwen, T., and White, M., *Encyclopaedia of Features, Events and Processes (FEPs) for the Swedish SFR and Spent Fuel Repositories*, (ISSN 1104–1374), Leicestershire, United Kingdom, August 2002.

SRR-CWDA-2009-00017, *Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site*, Savannah River Site, Aiken, SC, Rev. 0, October 29, 2009.

SRR-CWDA-2010-00128, *Performance Assessment for the H-Area Tank Farm at the Savannah River Site,* Savannah River Site, Aiken, SC, Rev. 0, March 14, 2011.

SRS-REG-2007-00002, *Performance Assessment for the F-Tank Farm at the Savannah River Site*, Savannah River Site, Aiken, SC, Rev. 1, March 31, 2010.