Ansökan om tillstånd enligt kärntekniklagen

- **Toppdokument**
  Ansökan om tillstånd enligt Kärntekniklagen för utbyggnad och fortsatt drift av SFR
- **Bilaga Begrepp och definitioner**
  Begrepp och definitioner för ansökan om utbyggnad och fortsatt drift av SFR
- **Bilaga F-PSAR SFR**
  Första preliminär säkerhetsredovisning för ett utbyggt SFR
  - **Allmän del 1**
    Anläggningsutformning och drift
    - **Kapitel 1**
      Inledning
    - **Kapitel 2**
      Förläggningsplats
    - **Kapitel 3**
      Konstruktionsregler
      - Tolkning och tillämpning av krav i SSMFS
      - Principer och metodik för säkerhetsklassning – Projekt SFR utbyggnad
      - Säkerhetsklassning för projekt SFR-utbyggnad
      - Acceptanskriterier för avfall, PSU
    - **Kapitel 4**
      Anläggningens drift
    - **Kapitel 5**
      Anläggnings- och funktionsbeskrivning
      - Preliminär plan för fysiskt skydd för utbyggt SFR
      - SFR Förslutningsplan
      - Metod och strategi för informations- och IT-säkerhet, PSU
    - **Kapitel 6**
      Radioaktiva ämnen
      - Radionuclide inventory for application of extension of the SFR repository - Treatment of uncertainties. **(1) (2)**
      - Låg- och medelaktivt avfall i SFR. Referensinventarium för avfall 2013 **(uppdaterad 2015-03)**
    - **Kapitel 7**
      Strålskydd
      - Dosprognos vid drift av utbyggt SFR
    - **Kapitel 8**
      Säkerhetsanalys för driftskedet
      - SFR – Säkerhetsanalys för driftskedet
    - ~~**Kapitel 9**~~
      ~~Mellanlagring av långlivat avfall~~ **Utgått maj 2017**
      - ~~Ansökansinventarium för mellanlagring av långlivat avfall i SFR~~ **Utgått maj 2017**
  - **Allmän del 2**
    Säkerhet efter förslutning
    - **Huvudrapport**
      Redovisning av säkerhet efter förslutning för SFR
      Huvudrapport för säkerhetsanalysen SR-PSU **(1) (3)**
      - **FHA report**
        Handling of future human actions in the safety asement **(2)**
      - **FEP report**
        FEP report for the safety assessment
      - **Waste process report**
        Waste process report for the safety assessment
      - **Geosphere process report**
        Geosphere process report for the safety assessment
      - **Barrier process report**
        Engineered barrier process report for the safety assessment
      - **Biosphere synthesis report**
        Biosphere synthesis report for the safety assessment
      - **Climate report**
        Climate and climate related issues for the safety assessment
      - **Model summary report**
        Model summary report for the safety assessment
      - **Data report**
        Data report for the for the safety assessment **(2)**
      - **Input data report**
        Input data report for the safety assessment **(2) (3)**
      - **Initial state report**
        Initial state report for the safety assessment **(2)**
      - **Radionuclide transport report**
        Radionuclide transport and dose calculations for the safety assessment **(2)**
      - **SDM-PSU Forsmark**
        Site description of the SFR area at Forsmark on completion of the site investigation
  - **Typbeskrivningar**
    - Preliminär typbeskrivning för hela BWR reaktortankar exklusive interndelar.
    - Preliminär typbeskrivning för skrot i fyrkokill
    - ~~Preliminär typbeskrivning för härdkomponenter i ståltankar~~ **Utgått maj 2017**
- **Bilaga AV PSU**
  Avvecklingsplan för ett utbyggt SFR
  Slutförvaret för kortlivat radioaktivt avfall
- **Bilaga VOLS-Ansökan PSU**
  Verksamhet, organisation, ledning och styrning för utbyggnad av SFR – Ansökans- och systemhandlingsskede
- **Bilaga VOLS-Bygg PSU**
  Verksamhet, organisation, ledning och styrning för utbyggnad av SFR – Tillståndsprövnings- och detaljprojekteringsskedet samt byggskedet.
- **Bilaga MKB PSU**
  Miljökonsekvensbeskrivning för utbyggnad och fortsatt drift av SFR
  - Samrådsredogörelse
  - ~~Konsekvensbedömning av vattenmiljöer vid utbyggnad av SFR~~
    Ersatt juli 2016 av bilaga SFR-U K:2
  - Naturmiljöutredning inför utbyggnad av SFR, Forsmark, Östhammar kommun.
- **Bilaga BAT**
  Utbyggnad av SFR ur ett BAT-perspektiv

Kompletteringar

(1) September 2015 – Svensk version av *Huvudrapport SR-PSU* i allmän del 2 samt ny version (3.0) av *Radionuclide inventory* i allmän del 1 kapitel 6
(2) Oktober 2015 – Fem uppdaterade rapporter i allmän del 2 samt ny version (4.0) av *Radionuclide inventory* i allmän del 1 kapitel 6
(3) Oktober 2017 – Uppdatering av *Huvudrapport SR-PSU* och *Input data report*

Technical Report

TR-14-07

FEP report for the safety assessment SR-PSU

Svensk Kärnbränslehantering AB

November 2014

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FEP report for the safety assessment SR-PSU

Svensk Kärnbränslehantering AB

November 2014

Preface

This report describes the processing of features, events and processes, FEPs, undertaken for the analysis of the post-closure radiation safety of the low-and intermediate level waste repository SFR in Forsmark. It forms part of the SR-PSU safety assessment, which supports SKBs licence application to extend the SFR repository.

The report is authored by Kristina Skagius, SKB. She has also developed the FEP database and carried out all the FEP implementations and mappings in the database. The work described in the report was conducted by the SR-PSU FEP coordinators, Maria Lindgren, Kemakta Konsult AB, and Kristina Skagius, SKB, based on experience from the FEP work conducted in the safety assessments of a spent fuel repository, SR-Can and SR-Site. Several other experts and generalists have been involved at specific stages of the work, see further Section 1.3.

The report has been reviewed by Mike Thorne, Mike Thorne and Associates Ltd, UK.

Stockholm, November 2014

Fredrik Vahlund

Project leader SR-PSU

Summary

This report documents the processing of features, events and processes (FEPs) that has been carried out within the safety assessment SR-PSU. The objective of the work was to establish an SR-PSU FEP catalogue within the frame of the SKB FEP database, which contains FEP catalogues from the two most recent safety assessments of a KBS-3 repository for spent nuclear fuel, SR-Site and SR-Can. The SR-PSU FEP catalogue was required to contain all FEPs that needed to be handled in SR-PSU and it was specified that it should be built on the FEP work conducted in earlier safety assessments of the SFR repository, SAR-08 and the SAFE project.

By using similar systematic procedures and experience from the work with the set-up of the SR-Site and SR-Can FEP catalogues, an SR-PSU FEP catalogue has been developed and included in the SKB FEP database. Based on the Interaction Matrices developed for SFR 1 in earlier safety assessments of the SFR repository and the SR-Site FEP catalogue, a preliminary version of the SR-PSU FEP catalogue was developed. The FEP processing work to establish the final version of the FEP catalogue has included audits against the Project FEPs in version 2.1 of the NEA international FEP database and against additional FEP lists from two low- and intermediate level waste projects, as well as the involvement of experts from different disciplines.

The resulting SR-PSU FEP catalogue contains initial state FEPs; internal process and variable FEPs, respectively, for the SFR system components waste form, packaging, engineered barriers in the waste vaults (BMA, BTF, Silo, BRT, BLA) and the geosphere; biosphere FEPs distinguished into processes, variables and sub-system components; and external FEPs categorised as climatic processes, large-scale geological processes and future human actions. In addition, the FEP catalogue contains methodology FEPs and site-specific factors.

Sammanfattning

Denna rapport redovisar det arbete som utförts inom säkerhetsanalysen SR-PSU för att identifiera egenskaper, händelser och processer (features, events, processes), FEP, relevanta för SFR. Syftet med arbetet var att skapa en SR-PSU FEP-katalog som bygger på det FEP-arbete som utförts i de senast utförda säkerhetsanalyserna för SFR, SAFE och SAR-08, och som innehåller alla FEP som behöver beaktas i analysen. FEP-katalogen för SR-PSU ska ingå i SKB:s FEP-databas, som sedan tidigare innehåller FEP-kataloger för SR-Site och SR-Can, de senast utförda säkerhetsanalyserna av det planerade KBS-3-förvaret för använt kärnbränsle.

I enlighet med arbetets syfte har en FEP-katalog för SR-PSU skapats inom ramen för SKB:s FEP-databas. Vid framtagandet av FEP-katalogen har en liknande systematiskt procedur tillämpats som vid framtagandet av FEP-katalogerna för SR-Site och SR-Can, och erfarenheter från dessa arbeten har också nyttjats. En preliminär version av FEP-katalogen för SR-PSU upprättades utgående från de interaktionsmatriser för SFR 1 som tagits fram i de tidigare säkerhetsanalyserna SAFE och SAR-08 och FEP-katalogen för SR-Site. Det vidare arbetet med att upprätta den slutliga versionen av FEP-katalogen har inkluderat en sortering av projekt-FEP i NEA:s internationella FEP-databas (version 2.1) till FEP i den preliminära SR-PSU FEP-katalogen, en kontroll mot ytterligare FEP-listor från två projekt för låg- och medelaktivt avfall, samt deltagande av experter inom de olika ämnesområdena.

Den slutliga versionen av SR-PSU FEP-katalog omfattar FEP för initialtillståndet; FEP för interna processer respektive variabler i SFR:s systemkomponenter avfall, avfallsbehållare, barriärer i förvarsdelarna (BMA, BTF, Silo, BRT, BLA), och geosfären; biosfärs-FEP uppdelade på processer, variabler samt delsystem inom biosfären; samt externa FEP i kategorierna klimatprocesser, storskaliga geologiska processer och framtida mänskliga handlingar. Dessutom innehåller FEP-katalogen metodik-FEP samt platsspecifika faktorer.

Contents

1 Introduction

1.1 Background

The final repository for short-lived radioactive waste (SFR) located in Forsmark, Sweden, is currently being used for the final disposal of low- and intermediate-level operational waste from Swedish nuclear facilities. SKB plans to extend SFR to host waste from the decommissioning of the nuclear power plants and other nuclear facilities. Additional disposal capacity is needed also for operational waste from nuclear power units in operation, since their operation life-times have been extended compared with what was originally planned.

The SFR repository includes waste vaults underground together with buildings above ground that include a number of technical installations. The underground part is located below the Baltic Sea. The existing facility (SFR 1) comprises five waste vaults with a disposal capacity of approximately 63,000 m^3. The extension (SFR 3) will have a disposal capacity of 110,000 m^3 in six new waste vaults, see Figure 1-1.

The long-term safety (post-closure safety) of the whole SFR has been assessed and documented in a Main report (SKB 2014a) with supporting documents (SR-PSU), see Section 1.2. The main purpose of the SR-PSU safety assessment is to demonstrate that SFR is safe in the long term. The Main report (SKB 2014a) is part of SKB´s licence application to extend and continue to operate SFR. The present report is a supporting document and describes the processing of features, events and processes, i.e. FEPs, undertaken for the safety assessment SR-PSU.

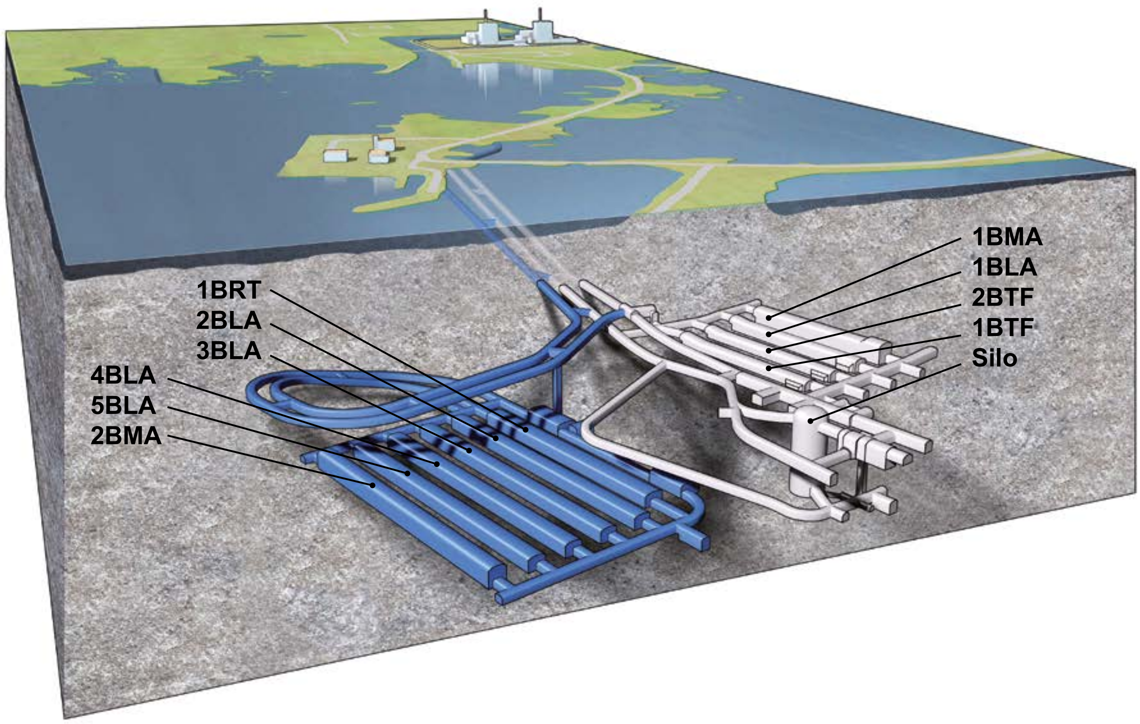


Figure 1-1. *Schematic illustration of SFR. The grey part is the existing repository (SFR 1) and the blue part is the planned extension (SFR 3). The waste vaults in the figure are the silo for intermediate-level waste, 1–2BMA vaults for intermediate-level waste, 1–2BTF vaults for concrete tanks, 1–5BLA vaults for low-level waste and the BRT vault for reactor pressure vessels.*

1.2 Report hierarchy in the SR-PSU safety assessment

The applied methodology for the long term safety assessment is reflected in the structure of the main report of the SR-PSU. The methodology comprises ten steps and is described in Chapter 2 of the Main report. Several of the steps carried out in the safety assessment are described in more detail in supporting documents, so called Main references that are of central importance for the conclusions and analyses in the Main report. The full titles of these reports together with the abbreviations by which they are identified in the following text together with short comments on the report contents are given in Table 1-1.

There are also a large number of additional references. The additional references include documents compiled within SR-PSU, but also documents compiled outside of the project, either by SKB or equivalent organisations as well as in the scientific literature. Additional publications and other documents are referenced in the usual manner.

A schematic illustration of the safety assessment documents is shown in Figure 1-2.

1.3 This report

This report documents the analysis and processing of features, events and processes (FEPs), which has been carried out within the safety assessment SR-PSU. The assessment of long- term safety of SFR (SR-PSU) is performed according to a developed methodology including ten steps, see Chapter 2 in the Main report (SKB 2014a) where the detailed assessment methodology is described. This report focusses on assessment Step 1 – Handling of features, event and processes.

1.3.1 Objective and scope of the FEP processing

The two most recent safety assessments of a KBS-3 repository for spent nuclear fuel, SR-Site (SKB 2011) and SR-Can (SKB 2006a), involved the development of an SKB FEP database, and procedures for a systematic analysis of FEPs and documentation of the analysis in the FEP database, see e.g. SKB (2010a). The outcome of the work was an SR-Can FEP catalogue which was further developed to an SR-Site FEP catalogue, both included in the SKB FEP database.

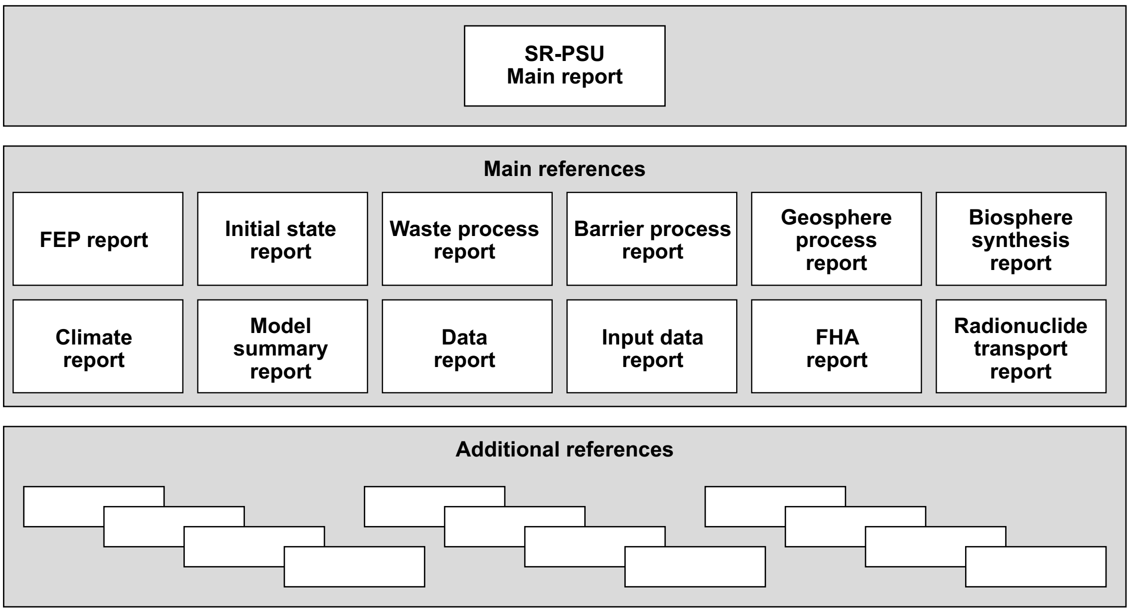


Figure 1-2. The hierarchy of the Main report, Main references and additional references in the SR-PSU assessment of post-closure safety. The additional references either support the Main report or any of the Main references.

Table 1-1. Main report and Main references in the SR-PSU long term safety assessment. All reports are available at www.skb.se.

Abbreviation used when referenced in this report	Text in reference list	Comment on content
Main report	**Main report, 2014**. Safety analysis for SFR. Long-term safety. Main report for the safety assessment SR-PSU. SKB TR-14-01, Svensk Kärnbränslehantering AB.	This document is the main report of the SR-PSU long-term post-closure safety assessment for SFR. The report is part of SKB´s licence application to extend and continue to operate SFR.
Barriers process report	**Engineered barriers process report**, **2014**. Engineered barrier process report for the safety assessment SR-PSU. SKB TR-14-04, Svensk Kärnbränslehantering AB.	Describes the current scientific understanding of the processes in the engineered barriers that have been identified in the FEP processing as potentially relevant for the long-term safety of the repository. Reasons are given in the process report as to why each process is handled a particular way in the safety assessment.
Biosphere synthesis report	**Biosphere synthesis report**, **2014**. Biosphere synthesis report for the safety assessment SR-PSU. SKB TR-14-06, Svensk Kärnbränslehantering AB.	Describes the handling of the biosphere in the safety assessment. The report summarises site description and landscape evolution, FEP handling, exposure pathway analysis, the radionuclide model for the biosphere, included parameters, biosphere calculation cases and simulation results.
Climate report	**Climate report**, **2014**. Climate and climate-related issues for the safety assessment SR-PSU. SKB TR-13-05, Svensk Kärnbränslehantering AB.	Describes the current scientific understanding of climate and climate-related processes that have been identified in the FEP processing as potentially relevant for the long-term safety of the repository. The report also describes the climate cases that are analysed in the safety assessment.
Data report	**Data report, 2014.** Data report for the safety assessment SR-PSU. SKB TR-14-10, Svensk Kärnbränslehantering AB.	Qualifies data and describes how data, including uncertainties, that are used in the safety assessment are quality assured.
FEP report	**FEP report, 2014.** FEP report for the safety assessment SR-PSU. SKB TR-14-07, Svensk Kärnbränslehantering AB.	Describes the establishment of a catalogue of features, events and processes (FEPs) that are of potential importance in assessing the long-term functioning of the repository.
FHA report	**FHA report**, **2014**. Handling of future human actions in the safety assessment SR-PSU. SKB TR-14-08, Svensk Kärnbränslehantering AB.	Describes radiological consequences of future human actions (FHA) that are analysed separately from the main scenario, which is based on the reference evolution and less probable evolutions.
Geosphere process report	**Geosphere process report**, **2014**. Geosphere process report for the safety assessment SR-PSU. SKB TR-14-05, Svensk Kärnbränslehantering AB.	Describes the current scientific understanding of the processes in the geosphere that have been identified in the FEP processing as potentially relevant for the long-term safety of the repository. Reasons are given in the process report as to why each process is handled a particular way in the safety assessment.
Initial state report	**Initial state report**, **2014**. Initial state report for the safety assessment SR-PSU. SKB TR-14-02, Svensk Kärnbränslehantering AB.	Describes the conditions (state) prevailing in SFR after closure. The initial state is based on verified and documented properties of the repository and an assessment of the evolution during the period up to closure.
Input data report	**Input data report**, **2014**. Input data report for the safety assessment SR-PSU. SKB TR-14-12, Svensk Kärnbränslehantering AB.	Describes the activities performed within the SR-PSU safety assessment and the input data used to perform these activities.
Model summary report	**Model summary report**, **2014**. Model summary report for the safety assessment SR-PSU. SKB TR-14-11, Svensk Kärnbränslehantering AB.	Describes the calculation codes used in the assessment.
Radionuclide transport report	**Radionuclide transport report**, **2014**. Radionuclide transport and dose calculations for the safety assessment SR-PSU. SKB TR-14-09, Svensk Kärnbränslehantering AB.	Describes the radionuclide transport calculations carried out for the purpose of demonstrating fulfilment of the criterion regarding radiological risk.
Waste process report	**Waste process report, 2014.** Waste form and packaging process report for the safety assessment SR-PSU. SKB TR-14-03, Svensk Kärnbränslehantering AB.	Describes the current scientific understanding of the processes in the waste and its packaging that have been identified in the FEP processing as potentially relevant for the long-term safety of the repository. Reasons are given in the process report as to why each process is handled in a particular way in the safety assessment.

The primary objective of the work with the processing of FEPs in SR-PSU was to establish an SR-PSU FEP catalogue within the frame of the SKB FEP database using similar procedures and experience from the work with the set up of the SR-Site and SR-Can FEP catalogues. The SR-PSU FEP catalogue was required to contain all FEPs that needed to be handled in SR-PSU and to build on the FEP work conducted in earlier safety assessments of the SFR facility, SAR-08 (SKB 2008) and the SAFE project (SKB 2001).

1.3.2 Participating experts

The procedures adopted for developing the SR-PSU FEP catalogue were similar to those adopted in the establishment of the SR-Site and SR-Can FEP catalogues (SKB 2010a). Decisions regarding the treatment of FEPs during the audit stage were made by Maria Lindgren, Kemakta Konsult AB, and Kristina Skagius, SKB, with the aid of the decisions made during the audit stage of the SR-Can and SR-Site FEP processing.

Maria Lindgren and Marie Wiborgh, Kemakta Konsult AB, and Klas Källström, SKB, participated in the work of the processing of the list of FEPs related to the initial state in SR-PSU. The list of FEPs related to external factors was processed by Jenny Brandefelt and Jens-Ove Näslund, SKB, (Climate) and by Eva Andersson, SKB, and Thomas Hjerpe, Facilia, (FHA).

The persons involved in the processing of FEPs related to internal processes were the experts involved in developing the process descriptions. All these experts are listed in the SR-PSU Process reports for the waste form and packaging (SKB 2014c), engineered barriers (SKB 2014d) and the geosphere (SKB 2014e). Eva Andersson, SKB, Sara Grolander, Miljökonsult, and Anders Löfgren, EcoAnalytica, have been responsible for the processing of FEPs related to the biosphere.

2 FEP processing procedures and prerequisites

This chapter gives the prerequisites for the work and an overview of the different activities undertaken during the establishment of the SR-PSU FEP catalogue. The development procedure is described in more detail in the following chapters together with the results from the different steps.

2.1 System definition

To be able to distinguish between FEPs belonging to the repository system and FEPs acting from outside the system, a definition of the system boundary is necessary. Furthermore, in the database, the system is divided into several system components. It should be noted that these definitions primarily were set up to facilitate the auditing procedure and the development of the SR-PSU part of the SKB FEP database. Therefore, all these definitions are not necessarily relevant in subsequent treatments of FEPs in the safety assessment, e.g. through modelling.

2.1.1 System boundary

To be able to distinguish between FEPs belonging to the repository system and FEPs acting from outside the system, the following definitions related to the system boundary were applied.

- Roughly the portion of the biosphere considered in the site descriptive model (SKB 2013) is regarded as internal, whereas the biosphere on a larger scale is regarded as external. The analysis of the biosphere extends downward to the surface of the rocks in this assessment. Depending on the analysis context this definition may be somewhat modified.
- Local effects of climate are internal, but not the climate system on a larger scale.
- Roughly the portion of the geosphere included in the site descriptive model (SKB 2013) is regarded as part of the system, i.e. the portion corresponding to the areal extent of the biosphere, and down to a depth of about 1,000 m. Depending on the analysis context, this definition may also be somewhat modified.
- Future human behaviour on a local scale is internal to the system, but not issues related to the characteristics and behaviour of future society at large.

It was also noted that, in general, a strict boundary definition is neither necessary nor indeed possible, and that the same boundaries are not necessarily relevant to all parts of the safety assessment.

In order to distinguish between factors affecting the initial state of the repository system and factors associated with the evolution of the system, the initial state of the system is defined as the expected state of the repository and its environs immediately after closure. This means that the evolution of the waste, waste packaging, engineered barriers as well as of the natural conditions at the site as a result of operation and construction of the facility extension have to be taken into account in defining the initial state.

2.1.2 System components

The existing SFR-facility comprises four waste vaults, one for intermediate level waste (1BMA) one for low level waste (1BLA) and two for intermediate level waste in concrete tanks (1–2BTF). It also comprises a silo for disposal of intermediate level waste (see Figure 1-1). The planned extension of the facility includes four additional vaults for low level waste (2–5BLA) one additional vault for intermediate level waste (2BMA) and one vault for decommissioned reactor pressure vessels (1BRT) (Figure 1-1).

Both non-stabilised and stabilised wastes are deposited in SFR in different types of packaging and the engineered barriers in the waste vaults are somewhat different. Therefore, for the purpose of FEP processing and the development of the SR-PSU FEP catalogue, the repository system is divided into the following system components.

Waste form. This system component comprises the non-stabilised wastes deposited in BTF, BLA and BRT, e.g. ion-exchange resins, ashes, trash and scrap, as well as the stabilised wastes deposited in BMA and in the silo, e.g. ion-exchange resins or sludge solidified in cement, scrap metal and refuse stabilised in cement, and ion-exchange resins stabilised in bitumen. The outer boundary of this system component is defined as the interface between the waste form and the packaging (SKB 2014c).

Concrete and steel packaging. This system component comprises all packaging materials used in SFR. These are: concrete tanks, concrete moulds, steel moulds, steel drums, ISO-containers and steel boxes (SKB 2014c).

BMA barriers. This system component comprises all engineered barriers in the BMA vaults, except the waste packages, i.e. reinforced concrete structures (floor, outer and inner walls, lid) and grout backfilled around the waste packages, crushed rock beneath the concrete floor and macadam in the space between the concrete structures and the rock walls as well as rock bolts and shotcrete on the rock walls (SKB 2014d). The wastes in BMA are contained in concrete and steel moulds and in steel drums. The engineered barriers are the same in 1 and 2BMA, but the design is somewhat different in detail (see Figure 2-1). 1BMA comprises one long concrete structure divided into compartments, whereas 2BMA comprises 14 caissons. The caissons are made of unreinforced concrete.

BTF barriers. This system component comprises all engineered barriers in the BTF vaults, except the waste packages, i.e. the concrete structures (floor, pillars along the rock walls, lid), concrete grout surrounding the waste packages and macadam on top of the concrete lid as well as rock bolts and shotcrete on the rock walls (SKB 2014d). The 1 and 2BTF vaults are primarily designed for disposal of dewatered ion-exchange resins in concrete tanks, but steel drums containing ashes from incineration at Studsvik as well as miscellaneous types of waste such as a reactor pressure vessel head are also deposited in 1BTF. The engineered barriers are the same in both vaults (see Figure 2-2).

Silo barriers. This system component comprises all engineered barriers in the silo, except the waste packages, i.e. concrete structures (floor, outer and inner walls, lid), grout surrounding the waste packages, sand/bentonite in the bottom and around the top of the silo, sodium-conditioned bentonite in the gap between the cylindrical concrete walls and the rock walls, different layers of backfill materials on top of the concrete lid, see Figure 2-3 and Figure 2-4, as well as rock bolts and shotcrete on the rock walls (SKB 2014d). The wastes in the silo are contained in concrete and steel moulds as well as in steel drums and surrounded by grout in the shafts inside the concrete cylinder.

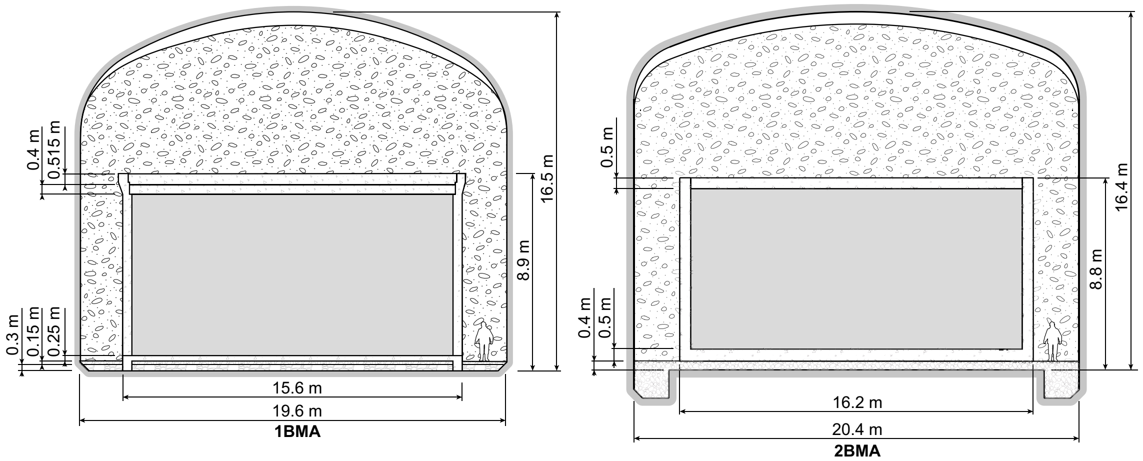


Figure 2-1. *Schematic cross-section of 1BMA (left) and 2BMA (right) after closure, showing the concrete compartments on a base of crushed rock and surrounded by backfilled macadam. The waste packages, concrete and steel moulds and steel drums, are surrounded by grout inside the concrete compartments/caissons.*

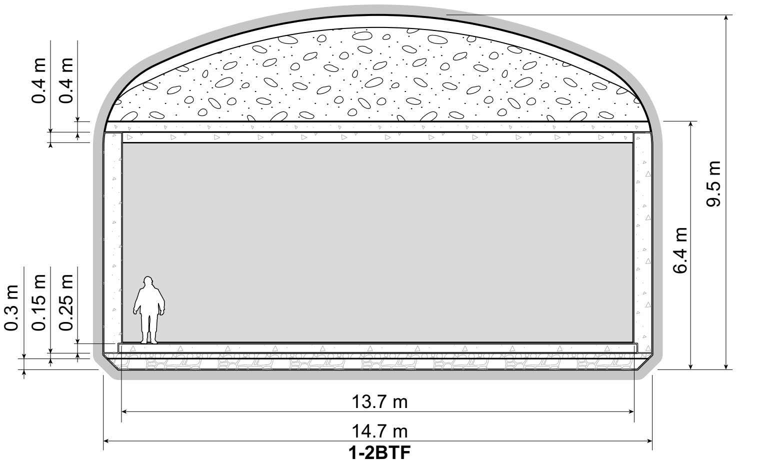


Figure 2-2. *Schematic cross-section of 1 and 2BTF after closure, showing the concrete floor, pillars at the rock walls, concrete lid and backfilled macadam on top of the lid. The waste packages, concrete tanks and, in 1BTF, steel drums, are surrounded by grout.*

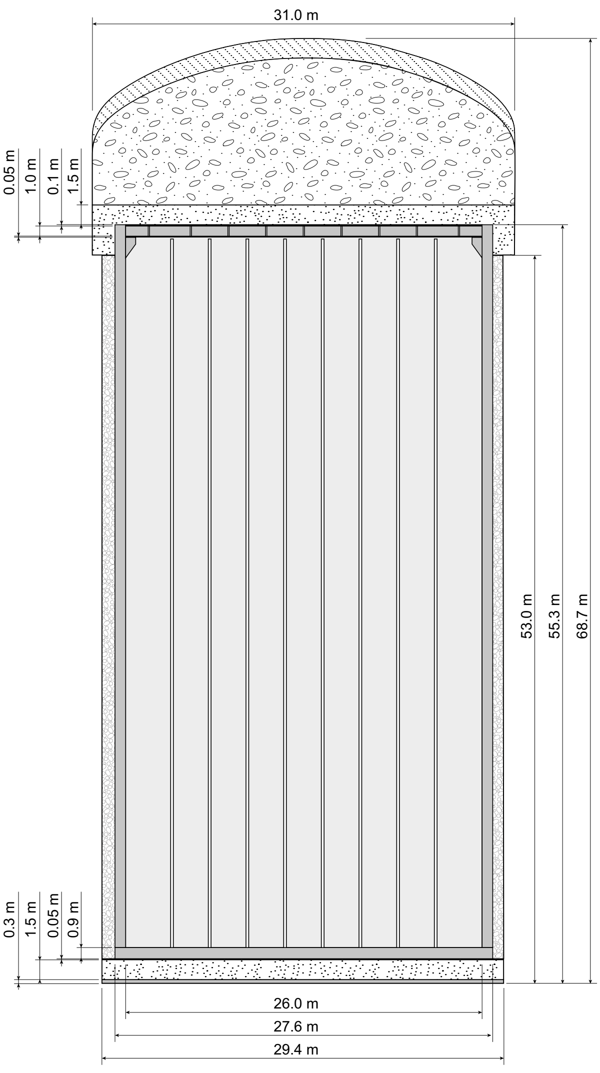
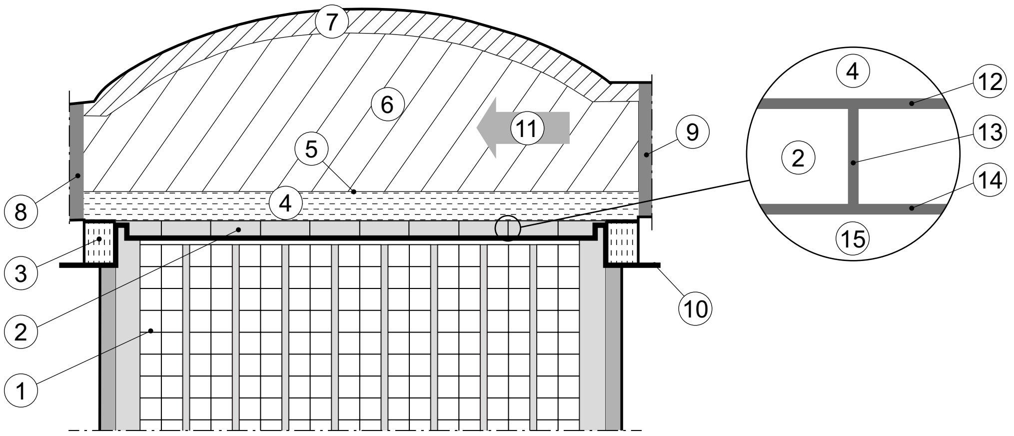


Figure 2-3. *Schematic cross-section of the silo after closure showing the concrete cylinder on a concrete bottom slab founded on a bed of 90/10 sand/bentonite and the bentonite surrounding the concrete cylinder. The design of the top barriers is shown in Figure 2-4. The waste packages, steel moulds and steel drums, are surrounded by grout inside the shafts in the cylinder.*



1. Waste
2. Reinforced concrete slab with sand layer and gas evacuation pipes.
3. Compacted fill of 30/70 bentonite/sand mixture.
4. Compacted fill of 10/90 bentonite/sand mixture.
5. Unreinforced concrete slab.
6. Compacted fill of friction material.
7. Cement-stabilised sand.
8. Constraining wall of concrete against silo roof tunnel.
9. Constraining wall of concrete against loading-in building.
10. Boundary between works belonging to grouting and backfilling.
11. Working direction for backfilling with material according to points 6 and 7.
12. Sand layer 100 mm.
13. Gas evacuation pipe Ø 0.1 m.
14. Sand layer 50 mm.
15. Grout (permeable).

Figure 2-4. *Schematic cross-section of silo top after closure.*

BRT barriers. The BRT vault is intended for whole reactor pressure vessels that are to be placed end-to-end in concrete cradles on a concrete floor. At closure, the reactor pressure vessels will be filled with concrete or cementitious grout and embedded in grout. The system component comprises all engineered barriers in the BRT vault, except the reactor pressure vessels, i.e. the concrete floor, concrete and grout in and around the reactor pressure vessels, macadam that is backfilled outside the embedded reactor pressure vessels, see Figure 2-6, as well as bolts and shotcrete on the rock walls (SKB 2014d).

BLA barriers. This system component comprises the concrete floor, and concrete walls in 2–5BLA (Figure 2-5), the void around the waste packages and outside the concrete walls (2–5BLA) as well as rock bolts and shotcrete on the rock surfaces (SKB 2014d). The 1–5BLA vaults contain low-level waste in ISO-containers that are stacked on the concrete floor.

Plugs and other closure components. This system component comprises plugs in both ends of the waste vaults, plugs in all tunnel – silo intersections, tunnel sections filled with bentonite and confined by mechanical plugs and backfilled macadam in the access tunnels as well as rock bolts and any shotcrete on the rock walls. Most mechanical plugs are concrete plugs, but also earth dam plugs are used. It also comprises borehole seals of highly compacted bentonite, where tight seals are needed, and cement-stabilised plugs where the boreholes pass through fracture zones (SKB 2014d).

Geosphere. This system component comprises the rock surrounding the repository. It also includes grout injected into fractures in the rock during construction of the repository to prevent water inflow to tunnels and other repository cavities. In the upward direction, the geosphere is bounded by the geosphere–biosphere interface, defined as the top of the weathered host rock. For boundaries in the other directions, see definitions above regarding the system boundary.

Biosphere. This system component comprises the near-surface properties and processes, both abiotic and biotic as well as humans and human behaviour, see also definitions above regarding system boundaries.

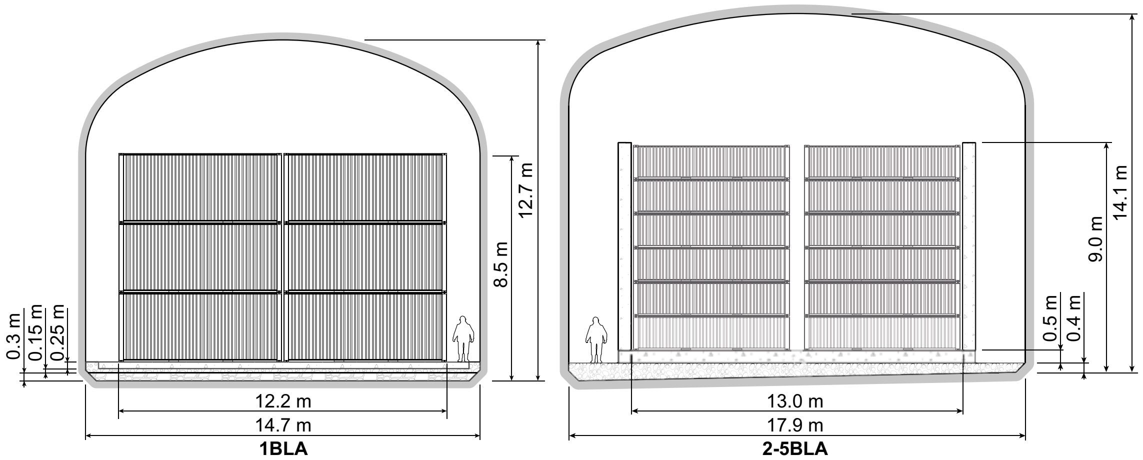


***Figure 2-5.** Schematic cross-section of 1BLA (left) and 2–5BLA (right) after closure, showing ISO containers with low-level waste stacked on the concrete floor. The empty spaces around the waste containers and outside the concrete walls (2–5BLA) will not be backfilled.*

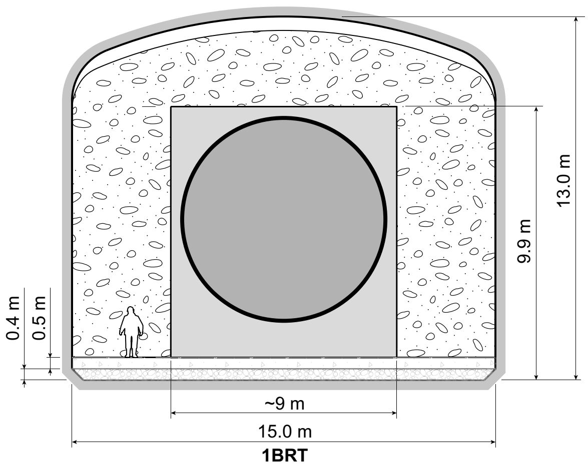


***Figure 2-6.** Schematic cross-section of BRT after closure, showing the concrete floor, the reactor pressure vessels embedded in grout and the surrounding macadam.*

The various system components are also characterised by a number of variables, both in terms of the initial state of these variables and their states during repository evolution. For the waste, packaging and the engineered barrier system components, the variables are given in the process reports for the waste form and packaging (SKB 2014c) and for the engineered barriers (SKB 2014d) and the initial states of these system components are described in the initial state report (SKB 2014b). The variables defined for the geosphere and biosphere system components are given in the geosphere (SKB 2014e) and biosphere process reports (SKB 2014j), respectively, and a description of the initial state of the geosphere and biosphere is provided in the SR-PSU Main report (SKB 2014a).

2.2 Overview of FEP processing procedure

The handling of FEPs in SR-PSU has in principle followed the same procedure as that established for the handling of FEPs in the most recent safety assessment, SR-Site, for the spent fuel repository as reported in the SR-Site FEP report (SKB 2010a) and documented in the SR-Site version of the SKB FEP database. The procedure is schematically illustrated in Figure 2-7 and summarised in the text below.

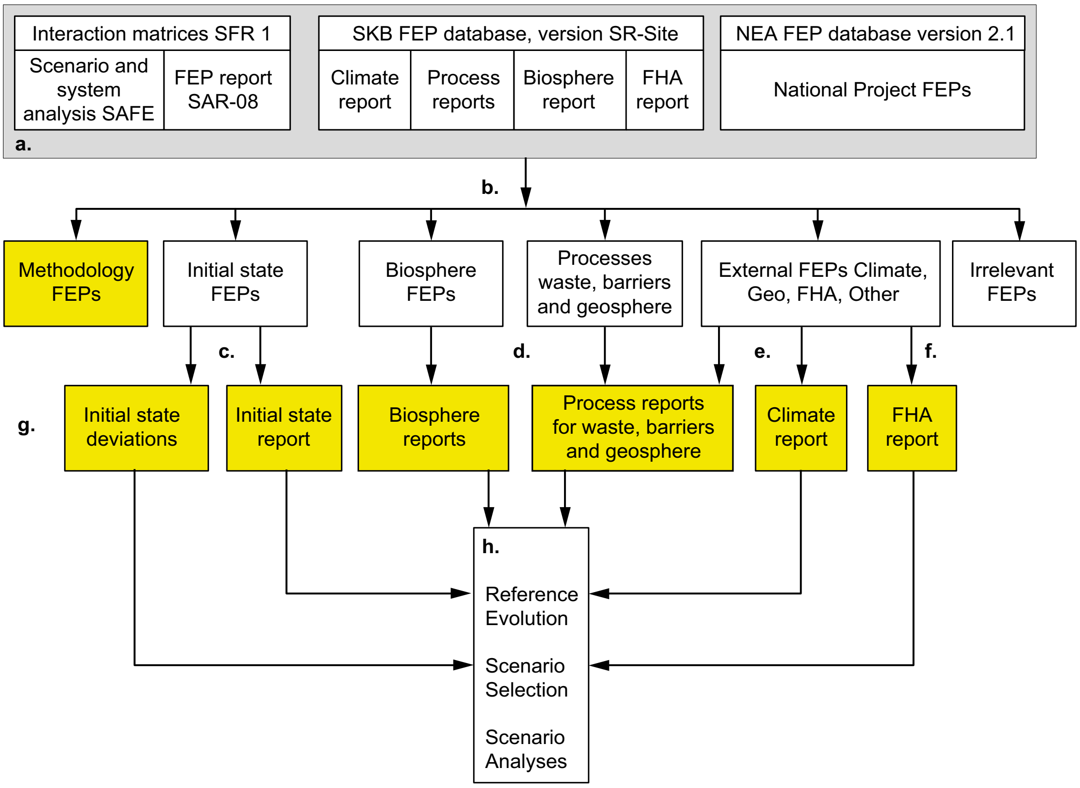


Figure 2-7. *The handling of FEPs in SR-Site.*

a) FEP sources

Three sources were used to identify relevant features, events and processes influencing the long-term safety of the SFR repository. These are the SR-Site FEP catalogue, Interaction Matrices developed for SFR 1 and the Project FEPs in version 2.1 of the NEA FEP database. Project FEPs are FEPs identified within safety assessments undertaken by various national organisations.

Since the SFR repository is located at Forsmark, which also is the proposed location for the spent fuel repository, it was judged that the Climate, Geosphere and Biosphere FEPs in the SR-Site FEP catalogue would be a good starting point for the corresponding FEPs in the PSU FEP catalogue

In earlier safety assessments of SFR 1, Interaction Matrices were used to identify FEPs and interactions between processes that affect the future evolution of the repository system. The original versions of the Interaction Matrices were developed within the SAFE project (SKB 2001), and these were later revisited and checked for their validity and the need of update as part of the SAR-08 safety assessment (SKB 2008).

As in the FEP processing in SR-Site, the project FEP databases included in the version 2.1 of the NEA FEP database (NEA 2006) were used as source for the FEP processing in SR-PSU.

b) FEP audit

The work started by developing lists of processes and variables for the different system components and importing these into the FEP database as records in the SR-PSU FEP catalogue. These lists were based on the contents of the SR-Site FEP catalogue and the Interaction Matrices for SFR 1. In addition, the so established preliminary SR-PSU FEP catalogue contained the same external FEPs and methodology FEPs as the SR-Site FEP catalogue and a sub-set of the initial state FEPs.

In the next step, the content of the preliminary SR-PSU FEP catalogue was systematically compared with all Project FEPs in the NEA FEP database, version 2.1. In addition, the Interaction Matrices for SFR 1 were updated in accordance with the needs identified in the SAR-08 safety assessment (SKB 2008) and the preliminary FEP catalogue was audited against these updated Interaction Matrices.

Since many of the projects in the NEA database are concerned with high-level waste, a review was also made of FEPs from two projects for low- and intermediate-level waste: Olkiluoto L/ILW in Finland and Rokkasho 3 in Japan (both in unpublished preliminary versions).

The purpose of these audits was to ensure that all factors relevant to SFR were identified and to classify all relevant factors as being related to the *initial state of the repository system*, to *internal system processes* or to *external factors*. As for the FEP audit in SR-Site, most project FEPs in version 2.1 of the NEA database could be mapped to one of these categories. All other FEPs were characterised as general methodology issues or determined to be irrelevant for the SFR repository system.

The FEP audit procedure and the results are described further in Chapter 3.

c) Processing of initial state FEPs

The initial state FEPs are related either to the expected initial state with tolerances or to deviations from the expected initial state outside tolerances. Each FEP related to the expected initial state was associated with the appropriate variable and system component and included in the description of the initial state for the system component in question. Each variable constitutes a FEP record in the SR-PSU FEP catalogue, see g) below.

The processing of initial state FEPs and the results obtained are described further in Section 4.2.

d) Processing of internal process FEPs and biosphere FEPs

Suggestions arising from the FEP audit regarding additions to, and modifications of, internal processes were addressed by the experts involved in the development of the SR-PSU Process reports. The results of their work were implemented in the updated versions of the SR-PSU process descriptions for the waste, engineered barriers and the geosphere. Each process in these reports also constitutes a FEP record in the SR-PSU FEP catalogue, see g) below.

Biosphere FEPs and the handling of these in the assessment are briefly described in the biosphere synthesis report (SKB 2014i), whereas full definitions of the biosphere FEPs are given in the general FEP report for the biosphere (SKB 2014j), and the handling of each process is fully described in SKB (2014k).

e and f) Processing of external FEPs

As in the FEP processing in SR-Site, FEPs in the NEA database defined as external FEPs in SR-PSU were subdivided into the categories listed below:

- Climate-related issues.
- Large-scale geological processes and effects.
- Future human actions.
- Other.

The handling of climate-related issues is documented in the SR-PSU Climate report (SKB 2014f) and corresponding climate FEPs are included in the SR-PSU FEP catalogue, see g) below. These climate FEPs are fewer than those defined for SR-Site, since during the FEP work in SR-PSU it was found appropriate to combine some of the climate FEPs defined in SR-Site.

Large-scale geological processes and effects are covered by two FEPs in the SR-PSU FEP catalogue, see g) below. These FEPs are the same as those defined for SR-Site and the descriptions provided in the SR-Site geosphere process report (SKB 2010c, Sections 4.1.2 and 4.1.3) apply also for SR-PSU (SKB 2014e, Section 4.1.1).

Future human actions, FHA, and how these are handled in the safety assessment are described in the FHA report (SKB 2014g). The same seven FHA FEPs as in the SR-Site FEP catalogue were originally defined. However, the processing pointed out the advantage of separating several of these FEPs to make them more specific. As a result of this, the SR-PSU FEP catalogue contains 17 FHA FEPs.

As in the SR-Site FEP processing, the only FEP included in the category "other" is "meteorite impact". This FEP is excluded from further analysis, but still defined as a FEP in the SR-PSU FEP catalogue and the justification for excluding this FEP from further analysis is documented in the FEP record.

The processing of external FEPs and the results obtained are further described in Section 4.3.

g) Establishment of the SR-PSU FEP catalogue

Based on the FEP processing briefly described above, an SR-PSU FEP catalogue was established. This FEP catalogue contains all FEPs that needed to be handled in SR-PSU and is thus fundamentally a subset of FEPs in the SKB FEP database. The SR-PSU FEP catalogue contains the FEP categories listed below.

- Initial state FEPs.
- Processes in the system components waste form, packaging, BMA barriers, BTF barriers, silo barriers, BLA and BRT barriers, plugs and other closure components and the geosphere.
- Variables in the system components waste form, packaging, BMA barriers, BTF barriers, silo barriers, BLA and BRT barriers, plugs and other closure components and the geosphere.
- Biosphere FEPs, comprising biosphere processes, sub-systems and variables.
- External FEPs.

As in the SR-Site FEP catalogue, the SR-PSU FEP catalogue also contains the categories Methodology FEPs and Site-specific factors, in addition to the categories listed above. The methodology FEPs address a number of issues relevant to the basic assumptions for the assessment and to the methodology used for the assessment that were identified in the NEA FEP database. Most of these are of a very general nature, but, for the sake of comprehensiveness, were also included in the FEP catalogue. The Site-specific factors represent issues that specifically were identified as relevant for the SR-PSU analysis, for example the nearby nuclear power plant at Forsmark and specifically the power cable to Finland (Fenno-Skan).

The contents of the FEP catalogue are described in more detail in Chapter 5.

h) Repository evolution

The contents of the SR-PSU FEP catalogue were propagated to the analysis of repository evolution. The expected initial state, all long-term processes and a reference external evolution were used to define a reference evolution for the repository system. Other FEPs were considered in the selection of scenarios. This step is described in the SR-PSU Main report (SKB 2014a) and is not further addressed in this FEP report, other than in respect of documentation aspects related to the FEP catalogue.

2.3 Quality assurance aspects

2.3.1 The SKB FEP database

The SKB FEP database was used as a tool for documentation of the outcome of the different steps in the FEP processing procedure as the work proceeded. This was done both in SR-Can and SR-Site as well as in SR-PSU. Thus, the FEP database in itself is regarded as a quality assurance instrument. For that purpose, it contains all source information in terms of the Project FEPs included in the NEA FEP database version 1.2 (NEA 1999) and in version 2.1 (NEA 2006), the contents of the SR 97 Process report (SKB 1999) in database format, the Interaction Matrices developed for a deep repository of the KBS-3 type (Pers et al. 1999), the Interaction Matrices developed for SFR 1 (SKB 2001, 2008), as well as the resulting SR-Can (SKB 2006b), SR-Site (SKB 2010a) and SR-PSU FEP catalogues. In addition, the SKB FEP database contains files created for documentation of the outcome of the FEP audit in SR-Can, in SR-Site and in SR-PSU, one for the result of the audit against the NEA Project FEPs (NEA Mapping) and one for the result of the audit against the Interaction Matrices (Matrix Mapping). The overall structure of the SKB FEP database is shown in Figure 2-8.

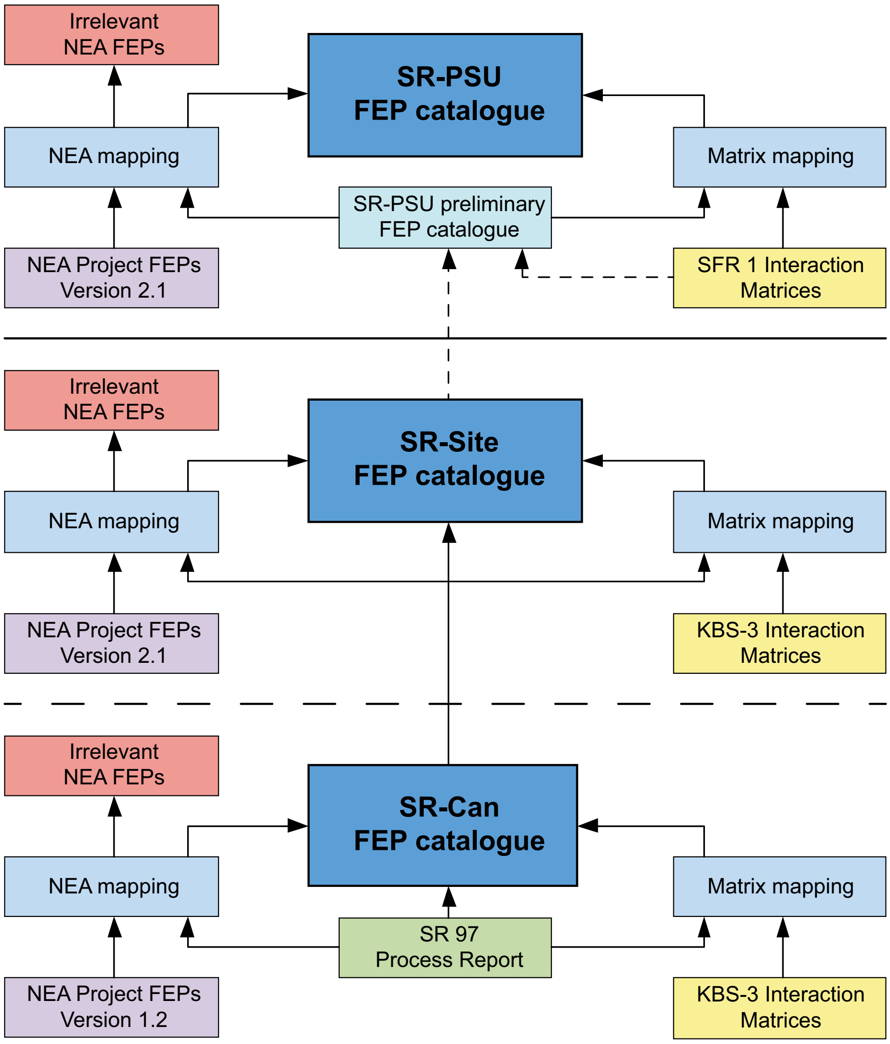


Figure 2-8. *Overall structure of the SKB FEP database.*

In order to ensure a proper handling of the SKB FEP database, routines for the development and management of it were defined and applied in SR-Can, in SR-Site and in SR-PSU. These are summarised in the following sections and further addressed, where appropriate, in the following chapters.

2.3.2 Import of NEA FEPs and Matrix interactions

The database was created with the database programme FileMaker Pro, which is the same database programme as was used to set up the NEA FEP database as well as the KBS-3 and SFR 1 Interaction Matrices. This made it possible to import an electronic copy of the register in the NEA FEP database containing the Project FEPs (file PROFEP) and of the files containing the documentation on the Interaction Matrices. These files, NEA Project FEPs, KBS-3 Interaction Matrices and SFR 1 Interaction Matrices in Figure 2-8, are, however, not used for documentation. The documentation is created in the files NEA Mapping and Matrix mapping (see Figure 2-8). These files were created by exporting the Project FEP number, the Project FEP name and the International FEP number from the NEA FEP database (file PROFEP) to corresponding records in the NEA Mapping file in the SKB database. For creating the Matrix Mapping file, the Matrix name, the interaction number and interaction name were exported from the files KBS-3 Interaction Matrices and SFR 1 Interaction Matrices, respectively, to corresponding records in the Matrix mapping file. This means that the full copies of the NEA Project FEP file and the Interaction Matrices files are used for displaying the definitions/descriptions of the NEA Project FEPs and the Matrix interactions only and no supplementary documentation was allowed in these files.

2.3.3 Routines for FEP processing and documentation of results

The FEP audit (b in Figure 2-7) in SR-Can and in SR-Site was carried out following a set of general procedures and rules. In principle, the same procedures and rules were adopted for the FEP audit in SR-PSU (Section 3.1.2). In addition, a number of criteria were defined that had to be fulfilled in order to determine that a FEP is not relevant for the SFR system (Section 3.1.3). These procedures, rules and criteria were applied in the work and the results of the audit as well as decisions made during the course of the work were documented in the FEP database (NEA Mapping in Figure 2-8).

The audit procedure was carried out by generalists and no attempt was made at this stage to make definite decisions on the relevance or importance of the FEPs for repository evolution. Therefore, the results of the audit, in terms of potentially relevant FEPs and, where relevant, their links to internal processes, was propagated to experts within the project for further processing, together with instructions on how to document the result of that processing. The information in the FEP database was provided as digital word documents, which were created by exporting relevant information directly from the FEP database to the digital documents.

The experts documented the results of their FEP processing using protocols addressing, for each NEA Project FEP, whether it is handled or not handled in SR-PSU and if not handled, the reason for this. The information developed under these protocols was then imported to the FEP database, where it is accessible for view via the FEP records in the SR-PSU FEP catalogues (see Chapter 5). In addition, the expert responsible for the documentation of the handling is identified in the appropriate record in the database as well as the date when the information was included in the document. Before entering the information into the database, its completeness and consistency were checked. Minor revisions of more administrative character, such as adding cross-references and duplicating documentation of handling of similar FEPs when this information was lacking, were made by the person responsible for checking the information delivered under the protocols without consulting the expert providing the information. If larger modifications were judged necessary, the document was returned to the experts for approval of the modifications made.

Print-outs of this information from the FEP database (FEP tables) are provided as Appendices to this report.

2.3.4 Routines for management of the FEP database

Some general rules for administration of the FEP database have been followed throughout the development work. These are listed below.

- Only one person has been allowed to make modifications to the structure and content of the database. For the SR-PSU as well as for the previous SR-Can and SR-Site projects, this person has been Kristina Skagius, SKB.
- Input of information to the database was required only to be made from documents that were dated, signed and provided by the experts assigned for the task.
- The final official SR-Can, SR-Site and SR-PSU versions of the FEP database are made available as stand alone, write-protected versions.

Before delivering the final current version of the SKB FEP database, the content of the SR-PSU part of the database was checked. The corresponding check of the SR-Can and SR-Site parts of the database were made in SR-Site (SKB 2010a). The check was made in order to ensure that:

1. All NEA Project FEPs in version 2.1 of the NEA FEP database are included in the SR-PSU part of the SKB FEP database.
2. All Matrix interactions in the SAR-08 repository, geosphere and biosphere matrices are included in the SR-PSU part of the FEP database.
3. All NEA Project FEPs and Matrix interactions included in the SR-PSU part of the FEP database are flagged as Relevant or Not relevant for the SFR repository systems.
4. All NEA Project FEPs and Matrix interactions included in the SR-PSU part of the FEP database and flagged as Not Relevant for the SFR repository system are associated with documentation justifying their omission.
5. All NEA Project FEPs and Matrix interactions included in the SR-PSU part of the FEP database and flagged as Relevant for the SFR repository system are associated with a documented description of their handling in SR-PSU.
6. All processes in process reports, defined categories of initial states, defined external factors, and defined system variables have a corresponding record in the SR-PSU FEP catalogue.

The outcome of this check of the SR-PSU part of the FEP database is provided in Appendix 1.

3 FEP audit

As a first step in the establishment of the SR-PSU FEP catalogue, a preliminary version of the catalogue was set up. The preliminary version of the SR-PSU FEP catalogue was based on the contents of the Interaction Matrices for SFR 1 and the SR-Site FEP catalogue. Since the SFR repository is located at Forsmark, which also is the proposed location for the spent fuel repository, it was judged that the Climate, Geosphere and Biosphere FEPs in the SR-Site FEP catalogue would be a good starting point for the corresponding FEPs in the PSU FEP catalogue. In addition, the SR-Site FHA FEPs were used as input because of their general nature.

The content of the preliminary SR-PSU FEP catalogue was then systematically compared with all Project FEPs in the NEA FEP database, version 2.1. In addition, the Interaction Matrices for SFR 1 (SKB 2001) were updated in accordance with the needs identified in the SAR-08 safety assessment (SKB 2008) and the preliminary FEP catalogue was audited against these updated Interaction Matrices. This work is described in the following sections of this chapter.

3.1 Comparison with the NEA FEP database

3.1.1 Introduction

The NEA international FEP database is the outcome of work by the NEA FEP Database Working Group and it consists of two parts; the international FEP List and Project Databases. The audit was carried out using the Project Databases, which is a collection of FEP lists and databases compiled during repository assessment studies in various countries. Version 2.1 covers project-specific records, Project FEPs, from ten projects. The main features of the repository concepts for each of these projects are given in Table 3-1.

To facilitate the audit against the Project FEPs in the NEA FEP database and documentation of the auditing results, a “NEA mapping” file was created. The mapping file links information in the corresponding Project data file (PROFEP) in version 2.1 of the NEA FEP database with the SR-PSU files in the SKB FEP database.

3.1.2 General auditing procedure and rules

The NEA Project data file (PROFEP) in version 2.1 of the FEP database contains 1,671 FEPs. In order to make the audit work efficient, the mapping of the NEA Project FEPs was carried out by two person (Kristina Skagius and Maria Lindgren), but some general procedures and rules were followed in order to keep expert judgements regarding details of process understanding to a minimum at this stage. These general procedures and rules were as listed below.

- The NEA Project FEPs regarded as irrelevant were marked as such and justification for their screening had to be provided (see Section 3.1.3 for screening criteria).
- Relevant FEPs occurring outside the system boundary were classified as External factors (see Section 3.1.4).
- A NEA Project FEP that clearly could be linked to one or several processes, variables or the initial state of one or more variables was so linked.
- Suggestions on modifications to the preliminary list of FEPs and/or to descriptions of the processes and variables onto which the NEA Project FEPs were to be mapped were allowed at this stage. These modifications were required to be documented and all objects for which modifications were required had to be marked in the database.
- The mapping was required to be based on the NEA Project FEP description, rather than the FEP name.
- Any associations outside the primary meaning of the FEP that arose from consideration of the FEP description were required to be documented.

Table 3-1. Projects included in the version 2.1 of the NEA FEP database

Project	Code	Waste type	Host rock	Engineered barrier system concept
The Joint SKI/SKB Scenario Development Project, 1989	J	Spent PWR/BWR fuel	Crystalline basement	Corrosion-resistant copper containers, borehole emplacement with bentonite buffer
NEA Systematic Approaches to Scenario Development, 1992	N	Intermediate and low-level wastes	Hard rock	Steel and concrete packages, emplaced in caverns with cementitious grout and backfill
HMIP Assessment of Nirex Proposals – System Concept Group, 1993	H	Intermediate and low-level wastes	Tuff, Borrowdale Volcanic Group	Steel and concrete packages, emplaced in caverns with cementitious grout and backfill for ILW
AECL Scenario Analysis for EIS of Canadian Disposal Concept, 1994	A	Used CANDU fuel bundles	Plutonic rock of the Canadian Shield	Thin-walled titanium containers, borehole emplacement with bentonite–sand buffer
Nagra Scenario Development for Kristallin, 1994	K	Vitrified waste from reprocessing of spent PWR/BWR fuel	Crystalline basement under sedimentary cover in Northern Switzerland	Thick steel containers, in-tunnel emplacement with bentonite buffer
SKI SITE-94 Deep Repository Performance Assessment Project, 1995	S	Spent PWR/BWR fuel	Crystalline basement (based on geologic data from the Äspö site in south central Sweden)	Fuel, canister, bentonite buffer and tunnel backfill
US DOE Waste Isolation Pilot Plant, CCA, 1996	W	Contact- (CH) and remote handled (RH) Transuranic (TRU) waste	Salt (Salado Formation, New Mexico USA)	Magnesium oxide backfill as chemical conditioner, crushed salt, clay, concrete and asphalt seal components
AECL Issues for the 'Intrusion Resistant Underground Structure', 1997	I	Baled and bitumenised LLW from Chalk River Laboratories operations	Large sand ridge	Reinforced concrete vault above the water table
SCK.CEN Catalogue relevant to disposal in Boom Clay, 1994	M	Witrified high level waste (HLW), spent fuel (SF) and medium level waste (ILW)	Plastic clay, the Boom clay at Mol	Emplacement in concrete lined galleries
SKI Encyclopedia of FEPs for SFR and Spent Fuel Repositories, 2002	E	LLW and ILW in SFR repository; Spent BWR/PWR fuel in SFL repository	Crystalline basement: SFR ca 60 m below seabed at Forsmark; SFL* ca 500 m below ground level	LLW and ILW in vaults and concrete silo at SFR repository; SF in copper–steel canisters in bentonite lined boreholes (KBS-3V) in SFL* repository

* Earlier name of the Swedish spent fuel repository that is used in the NEA FEP database.

The general rules followed are essentially the same as those applied in the FEP processing for SR-Site (SKB 2010a). This made it possible to utilise the experience gained from the SR-Site work when carrying out this step.

3.1.3 Relevance screening

The relevance of each NEA Project FEP for the SFR repository system was judged on the basis of pre-defined relevance criteria. Essentially the same screening criteria as used in the SR-Site FEP processing were adopted, but adapted to the SFR repository system. The FEP could be screened out if one of the following criteria was fulfilled.

- The FEP is not appropriate to the actual waste, waste packaging or waste package design, repository design, geological or geographical setting.
- The FEP is very general and covered by other more specific NEA Project FEPs.
- The FEP is defined by a heading without any description of what is meant by the heading, but from the interpretation of the heading it is judged that the FEP is covered by other NEA Project FEPs.

In addition to the pre-defined criteria listed above, the need for a few supplementary criteria was identified during the audit work. A few of the entries among the NEA Project FEPs were considered as not being FEPs and were screened out with that justification. A few other entries were considered as not being relevant for post-closure safety and were screened out with that justification.

It should be emphasised that certain aspects given in a FEP description could be relevant for the SFR repository system, even if the FEP mainly related to a system deviating from the SFR system. For example, NEA FEPs that are related to bentonite barriers in a spent fuel repository concept are not necessarily screened out, since bentonite is part of the SFR repository system and the aspects addressed in the NEA FEP description might, therefore, be relevant. In these cases, the FEP was judged as relevant and treated further as described in the following sub-sections.

It should also be noted that the general strategy in the screening of FEP relevance was to judge FEPs as relevant rather than to screen them out at this stage, unless it was clearly obvious that they are irrelevant. By this approach, the final decision regarding the relevance of a FEP and reasons for the decision as to whether it should be included were left to the various experts involved in the further processing of the audit results. However, in a few cases, the documented justification provided by the experts involved in the SR-Site FEP processing was used to screen out a NEA Project FEP as irrelevant already at this stage in the process.

3.1.4 Classification of relevant FEPs

In SR-PSU, NEA Project FEPs assessed to be relevant for the SFR repository system were classified into one or more of the categories listed below. These are the same categories as were used in the FEP processing for SR-Site (and SR-Can) (SKB 2010a):

- Internal processes.
- Variables/initial states.
- Biosphere.
- External factors.
- Methodology issues.

Internal processes

This category was used to classify FEPs that were judged to describe a process relevant to one or several of the system components defined for the SR-PSU assessment, excluding the biosphere, see below.

Variables/initial states

This category was used to classify FEPs that were judged to affect a variable defined to describe the state of a system component, either the initial state of the system component or the state during evolution. If the FEP was considered to address both a process relevant for the evolution of a system component and a variable affected by that process, it was always assigned to the category system process, but not always also to the category variable/initial state. However, all FEPs that were judged to be relevant to the initial state of a system component were assigned to the category variables/initial states.

Biosphere

The biosphere system can be divided into a number of sub-systems and this category was used to classify FEPs that were judged to describe a sub-system or a process relevant to one or several of the sub-systems.

External factors

This category was used for NEA FEPs that act outside the boundary of the SFR repository system. As in SR-Site (and SR-Can), a further division was made into the sub-categories “Large-scale geological processes and effects”, “Climatic processes and effects”, “Future human actions” and “Other”, i.e. the same classification as is used in the NEA FEP database.

Methodology issues

A number of relevant issues relating to the factual basis for the assessment and to the methodology of the assessment were identified in the NEA FEP database during the FEP processing in SR-Site (and SR-Can) (SKB 2010a). Most of these are of a very general nature, but were for the sake of comprehensiveness also included in the SR-Site and SR-Can FEP catalogues as two FEPs, "Assessment basis" and "Methodology issues". For the same reason, these two methodology FEPs have also been included in the SR-PSU FEP catalogue (see further Section 4.5).

3.1.5 Documentation of audit results

The results of the audits in SR-PSU were documented in the NEA mapping file in the database. A short description of the type of documentation made is given here.

FEP relevance

The relevance of the FEP for the SFR system was documented in the NEA mapping file (see Figure 2-8) together with justification for the judgement "not relevant", when applicable. Out of the total number of 1,671 Project FEPs in version 2.1 of the NEA database, 553 FEPs were screened out as being irrelevant for the SR-PSU assessment. Examples of screened-out FEPs are those related to magmatic activity and volcanism, and FEPs addressing aspects specific to spent fuel.

Processes and variables/initial states

All NEA Project FEPs assigned to the categories "Internal processes" and "Variables/initial states" were marked as such in the mapping files and were compared with processes and variables in the preliminary version of the SR-PSU FEP catalogue. For NEA FEPs that were judged to be covered by processes or variables in the preliminary version of the SR-PSU FEP catalogue, the links between NEA Project FEPs and SR-PSU processes and variables were documented in the mapping file. In addition, NEA Project FEPs not covered by SR-PSU processes or variables or aspects of NEA Project FEPs not addressed were also documented in the mapping file. The result of this work pointed out the need for some minor modifications in the list of processes and variables/initial states in the preliminary version of the SR-PSU FEP catalogue.

The number of NEA FEPs assigned to the category "Internal processes" in the SR-PSU part of the SKB FEP database is 537, whereas 189 NEA FEPs are assigned to the category "Variables/initial states".

Biosphere

For SR-PSU, a biosphere process report has been developed (SKB 2014j). This report contains general descriptions of the processes considered to be of importance for the safety assessment and it builds on the biosphere report developed for SR-Site (SKB 2010b). In addition, the biosphere process report contains definitions of sub-systems of the biosphere and variables (features) needed to describe the evolution of the biosphere in relation to those aspects that are of importance for radionuclide accumulation and transport. For each sub-system, process and variable (feature) defined in the biosphere process report, a biosphere FEP has been included in the SR-PSU FEP catalogue (see Section 5.5). All NEA Project FEPs classified as belonging to the biosphere were linked to the defined SR-PSU biosphere FEPs and the links are documented in the SR-PSU mapping file. In total, 279 NEA FEPs are assigned to the Biosphere category.

External factors

All Project FEPs in the NEA FEP database classified as relevant external factors and marked as belonging to one of the categories "Climatic processes and effects", "Large-scale geological processes and effects", "Future human actions" or "Other" were linked to the appropriate SR-PSU FEP in the SR-PSU FEP catalogue. The SR-PSU FEPs in the categories "Climatic processes and effects" and "Large-scale geological processes and effects" were initially the same as those defined for SR-Site (SKB 2010a) and so also is the only FEP in the category "Other". Concerning the FEPs in the categories "Climatic processes and effects" and "Future human actions", FHA, a review of the SR-Site FEPs was made. This resulted in some modifications in the list of Climate and FHA FEPs in the SR-PSU FEP catalogue as compared with the FEPs defined in SR-Site (see Section 4.3).

The links between Project FEPs in version 2.1 of the NEA FEP database and SR-PSU external FEPs are documented in the NEA mapping file (Figure 2-8). In total, 212 NEA FEPs are assigned to external factors in SR-PSU.

Methodology issues

NEA Project FEPs judged to belong to the categories "Assessment basis" and "Methodology comment" were marked as such in the NEA mapping file (Figure 2-8). Of all Project FEPs included in version 2.1 of the NEA FEP database, 24 are associated with the SR-PSU FEP "Assessment basis" and 99 with the SR-PSU FEP "Assessment methodology".

3.2 Audit against SAR-08 and SAFE Interaction Matrices

3.2.1 SAR-08 and SAFE Interaction Matrices

In the two most recent safety assessments of the SFR repository, SAFE and SAR-08 (SKB 2001, 2008), Interaction Matrices were used as a tool to identify processes and interactions between processes that have to be considered in quantitative analyses of the system. The work was mainly conducted in SAFE, but revisited and updated in SAR-08, because of an extension in the time frame for which safety should be demonstrated (from 10,000 years after repository closure in SAFE to 100,000 years after closure in SAR-08) but also in order to handle feedback from the authorities on the SAFE documentation.

The basic principle of an Interaction Matrix is to list the parameters defining the properties and conditions in the physical components of the system studied along the leading diagonal elements of a square matrix. Events and processes that are influenced by and affect the properties and conditions defined in the leading diagonal elements of the matrix occur in the off-diagonal elements of the matrix.

In SAFE and SAR-08, the SFR disposal system was described by three coupled Interaction Matrices: one for the repository vaults (Repository matrix), one for the geosphere (Geosphere matrix) and one for the biosphere (Biosphere matrix). These matrices contained all interactions identified as well as the importance assigned to each interaction according to a defined priority scale.

No separate process reports were developed in SAFE or SAR-08, but the important interactions (processes) in the Interaction Matrices were compiled into a system description for the base scenario in SAFE (SKB 2001, Chapter 4). The revisiting of this qualitative FEP analysis that was conducted in SAR-08 resulted in the addition of a few interactions and in the need to upgrade the earlier judged importance of a number of interactions (SKB 2008, Chapter 5). The main reason for these modifications was the above mentioned increased time period that should be covered in the assessment, which implied that the climatic processes permafrost and glaciation that were not included in SAFE had to be considered in SAR-08.

The interactions (processes) judged as important in SAFE (SKB 2001) and the additions made after the revision in SAR-08 (SKB 2008) are listed in Table 3-2 for the repository system, in Table 3-3 for the geosphere system and in Table 3-4 (abiotic related) and Table 3-5 (biotic related) for the biosphere system, as these systems are defined in SAFE and SAR-08.

Table 3-2. Important processes in the repository system as identified in SAFE (SKB 2001, Section 4.2) and later updated in SAR-08 (SKB 2008, Section 5.1). Note that processes may apply to systems without that being marked in the table, since the table is restricted to show processes assessed as important in SAFE and SAR-08.

Process/interaction	Waste form	Concrete and steel packaging	Concrete backfill and structures	Bentonite barriers	Vaults and backfill
Recrystallisation	X	X	X		
Expansion/contraction	X				X
Water uptake	X			X	
Chemical and microbial degradation	X				
Corrosion of metals	X	X	X		
Dissolution/precipitation	X	X	X	X	X
Cracking/deformation	X	X	X		
Microbial activity/growth	X	X	X	X	X
Irradiation	X				
Rock fallout/redistribution			X		
Bentonite expansion and contraction				X	
Montmorillonite transformation				X	
Ion exchange				X	
Dispersion of clay particles				X	
Redistribution of backfill					X
Bentonite intrusion					X
Osmosis	X			X	
Sorption	X	X	X	X	X
Diffusion	X	X	X	X	X
Advection and mixing	X	X	X	X	X
Dispersion	X	X	X	X	X
Erosion/colloid formation/colloid transport	X	X	X	X	X
Gas dissolution/ degassing	X	X	X	X	X
Water flow	X	X	X	X	X
Two phase flow and saturation	X	X	X	X	X
Gas generation through degradation of organic material	X	X	X	X	X
Gas generation through metal corrosion	X	X	X	X	X
Gas generation through radiolysis	X				
Gas flow	X	X	X	X	X
Heat generating reactions	X				
Heat conduction	X				
Advection of radioactive gas	X	X	X	X	X
Methylation/transformation	X	X	X	X	X
Radioactive/radionuclide decay	X	X	X	X	X
Phase changes[1)]	X	X	X	X	X
Erosion[1)]				X	
Rock fallout[1)]				X	
Heat transport[1)]	X	X	X	X	X
Contaminant transport[1)]	X	X	X	X	X
Concentration/dilution[1)]	X	X	X	X	X

[1)] New interaction (process) defined in SAR-08.

Table 3-3. Important processes in the geosphere system as identified in SAFE (SKB 2001, Section 4.3) and later updated in SAR-08 (SKB 2008, Section 5.2). Note that processes may apply to systems without that being marked in the table, since the table is restricted to show processes assessed as important in SAFE and SAR-08.

Process/interaction	Access tunnels and boreholes	Plugs	Rock matrix and rock fractures
Dissolution/precipitation	X	X	X
Ionic strength effects	X		
Redistribution of particles in the flowing water	X		
Microbial activity, growth, degradation	X	X	X
Water uptake in bentonite		X	
Bentonite expansion/dispersion		X	
Recrystallisation		X	
Cracking of concrete in plugs		X	
Corrosion		X	
Ion exchange, sorption		X	X
Redistribution of stress			X
Diffusion and matrix diffusion	X	X	X
Advection/dispersion	X	X	X
Colloid formation and transport	X	X	X
Gas dissolution/degassing	X	X	X
Water flow – permeability, driving forces	X	X	X
Gas flow – saturation, permeability, pressure	X	X	X
Deformation and stability	X		X
Degradation of rock reinforcement	X		X
Transport with gas	X	X	X
Transport with colloids or microbes			X
Methylation/transformation			X
Radioactive decay	X	X	X
Flow in open boreholes[1)]	X		
Phase changes[1)]	X	X	X
Heat conduction and heat transport[1)]	X	X	X
Erosion[1)]		X	
Concentration/dilution[1)]	X	X	X
Borehole penetration[1)]			X
Ice load including stress and strain changes[1]			X

[1)] New interaction (process) defined in SAR-08.

Table 3-4. Important processes related to the abiotic components of the biosphere system as identified in SAFE (SKB 2001, Section 4.4) and later updated in SAR-08 (SKB 2008, Section 5.3 and Appendix C). Note that processes may apply to systems without that being marked in the table, since the table is restricted to show processes assessed as important in SAFE and SAR-08.

Process/interaction	Quaternary deposits	Water in Quaternary deposits	Surface water	Gas/ Atmosphere
Relocation	X			
Bioturbation	X			
Change in water content	X			
Erosion	X			
Sedimentation	X			
Water transport and convection		X	X	
Recharge/discharge		X	X	
Evaporation/condensation		X	X	
Water extraction		X		
Wind stress and wave formation			X	
Movement – human induced			X	
Precipitation			X	
Sea currents			X	
Sea level changes			X	
Re-suspension			X	X
Mixing		X	X	
Property changes			X	
Gas transport				X
Heat storage			X	
Heat convection			X	
Light absorption			X	
Sorption/desorption	X	X	X	
Phase transitions	X	X	X	X
Radioactive decay	X	X	X	X
Heat transport	X	X	X	X

Table 3-5. Important processes related to the biotic components of the biosphere system as identified in SAFE (SKB 2001, Section 4.4) and later updated in SAR-08 (SKB 2008, Section 5.3 and Appendix C). Note that processes may apply to systems without that being marked in the table, since the table is restricted to show processes assessed as important in SAFE and SAR-08.

Process/interaction	Primary producers	Decomposers	Filter feeders	Herbivores	Carnivores	Humans
Settlement	X	X	X	X	X	X
Feeding, food supply	X	X	X	X	X	
Stimulation/inhibition	X	X	X	X	X	X
Water uptake	X	X	X	X	X	1)
Light attenuation	X					
Insolation	X					
Material supply						X
Water use						X
Particle production and trapping		X				X
Sorption/uptake and excretion	X	X	X	X	X	X
Growth	X	X	X	X	X	X
Exposure	X	X	X	X	X	X
Radioactive decay	X	X	X	X	X	X

1) Included in Water use.

3.2.2 Audit procedure and documentation

The content of the SAR-08 Interaction Matrices for the repository system and the geosphere system was mapped to the content of the preliminary SR-PSU FEP catalogue in a similar way as was done for the NEA Project FEPs. However, no mapping of the content of the SAR-08 biosphere matrix was made. This is because this matrix has been further developed within the frame of the most recent safety assessment of a repository for spent nuclear fuel at Forsmark, SR-Site (SKB 2011), and this most recent work has been considered in the establishment of the set of biosphere FEPs in the SR-PSU FEP catalogue.

For carrying out the audit and for documentation of the results, a Matrix mapping file was created (see Figure 2-8). This file comprises a link between a file containing the information regarding all interactions in the SAR-08 Interaction Matrices and the other files in the SR-PSU part of the SKB FEP database. The three SAR-08 Interaction Matrices contain in total 1260 defined interactions and diagonal elements (51), of which 474 interactions and diagonal elements (15) belong to the biosphere matrix. Thus, the repository and geosphere matrices contain 786 interactions and diagonal elements (36). In the audit process, 32 interactions were assessed as not relevant and a motivation for this judgement was included in the Matrix mapping file. The remaining 754 interactions and diagonal elements were all sorted to the SR-PSU FEP catalogue.

The various categories used for classification of the interactions are the same as those used in the audit against the NEA Project FEPs, namely "Internal processes", "Variable/initial state", "External factor", "Biosphere" and "Methodology issues". For each interaction, this classification is marked in the Matrix mapping file.

Matrix interactions assigned to the categories "Internal processes" and "Variable/initial states" were linked to the appropriate process, variable or initial state record in the SKB database. This link was documented in the Matrix mapping file. If the interaction was not addressed in the SR-PSU FEP catalogue, this was marked and commented on in the Matrix mapping file. Of all the 744 interactions defined in the two matrices, 653 were classified as relevant for a system process. The corresponding number of interactions assigned to the category "Variable/initial state" is 735.

Seven of the interactions in the geosphere matrix were classified as belonging to the category "External factors". These interactions are related to human intrusion, future climate changes, ice load during glaciations and earthquakes. These aspects were judged to be covered by NEA FEPs and, therefore, were not further handled. Several interactions in the geosphere matrix (28) were also sorted to the biosphere system, in addition to be classified as belonging to the geosphere. These interactions are covering the interface between the geosphere and the biosphere and are also present in the SAR-08 biosphere matrix. For the same reason as stated above, i.e. the further development of the SAR-08 biosphere matrix, these interactions were not further handled in this auditing process.

Two interactions in the repository matrix and seven in the geosphere matrix were classified as being methodology issues. These interactions are related to chemical toxicants and naturally occurring radionuclides (radon generation in the rock) and these types of issues are outside the scope of the safety assessment SR-PSU. They were not further addressed.

3.3 Audit against other international FEP lists

Many of the projects in the NEA database are concerned with spent fuel or high-level waste. At the time of the FEP audit work, unpublished preliminary versions of FEP lists from two projects for low- and intermediate-level waste were available, namely Olkiluoto L/ILW in Finland and Rokkasho 3 in Japan. In order to further increase the support for the content of the SR-PSU FEP catalogue it was checked against these FEP lists. The review did not lead to any changes in the FEP catalogue. However, no formal documentation of the outcome of the review was made in the FEP database because of the unpublished status of the FEP lists.

4 Further processing of FEPs

The result of the audit against the Project FEPs in the NEA FEP database and the SAR-08/SAFE Interaction Matrices was used to create check lists for the preparation of process descriptions, descriptions of the initial states of the repository system components and of external factors as described in the SR-PSU process reports (SKB 2014c, d, e), Initial state report (SKB 2014b), Climate report (SKB 2014f) and the FHA report (SKB 2014g). Furthermore, all NEA Project FEPs associated to biosphere FEPs defined for SR-PSU were checked in order to ensure that important aspects are addressed in the SR-PSU biosphere reports (SKB 2014j, k). The different procedures applied for the post-processing of the audit results are described in this chapter.

4.1 Internal processes

The audit against the NEA Project FEPs and SAR-08/SAFE Interaction Matrices resulted in proposed modifications to the preliminary lists of processes to be included as well as comments on important aspects to be addressed in the descriptions. This information was propagated to the experts responsible for preparing the process descriptions for consideration. In addition, lists of all NEA Project FEPs, together with identification of the processes with which they are associated, were provided to the experts. These lists were used to ensure that all relevant aspects of a process were addressed in the process description and appropriately handled in SR-PSU and the handling of each NEA Project FEP was documented in tables created for this purpose.

The result of the post-processing was documented in the SKB FEP database. Each process was defined as an SKB FEP and was incorporated in the SR-PSU FEP catalogue (see Section 5.3). The documented handling of each NEA Project FEP was also added to the FEP database and linked to the SR-PSU FEP in the FEP catalogue. The results for the different system components are further commented upon in the following sub-sections.

All SAFE and SAR-08 matrix interactions are also linked to the appropriate SR-PSU FEP in the FEP catalogue, but no formal documentation of the handling of each interaction has been made, although the option for this is included in the FEP database. However, the coverage of the interactions assessed as important in SAFE and SAR-08, as tabulated in Section 3.2.1, is discussed in the following sub-sections. It is judged as not likely that this limitation has had any important implications for the SR-PSU assessment. This is because the SAFE and SAR-08 Interaction Matrices were used as input when setting up the SR-PSU FEP catalogue.

4.1.1 Waste form

Twenty-two processes are defined for the system component *Waste form* in the SR-PSU Waste form and packaging process report (SKB 2014c), and these are represented in the FEP database by FEP record identities WM01 to WM22 (see Table 5-2).

A sorting of the SR-PSU process FEPs for the waste form to the corresponding interactions (processes) defined in SAFE and SAR-08, as listed in Table 3-2, is provided in Table 4-1. The table shows that all important interactions (processes) defined in SAFE and SAR-08 are covered by the processes in SR-PSU. A comparison with the list of waste form processes in SR-PSU (see Table 5-2) reveals that all SR-PSU processes are connected to at least one of the important interaction (processes) identified in SAFE and SAR-08, but also that several SR-PSU processes in some cases are connected to the same interaction identified in SAFE and SAR-08. This shows that the coverage of some processes has changed as a result of the FEP work in SR-PSU, resulting in some additional entries, but without the need to add any process not addressed in the previous work.

The tables documenting the handling of NEA Project FEPs associated with processes in the system component *Waste form* are provided in Appendix 4. These FEP tables are also included in the FEP database and linked to the corresponding FEP records in the SR-PSU FEP catalogue.

Table 4-1. Important interactions (processes) for the waste form as defined in SAFE and SAR-08 (see Table 3-2) and the corresponding processes in SR-PSU.

SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process	SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process
Recrystallisation	Dissolution, precipitation and recrystallisation	Water flow	Water transport under saturated conditions
Expansion/contraction	Fracturing	Two phase flow and saturation	Water uptake and transport during unsaturated conditions
Water uptake	Water uptake/swelling	Gas generation through degradation of organic material	Degradation of organic materials Gas formation and transport
Chemical and microbial degradation	Degradation of organic materials Microbial processes	Gas generation through metal corrosion	Metal corrosion Gas formation and transport
Corrosion of metals	Metal corrosion	Gas generation through radiolysis	Radiolytic decomposition of organic material Gas formation and transport
Dissolution/precipitation	Dissolution, precipitation and recrystallisation Colloid formation and transport Speciation of radionuclides	Gas flow	Gas formation and transport
Cracking/deformation	Fracturing	Heat generating reactions	Degradation of organic materials Metal corrosion Microbial processes
Microbial activity/growth	Microbial processes	Heat conduction	Heat transport
Irradiation	Radiation attenuation/heat generation Radiolytic decomposition of organic material Water radiolysis	Advection of radioactive gas	Transport of radionuclides in the gas phase
Osmosis	Water uptake/swelling	Methylation/ transformation	Microbial processes
Sorption	Sorption/uptake	Radioactive decay Radionuclide decay[1)]	Radioactive decay Transport of radionuclides in the water phase Transport of radionuclides in the gas phase
Diffusion	Diffusive transport of dissolved species	Phase changes	Phase changes/freezing
Advection and mixing	Advective transport of dissolved species	Heat transport	Heat transport
Dispersion	Advective transport of dissolved species	Contaminant transport	Transport of radionuclides in the water phase
Erosion/colloid formation/ colloid transport	Colloid formation and transport	Concentration/dilution[2)]	Phase changes/freezing
Gas dissolution/degassing	Gas formation and transport		

[1)] The SAFE/SAR-08 definition is: Radioactive decay will affect the type and amount of radionuclides at different locations in the repository system. In SR-PSU, this is described in the transport processes.

[2)] The SAR-08 definition is: Concentration and dilution of water occurring as result of change in water aggregate state.

4.1.2 Concrete and steel packaging

Sixteen processes are defined for the system component *Concrete and steel packaging* in the SR-PSU Waste form and packaging process report (SKB 2014c), and these are represented in the FEP database by FEP record identities Pa01 to Pa16 (see Table 5-3).

As for the waste form, a sorting of the SR-PSU process FEPs for the concrete and steel packaging to the corresponding interactions (processes) defined in SAFE and SAR-08, as listed in Table 3-2, has been made. The result is provided in Table 4-2 and it shows that all but one of the interactions (processes) in SAFE and SAR-08 are covered by the processes defined for the packaging in SR-PSU. The exception concerns gas generation through degradation of organic materials in the packaging.

Table 4-2. Important interactions (processes) for the concrete and steel packaging as defined in SAFE and SAR-08 (see Table 3-2) and the corresponding processes in SR-PSU.

SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process	SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process
Recrystallisation	Dissolution, precipitation and recrystallisation	Two phase flow and saturation	Water uptake and transport during unsaturated conditions
Corrosion of metals	Metal corrosion	Gas generation through degradation of organic material	
Dissolution/ precipitation	Dissolution, precipitation and recrystallisation Colloid formation and transport Speciation of radionuclides	Gas generation through metal corrosion	Metal corrosion Gas formation and transport
Cracking/deformation	Fracturing/deformation	Gas flow	Gas formation and transport
Microbial activity/growth	Microbial processes	Advection of radioactive gas	Transport of radionuclides in the gas phase
Sorption	Sorption/uptake	Methylation/transformation	Microbial processes
Diffusion	Diffusive transport of dissolved species	Radionuclide decay[1)]	Transport of radionuclides in the water phase Transport of radionuclides in the gas phase
Advection and mixing	Advective transport of dissolved species	Phase changes	Phase changes/freezing
Dispersion	Advective transport of dissolved species	Heat transport	Heat transport
Erosion/colloid formation/ colloid transport	Colloid transport and filtering	Contaminant transport	Transport of radionuclides in the water phase
Gas dissolution/degassing	Gas formation and transport	Concentration/dilution[2)]	Phase changes/freezing
Water flow	Water transport under saturated conditions		

[1)] The SAFE/SAR-08 definition is: Radioactive decay will affect the type and amount of radionuclides at different locations in the repository system. In SR-PSU, this is described in the transport processes.

[2)] The SAR-08 definition is: Concentration and dilution of water occurring as result of change in water aggregate state.

There are some organic materials present in the concrete packaging such as rubber liners and expansion cassettes. However, already in SAFE (SKB 2001, Section 4.2.9), it was concluded that the amount is probably small enough to make degradation of these a negligible gas source compared with gas from corrosion of reinforcements and metals. This and the small amount of organics in the packaging, in relation to that in the wastes, justifies the decision not to define a specific process for degradation of organic materials in the steel and concrete packaging.

The tables documenting the handling of NEA Project FEPs associated with processes in the system component *Concrete and steel packaging* are provided in Appendix 5. These FEP tables are also included in the FEP database and linked to the corresponding FEP records in the SR-PSU FEP catalogue.

4.1.3 BMA barriers

Nineteen processes are defined for the system component *BMA barriers* in the SR-PSU engineered barrier process report (SKB 2014d), and these are represented in the FEP database by FEP record identities BMABa01 to BMABa19 (see Table 5-4).

Of the system components defined in SAFE and SAR-08, "Concrete backfill and structures" and "Vaults and backfill" are those corresponding to the BMA barrier system in SR-PSU. The result of sorting the SR-PSU processes defined for the BMA barriers to the interactions (processes) defined for the corresponding system components in SAFE and SAR-08, as listed in Table 3-2, is provided in Table 4-3. The table shows that all important interactions (processes) defined in SAFE and SAR-08 are covered by the processes in SR-PSU. However, it should be noted that the SAFE and SAR-08 interaction "Bentonite intrusion" defined for the system component "Vaults and backfill" is not relevant for the BMA barriers since they contain no bentonite. Therefore, this interaction is not included in Table 4-3.

Table 4-3. Important interactions (processes) for the concrete backfill and structures and the vaults and backfill as defined in SAFE and SAR-08 (see Table 3-2) and the corresponding processes for the BMA barriers in SR-PSU.

SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process	SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process
Recrystallisation	Concrete degradation	Gas dissolution/degassing	Gas transport/dissolution
Expansion/contraction	Mechanical processes	Water flow	Water transport under saturated conditions
Corrosion of metals	Metal corrosion	Two phase flow and saturation	Water uptake and transport during unsaturated conditions
Dissolution/ precipitation	Concrete degradation Aqueous speciation and reactions Speciation of radionuclides	Gas generation through degradation of organic material	Microbial processes Gas formation
Cracking/deformation	Mechanical processes	Gas generation through metal corrosion	Metal corrosion Gas formation
Microbial activity/growth	Microbial processes	Gas flow	Gas transport/dissolution
Rock fallout/ redistribution	Mechanical processes	Advection of radioactive gas	Transport of radionuclides in the gas phase
Redistribution of backfill	Mechanical processes	Methylation/transformation	Microbial processes
Sorption	Sorption – concrete/ shotcrete Sorption – crushed rock backfill	Radionuclide decay[1)]	Transport of radionuclides in the water phase Transport of radionuclides in the gas phase
Diffusion	Diffusion	Phase changes	Phase changes/freezing
Advection and mixing	Advection and dispersion	Heat transport	Heat transport
Dispersion	Advection and dispersion	Contaminant transport	Transport of radionuclides in the water phase
Erosion/colloid formation/ colloid transport	Colloid stability, transport and filtering	Concentration/dilution[2)]	Phase changes/freezing

[1)] The SAFE/SAR-08 definition is: Radioactive decay will affect the type and amount of radionuclides at different locations in the repository system. In SR-PSU, this is described in the transport processes.

[2)] The SAR-08 definition is: Concentration and dilution of water occurring as result of change in water aggregate state.

A comparison with the list of BMA processes in SR-PSU (see Table 5-4 in Section 5.3) reveals that all SR-PSU processes are connected to at least one of the important interaction (processes) identified in SAFE and SAR-08, but also that several SR-PSU processes are connected to the same interaction identified in SAFE and SAR-08. This again shows that the coverage of some processes has changed as a result of the FEP work in SR-PSU, but without the need to add any process not addressed in the previous work.

The tables documenting the handling of NEA Project FEPs associated with processes in the system component *BMA barriers* are provided in Appendix 6. These FEP tables are also included in the FEP database and linked to the corresponding FEP records in the SR-PSU FEP catalogue.

4.1.4 BTF barriers

Eighteen processes are defined for the system component *BTF barriers* in the SR-PSU engineered barrier process report (SKB 2014d), and these are represented in the FEP database by FEP record identities BTFBa01 to BTFBa18 (see Table 5-5).

Similarly to the BMA barriers, the system components "Concrete backfill and structures" and "Vaults and backfill" defined in SAFE and SAR-08 are those corresponding to the BTF barrier system in SR-PSU. This is also reflected in the similarity in the set of processes defined for the BMA and BTF barriers in SR-PSU. The only difference is that the sorption process for BMA has been divided into sorption on concrete/shotcrete and sorption on crushed rock backfill, whereas sorption on both materials is addressed in the same process description for BTF. Therefore, the comparison of the set of processes defined for BMA with that for SAFE and SAR-08 provided in Table 4-3 is relevant also for BTF, as is the conclusion from the comparison (see Section 4.1.3).

The tables documenting the handling of NEA Project FEPs associated with processes in the system component *BTF barriers* are provided in Appendix 7. These FEP tables are also included in the FEP database and linked to the corresponding FEP records in the SR-PSU FEP catalogue.

4.1.5 Silo barriers

Twenty-six processes are defined for the system component *Silo barriers* in the SR-PSU engineered barrier process report (SKB 2014d), and these are represented in the FEP database by FEP record identities SiBa01 to SiBa26 (see Table 5-6).

Of the system components defined in SAFE and SAR-08, "Concrete backfill and structures", "Bentonite barriers" and "Vaults and backfill" are those corresponding to the Silo barrier system in SR-PSU. Table 4-4 shows the result of sorting the SR-PSU processes defined for the Silo barriers to the interactions (processes) defined for the corresponding system components in SAFE and SAR-08, as listed in Table 3-2. As for the other system components, this sorting shows that all interactions (processes) in SAFE and SAR-08 are covered by the SR-PSU processes.

Table 4-4. Important interactions (processes) for the concrete backfill and structures, bentonite barriers, and the vaults and backfill as defined in SAFE and SAR-08 (see Table 3-2) and the corresponding processes for the Silo barriers in SR-PSU.

SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process	SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process
Recrystallisation	Concrete degradation	Dispersion	Advection and dispersion
Expansion/contraction	Mechanical processes	Erosion/colloid formation/colloid transport	Montmorillonite colloid release Colloid transport and filtering
Water uptake	Water uptake and transport during unsaturated conditions	Gas dissolution/degassing	Gas transport/dissolution
Corrosion of metals	Metal corrosion	Water flow	Water transport under saturated conditions
Dissolution/ precipitation	Concrete degradation Dissolution/precipitation Alteration of impurities Cementation in bentonite Aqueous speciation and reactions Speciation of radionuclides	Two phase flow and saturation	Water uptake and transport during unsaturated conditions
Cracking/deformation	Mechanical processes	Gas generation through degradation of organic material	Microbial processes Gas formation
Microbial activity/growth	Microbial processes	Gas generation through metal corrosion	Metal corrosion Gas formation
Rock fallout/redistribution	Mechanical processes	Gas flow	Gas transport/dissolution
Bentonite expansion and contraction	Mechanical processes	Advection of radioactive gas	Transport of radionuclides in the gas phase
Montmorillonite transformation	Montmorillonite transformation	Methylation/transformation	Microbial processes
Ion exchange	Sorption (including ion exchange of major ions)	Radionuclide decay[1)]	Transport of radionuclides in the water phase Transport of radionuclides in the gas phase
Dispersion of clay particles	Montmorillonite colloid release	Phase changes	Phase changes/freezing
Redistribution of backfill	Mechanical processes	Erosion	Montmorillonite colloid release
Bentonite intrusion	Mechanical processes	Rock fallout	Mechanical processes
Osmosis	Osmosis	Heat transport	Heat transport
Sorption	Sorption (including ion exchange of major ions)	Contaminant transport	Transport of radionuclides in the water phase
Diffusion	Diffusion	Concentration/dilution[2)]	Phase changes/freezing
Advection and mixing	Advection and dispersion		

[1)] The SAFE/SAR-08 definition is: Radioactive decay will affect the type and amount of radionuclides at different locations in the repository system. In SR-PSU, this is described in the transport processes.

[2)] The SAR-08 definition is: Concentration and dilution of water occurring as result of change in water aggregate state.

A comparison with the list of Silo processes in SR-PSU (see Table 5-6 in Section 5.3) reveals that most SR-PSU processes are connected to at least one of the important interactions (processes) identified in SAFE and SAR-08. The exceptions are Piping/erosion (SiBa06 in Table 5-6) and Iron-bentonite interaction (SiBa18 in Table 5-6), which are not specifically included in SAFE and SAR-08. Another observation is that the processes defined in SR-PSU for the description of the chemical evolution of the Silo barrier materials are more specific and, hence, larger in number. On the contrary, the different mechanical interactions (processes) identified in SAFE and SAR-08 has, in SR-PSU, been grouped together under the heading/name "Mechanical processes" (SiBa07 in Table 5-6). The latter is also the case for the barriers in the other waste vaults.

The tables documenting the handling of NEA Project FEPs associated with processes in the system component *Silo barriers* are provided in Appendix 8. These FEP tables are also included in the FEP database and linked to the corresponding FEP records in the SR-PSU FEP catalogue.

4.1.6 BRT barriers

Eighteen processes are defined for the system component *BRT barriers* in the SR-PSU engineered barrier process report (SKB 2014d), and these are represented in the FEP database by FEP record identities BRTBa01 to BRTBa18 (see Table 5-7).

BRT, a vault for disposal of reactor pressure vessels, is not part of the repository that exists today (SFR 1), but part of the planned extension of the facility. Hence, this vault was not included in the SAFE and SAR-08 FEP work (SKB 2001, 2008). Based on the similarity with the BTF vault as concerns the barrier materials, the same set of processes as defined for the BTF barriers was selected for the BRT barriers.

The tables documenting the handling of NEA Project FEPs associated with processes in the system component *BRT barriers* are provided in Appendix 9. These FEP tables are also included in the FEP database and linked to the corresponding FEP records in the SR-PSU FEP catalogue.

4.1.7 BLA barriers

Sixteen processes are defined for the system component *BLA barriers* in the SR-PSU engineered barrier process report (SKB 2014d), and these are represented in the FEP database by FEP record identities BLABa01 to BLABa16 (see Table 5-8).

Of the system components defined in SAFE and SAR-08, "Concrete backfill and structures" and "Vaults and backfill" are those corresponding to the BLA barrier system in SR-PSU. The result of sorting the SR-PSU processes defined for the BLA barriers to the interactions (processes) defined for the corresponding system components in SAFE and SAR-08, as listed in Table 3-2, is provided in Table 4-5. This sorting shows that all important interactions (processes) defined in SAFE and SAR-08 are covered by the processes in SR-PSU.

A comparison with the list of BLA processes in SR-PSU (see Table 5-8) shows that all SR-PSU processes are connected to at least one of the important interactions (processes) identified in SAFE and SAR-08. Since concrete construction materials in BLA are limited to the concrete floor and shotcrete lining of the rock walls and that the only corroding material is the rock bolts, the chemical degradation of these materials are described in one process only in SR-PSU.

The tables documenting the handling of NEA Project FEPs associated with processes in the system component *BLA barriers* are provided in Appendix 10. These FEP tables are also included in the FEP database and linked to the corresponding FEP records in the SR-PSU FEP catalogue.

4.1.8 Plugs and other closure components

Twenty-one processes are defined for the system component *Plugs and other closure components* in the SR-PSU engineered barrier process report (SKB 2014d), and these are represented in the FEP database by FEP record identities Pg01 to Pg21 (see Table 5-9).

Table 4-5. Important interactions (processes) for the concrete backfill and structures and the vaults and backfill as defined in SAFE and SAR-08 (see Table 3-2) and the corresponding processes for the BLA barriers in SR-PSU.

SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process	SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process
Recrystallisation	Degradation of rock bolts, reinforcement and concrete	Gas dissolution/ degassing	Gas transport/dissolution
Expansion/contraction	Mechanical processes	Water flow	Water transport under saturated conditions
Corrosion of metals	Degradation of rock bolts, reinforcement and concrete	Two phase flow and saturation	Water uptake and transport during unsaturated conditions
Dissolution/ precipitation	Degradation of rock bolts, reinforcement and concrete Aqueous speciation and reactions Speciation of radionuclides	Gas generation through degradation of organic material	Microbial processes
Cracking/deformation	Mechanical processes	Gas generation through metal corrosion	Degradation of rock bolts, reinforcement and concrete
Microbial activity/ growth	Microbial processes	Gas flow	Gas transport/dissolution
Rock fallout/ redistribution	Mechanical processes	Advection of radioactive gas	Transport of radionuclides in the gas phase
Redistribution of backfill	Mechanical processes	Methylation/transformation	Microbial processes
Sorption	Sorption	Radionuclide decay[1)]	Transport of radionuclides in the water phase Transport of radionuclides in the gas phase
Diffusion	Diffusion	Phase changes	Phase changes/freezing
Advection and mixing	Advection and dispersion	Heat transport	Heat transport
Dispersion	Advection and dispersion	Contaminant transport	Transport of radionuclides in the water phase
Erosion/colloid formation/ colloid transport	Colloid stability, transport and filtering	Concentration/dilution[2)]	Phase changes/freezing

[1)] The SAFE/SAR-08 definition is: Radioactive decay will affect the type and amount of radionuclides at different locations in the repository system. In SR-PSU, this is described in the transport processes.

[2)] The SAR-08 definition is: Concentration and dilution of water occurring as result of change in water aggregate state.

Of the system components defined in SAFE and SAR-08, "Access tunnels and boreholes" and "Plugs" are those corresponding to the system Plugs and other closure components in SR-PSU. The result of sorting the SR-PSU processes defined for this system to the interactions (processes) defined for the corresponding system components in SAFE and SAR-08, as listed in Table 3-3, is provided in Table 4-6. This sorting shows that all interactions (processes) in SAFE and SAR-08 are covered by the SR-PSU processes, except "Flow in open boreholes" and to some extent "Colloid formation and transport".

As stated in the Engineered barrier process report (SKB 2014d, Section 2.9), boreholes that were included in the preliminary investigations and those that intersect or are located very close to the underground facility have been or will be sealed prior to the start of construction of SFR 3, and the remaining boreholes will be sealed after operation is concluded. Flow in open boreholes is thus not included as a specific FEP, but is covered by the initial state FEP ISGen05 Design deviations – Mishaps (see Section 4.2). Concerning colloid formation and transport, colloid formation is addressed in the PSU processes Piping/erosion and Montmorillonite colloid release. The possibility brought up in SAFE (SKB 2001) that plugs can act as a filter for colloids is, however, not specifically addressed in the PSU Engineered barrier process report (SKB 2014d). This is justified, since, cautiously, no credit is taken for any retention of colloids (with potentially associated radionuclides) in the plugs.

A comparison with the list of Plug and other closure component processes in SR-PSU (see Table 5-9) shows that all SR-PSU processes, with one exception, are connected to at least one of the important interactions (processes) identified in SAFE and SAR-08. The exception is the PSU process Osmosis (Pg14). However, a corresponding interaction/process is included in the SAFE and SAR-08 Geosphere interaction matrix (Ge10.11c), but assessed as being of negligible importance for the long-term function of the repository (SKB 2001, Appendix E).

Table 4-6. Important interactions (processes) for the access tunnels and boreholes and plugs as defined in SAFE and SAR-08 (see Table 3-3) and the corresponding processes for the plugs and other closure components in SR-PSU.

SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process	SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process
Dissolution/ precipitation	Dissolution, precipitation, recrystallisation and clogging in backfill Montmorillonite transformation Alteration of impurities in bentonite Aqueous speciation and reactions Speciation of radionuclides	Gas dissolution/degassing	Gas transport/dissolution
Ionic strength effects	Sorption (including ion-exchange of major ions) Montmorillonite colloid release	Water flow – permeability, driving forces	Water transport under saturated conditions
Redistribution of particles in the flowing water	Mechanical processes	Gas flow – saturation, permeability, pressure	Water uptake and transport during unsaturated conditions Gas transport/dissolution
Microbial activity, growth, degradation	Microbial processes	Deformation and stability	Mechanical processes
Water uptake in bentonite	Water uptake and transport during unsaturated conditions	Degradation of rock reinforcement	Degradation of rock bolts, reinforcements and concrete
Bentonite expansion/ dispersion	Mechanical processes Montmorillonite colloid release	Transport with gas	Transport of radionuclides in the gas phase
Recrystallisation	Degradation of rock bolts, reinforcements and concrete	Radionuclide decay[1)]	Transport of radionuclides in the water phase Transport of radionuclides in the gas phase
Cracking of concrete in plugs	Mechanical processes	Phase changes	Phase changes/freezing
Corrosion	Degradation of rock bolts, reinforcements and concrete	Flow in open boreholes	
Ion exchange, sorption	Sorption (including ion-exchange of major ions)	Heat conduction and heat transport	Heat transport
Diffusion	Diffusion	Erosion	Piping/erosion Montmorillonite colloid release
Advection/dispersion	Advection and dispersion Transport of radionuclides in the water phase	Concentration/dilution[2)]	Phase changes/freezing
Colloid formation and transport	Piping/erosion Montmorillonite colloid release		

[1)] The SAFE/SAR-08 definition is: Radioactive decay will affect the type and amount of radionuclides at different locations in the repository system. In SR-PSU, this is described in the transport processes.

[2)] The SAR-08 definition is: Concentration and dilution of water occurring as result of change in water aggregate state.

The tables documenting the handling of NEA Project FEPs associated with processes in the system component *Plugs and other closure components* are provided in Appendix 11. These FEP tables are also included in the FEP database and linked to the corresponding FEP records in the SR-PSU FEP catalogue.

4.1.9 Geosphere

Twenty-two processes are defined for the system component *Geosphere* in the SR-PSU geosphere process report (SKB 2014e), and these are represented in the FEP database by FEP record identities Ge01 to Ge24 (see Table 5-10 in Section 5.3). All these processes are also defined for the geosphere in SR-Site (SKB 2010a), with the modification that Radionuclide speciation has been added as a separate process in SR-PSU and three of the SR-Site geosphere processes have not been included in SR-PSU. These are "Creep", "Formation/dissolution/reaction of gaseous species", and "Radiation effects (rock and grout)". The two former are in SR-PSU covered by other SR-PSU processes, three of the mechanical processes (Ge05, 06 and 07) and Gas transport/dissolution, respectively. Radiation effects are excluded because of low levels of radioactivity in the waste.

Of the system components defined in SAFE and SAR-08, "Rock matrix and rock fractures" corresponds to the system Geosphere in SR-PSU. The result of sorting the SR-PSU processes defined for this system to the interactions (processes) defined for the corresponding system components in SAFE and SAR-08, as listed in Table 3-3, is provided in Table 4-7. This sorting shows that all interactions (processes) in SAFE and SAR-08 are covered by the SR-PSU processes.

A comparison with the list of geosphere processes in SR-PSU (see Table 5-10 in Section 5.3) shows that all but three of the SR-PSU processes are connected to at least one of the important interactions (processes) identified in SAFE and SAR-08. The processes that are added in SR-PSU, as compared with SAFE and SAR-08, are Erosion/sedimentation in fractures (Ge09), Methane hydrate formation (Ge19) and Earth currents (Ge21).

The tables documenting the handling of NEA Project FEPs associated with processes in the system component *Geosphere* are provided in Appendix 12. These FEP tables are also included in the FEP database and linked to the corresponding FEP records in the SR-PSU FEP catalogue.

Table 4-7. Important interactions (processes) for the rock matrix and rock fractures as defined in SAFE and SAR-08 (see Table 3-3) and the corresponding processes for the geosphere system in SR-PSU.

SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process	SAFE/SAR-08 interaction (process)	Corresponding SR-PSU process
Dissolution/precipitation	Reactions groundwater/rock matrix Dissolution/precipitation of fracture-filling minerals Speciation of radionuclides	Degradation of rock reinforcement	Degradation of grout
Microbial activity, growth, degradation	Microbial processes	Transport with gas	Transport of radionuclides in the gas phase
Redistribution of stress	Deformation of intact rock Displacements along existing fractures Fracturing	Transport with colloids or microbes[1)]	Transport of radionuclides in the water phase
Diffusion and matrix diffusion	Diffusive transport in the rock mass Transport of radionuclides in the water phase	Methylation/transformation	Microbial processes
Advection/dispersion	Advective transport/mixing of dissolved species Transport of radionuclides in the water phase	Radionuclide decay[2)]	Transport of radionuclides in the water phase Transport of radionuclides in the gas phase
Ion exchange, sorption	Speciation and sorption Transport of radionuclides in the water phase	Phase changes	Freezing
Colloid formation and transport	Colloidal processes	Heat conduction and heat transport	Heat transport
Gas dissolution/degassing	Gas flow/dissolution	Concentration/dilution[3)]	Salt exclusion
Water flow – permeability, driving forces	Groundwater flow	Borehole penetration[4)]	Groundwater flow
Gas flow – saturation, permeability, pressure	Gas flow/dissolution	Ice load including stress and strain changes	Deformation of intact rock Displacements along existing fractures Fracturing
Deformation and stability	Deformation of intact rock Displacements along existing fractures Fracturing		

[1)] The SAFE and SAR-08 interaction concerns colloids and microbes acting as carriers for radionuclides. In SR-PSU, these aspects are addressed in the description of the radionuclide transport process.

[2)] The SAFE/SAR-08 definition is: Radioactive decay will affect the type and amount of radionuclides at different locations in the repository system. In SR-PSU, this is described in the transport processes.

[3)] The SAR-08 definition is: Concentration and dilution of water occurring as result of change in water aggregate state.

[4)] The SAR-08 interaction concerns drilling of future boreholes and their impact on groundwater flow. This is addressed in FHA FEPs, but influence of human actions on groundwater flow is also addressed in the description of the geosphere process Groundwater flow.

4.2 Initial state

As in SR-Can (SKB 2006b) and SR-Site (SKB 2010a), initial state FEPs are defined as being related either to expected conditions within acceptable variations/tolerances or to deviations from these expected conditions. In the FEP processing, all NEA Project FEPs and matrix interactions categorised as initial state FEPs were documented as relevant for either the initial state or for deviations from the initial state. NEA Project FEPs and matrix interactions relevant to the initial state were further handled in the process of developing the descriptions of the initial states of the repository system components as documented in the SR-PSU Initial state report (SKB 2014b). The handling was documented in tables created for this purpose and added to the SKB FEP database with a link to the appropriate Variable FEP record in the SR-PSU FEP catalogue (see Section 5.4).

NEA Project FEPs and matrix interactions relevant to deviations in the initial state were used together with the Initial state FEPs defined in SR-Site to define appropriate Initial state FEPs for SR-PSU for further consideration. These FEPs are not system specific, but related to more general deviations, and are included in the SR-PSU FEP catalogue with FEP record identities starting with IS and followed by a letter code Gen for general deviations in initial state (Table 5-1).

In the further processing, it was decided to exclude three of the SR-PSU Initial state FEPs from scenario selection. One of them (ISGen01) is related to severe perturbations like fire, explosions, sabotage and severe flooding (ISGen01). The reasons for excluding this FEP are i) the probabilities for such events are low and ii) if they occur, they shall be reported to SSM, their consequences assessed and correcting or mitigating actions made accordingly. The second FEP excluded concerns effects of phased operation (ISGen02). Since phased operation is in accordance with the plans, but the whole repository will be closed at the same time, potential effects of phased operation are not considered to be a deviation from the initial state. The third FEP excluded is related to effects detrimental to safety after repository closure caused by monitoring activities (ISGen04). This FEP was excluded from further analysis because this type of monitoring will not be accepted.

One of the two remaining Initial state FEPs, ISGen05, concerns undetected design deviations and mishaps during manufacturing, transportation, deposition and repository operations etc. Measures to avoid or mitigate such deviations during excavation, manufacturing, handling deposition etc are described in the SR-PSU Initial state report (SKB 2014b). To the extent that such mishaps may still occur, these issues are covered by the data uncertainty ranges that are used in the analyses.

The last Initial state FEP (ISGen03) concerns the effects of an abandoned, not completely sealed repository or open monitoring boreholes (ISGen03). These issues were propagated to scenario selection (Chapter 7 in the SR-PSU Main report (SKB 2014a)).

The FEP tables with documentation of how NEA Project FEPs sorted to Initial state FEPs are handled are provided in Appendix 3. These tables are also included in the FEP database.

4.3 External factors

As described in Section 3.1.4, NEA Project FEPs defined as External factors to the repository system were classified into the following four categories: “Climate processes and effects”, “Large-scale geological processes and effects”, “Future human actions”, and “Others”. The same division was used in the FEP-work for SR-Can and SR-Site (SKB 2010a), which, after further processing, resulted in the inclusion of relevant FEPs in the SR-Can and SR-Site FEP catalogues. These SR-Site FEPs were the starting point for the further processing of External FEPs in SR-PSU, which included a documentation of the handling of each Project FEP in version 2.1 of the NEA FEP database associated with external factors. This documentation of the handling of each NEA FEP was added to the FEP database and linked to the appropriate SR-PSU FEP in the catalogue.

4.3.1 Climatic processes and effects

Climate and climate-related issues and their handling in SR-PSU are described in the SR-PSU Climate report (SKB 2014f) and seven Climate FEPs are included in the FEP database to represent these issues (see Table 5-13 in Section 5.6). Both SFR and the planned final repository for spent fuel are located at Forsmark. Therefore, the definition of climate FEPs in SR-PSU was based on the list of climate FEPs in SR-Site (SKB 2010a), but some modifications were made. It was decided to include the SR-Site FEP Cli01 (Components of the climate system) into Cli02 (Climate forcing) and denote the SR-PSU FEP Cli02 Climate forcing. Similarly, the SR-Site FEPs Cli03 (Climate dynamics) and Cli04 (Climate in Sweden and Forsmark) were combined into SR-PSU FEP Cli03 Climate evolution. The SR-PSU FEP Cli05 Permafrost development is the same as that for SR-Site and the SR-PSU FEP Cli06 Ice-sheet dynamics and hydrology is a combination of the SR-Site FEPs Cli06 (Ice-sheet dynamics) and Cli07 (Ice-sheet hydrology). Cli08 (Glacial isostatic adjustment) and Cli09 (Shore-level changes) are the same Climate FEPs in both SR-PSU and SR-Site, and the SR-PSU Climate FEP Cli10 (Denudation) corresponds to the SR-Site FEP Cli11 (Denudation).

As for internal processes, the handling of NEA Project FEPs associated with climatic processes was documented in FEP tables. These tables are provided in Appendix 13. The information in these tables is also included in the FEP database.

4.3.2 Large-scale geological processes and effects

In SR-Site, two FEPs were defined to cove large-scale geological processes occurring in the past and currently ongoing and their impact on the current mechanical state of the Baltic Shield and the repository rock. The same two FEPs are defined for SR-PSU, namely "Mechanical evolution of the Shield" (LSGe01) and "Earthquakes" (LSGe02) (see also Table 5-14), since both repositories are planned to be located in Forsmark.

The FEP tables with documentation of how NEA Project FEPs sorted to large-scale geological processes are handled in SR-PSU are provided in Appendix 13. The information in these tables is also included in the FEP database.

4.3.3 Future human actions (FHA)

Future human actions and how these are handled in the safety assessment are described in the SR-PSU FHA report (SKB 2014g). As for climatic processes, the starting point for the definition of FHA FEPs was the SR-Site FHA FEPs (SKB 2010a). However, for the purpose of SR-PSU, a need to make the FHA FEPs more tied to the safety functions of the SFR repository system and other factors relevant from the perspective of post-closure safety was identified. This resulted in an increase in the number of FHA FEPs from seven in SR-Site to seventeen in SR-PSU (see Table 5-15). The documentation of the handling of each NEA Project FEP mapped to these SR-PSU FEPs is provided in Appendix 13 and is also included in the FEP database.

4.3.4 Other

As in the FEP work in SR-Site (SKB 2010a), all NEA FEPs sorted to this group are related to meteorites and their impact on repository performance. Meteorite impact was excluded from further analysis in SR-Site, but was defined as a FEP in the SR-Site FEP catalogue for documentation purposes. For the same reason, meteorite impact is kept also as a FEP in the SR-PSU FEP catalogue, but excluded from further analysis in SR-PSU. The justification for excluding meteorite impact is that there is very little likelihood that a meteorite big enough to damage the repository will actually impact the Earth. The probability that the impact will occur on the repository site is even lower. Moreover, such an impact would cause great damage to the local and regional biosphere, humans included (Collins et al. 2005). These direct effects of a meteorite impact are judged to be far more serious than any possible radiological consequences. The justification for excluding this FEP from further analysis is documented in the FEP record in the SR-PSU FEP catalogue and the FEP tables containing the handling of NEA project FEPs associated with this SR-PSU FEP are linked to this FEP record in the database.

4.4 Biosphere FEPs

The biosphere FEPs for SR-PSU are described in a general FEP report for the biosphere (SKB 2014j) that contains definitions of subcomponents (e.g. regolith, water and primary producers) and variables (properties of the subcomponents) as well as general descriptions of the processes that are considered to be of importance for the alteration of the subcomponents over time and for transport and accumulation of radionuclides between and within the subcomponents. The biosphere process FEPs are the same as those defined for SR-Site, with the exception that the FEP Terrestrialisation in SR-Site (Bio50 in SKB 2010a) has been re-defined as a variable FEP (see Section 5.5). In addition, five of the remaining general biosphere process FEPs are judged to be of no importance for a low- and intermediate level waste repository located at Forsmark and, therefore, have been excluded. The excluded processes have a record in the FEP catalogue where the exclusion is motivated. Thus, the SR-PSU FEP catalogue contains 50 biosphere process records (see Table 5-11).

All NEA Project FEPs associated with the defined SR-PSU biosphere process FEPs have been checked by the experts involved in the biosphere analyses for SR-PSU and the handling of each NEA Project FEP has been documented and included in the FEP database. FEP tables with the documented handling are also provided in Appendix 14. The handling of NEA FEPs associated with biosphere variable and system component FEPs (see Section 5.5) has been documented by Kristina Skagius, SKB, based on the documented handling of NEA Project FEPs associated with the biosphere process FEPs.

4.5 Methodology issues

A large number of the NEA Project FEPs are related to basic assumptions for the assessment and to the methodology adopted for the assessment. Most of them are of a very general nature and it could be argued that these issues are not FEPs in the sense that they affect the future evolution of a repository. However, for the sake of comprehensiveness, these issues were, as in SR-Site (SKB 2010a), also propagated to the SR-PSU FEP catalogue and associated with two SR-PSU FEPs, "Assessment basis" (Meth01) and "Assessment methodology" (Meth02). As a result of the review of project FEPs in the NEA database, it was found that the FEP catalogue that was used for SR-Site can, as far as methodology-related issues are concerned, also be used for SR-PSU.

As in SR-Site (SKB 2010a), NEA Project FEPs categorised as belonging to the assessment basis (Meth01) in SR-PSU relate to:

- Biological evolution that might lead to different effects of radiation in the future compared with today.
- Changes in society's ability to treat cancer or its view on radiation hazards.
- Issues that are addressed in the environmental impact assessment rather than in the safety assessment.

In addition, NEA Project FEPs concerning technological advances in food production have been assigned to this SR-PSU (and SR-Site) FEP.

NEA Project FEPs associated with the SR-PSU FEP "Assessment methodology" are, as in SR-Site, related to data and modelling issues such as correlations and uncertainties, design issues and implementation of various features in the modelling.

5 The SR-PSU FEP catalogue

Based on the FEP processing conducted in SR-PSU, an SR-PSU FEP catalogue was established. The resulting FEP catalogue contains all FEPs defined for the SR-PSU assessment. The SR-PSU FEP catalogue is included in the SKB FEP database together with files documenting the FEP processing results. The FEP database also encompasses the SR-Site version, as well as the SR 97 and the SR-Can versions of the FEP database (see Figure 2-8). The content of the SR-PSU FEP catalogue and the information it provides are described in this chapter. An electronic version of the SKB FEP database is available on a CD together with instructions on how to navigate in the FEP database.

5.1 General

The SR-PSU FEP catalogue contains FEPs in the following categories:

- Initial state FEPs.
- Internal processes in the system components waste form, waste packaging, barriers in the waste vaults (1–2BMA, Silo, etc.) and the geosphere.
- Variables for the system components waste form, waste packaging, barriers in the waste vaults (1–2BMA, Silo, etc.) and the geosphere.
- Biosphere FEPs.
- External FEPs.
- Methodology-related issues.

In addition, there is the possibility to enter in the FEP catalogue any issue that is, for whatever reason, identified as relevant for the safety assessment. For SR-PSU, construction of a nearby repository (Spent Fuel Repository) and the nearby nuclear power plant including the Fenno-Skan cable (underwater cable between Sweden and Finland), have been identified.

In the FEP catalogue, each SR-PSU FEP is represented by a FEP record containing the SR-PSU FEP ID, the FEP name, a short description, a summary of the handling of the FEP in SR-PSU and references to reports where more extensive documentation of the FEP and its handling are to be found. An example is given in Figure 5-1. More FEP-type specific information is also accessible through the FEP records. This is further discussed in the following sections.

In total, the SR-PSU FEP catalogue contains 353 FEP records.

5.2 Initial state FEPs

The initial state FEPs in the SR-PSU FEP catalogue are related to deviations from the intended initial state of the system components that follow from undetected mishaps, sabotage, failure to close the repository, etc. These FEPs are listed in Table 5-1. Initial state FEPs in the SR-PSU FEP catalogue that are related to the intended initial state are handled in the category "variables" in the SR-PSU FEP catalogue (see Section 5.4).

As mentioned in Section 4.2, three of these FEPs (ISGen01, ISGen02 and ISGen04) are excluded from the assessment. This and the reasons for exclusion are documented in the FEP records. The two remaining initial state FEPs were considered in the reference evolution or the scenario selection and scenario analysis in SR-PSU. The handling of these FEPs in the analysis is documented in the FEP records and references are given to appropriate sections in the SR-PSU Main report (SKB 2014a) where the handling is described.

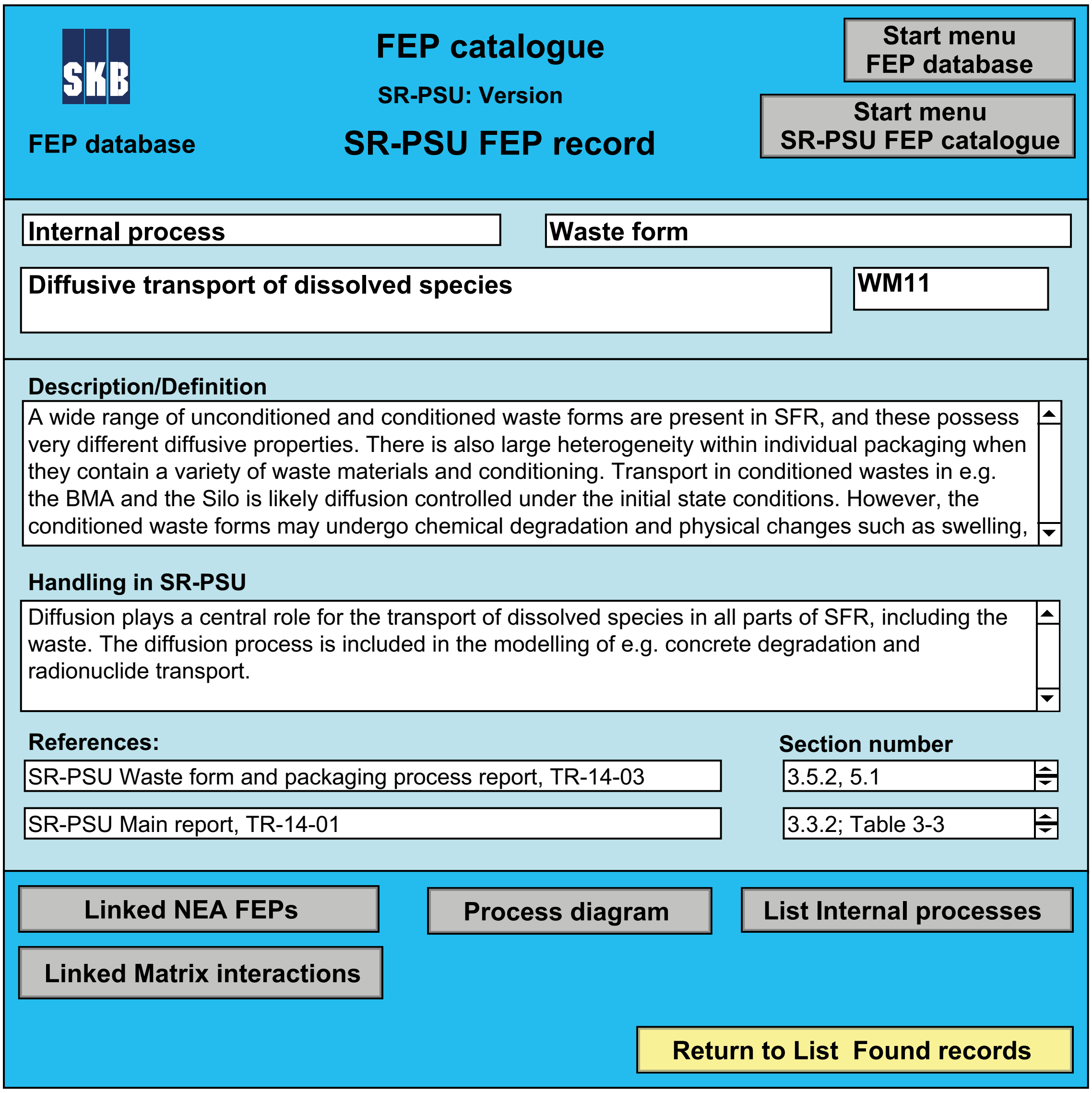


Figure 5-1. *Print-out from the SR-PSU FEP catalogue to illustrate the basic information available for each SR-PSU FEP.*

Table 5-1. Initial state FEPs in the SR-PSU FEP catalogue. The handling of the FEPs in the assessment is summarised in Table 3-1 in the SR-PSU Main report (SKB 2014a).

FEP ID	FEP name	Description
ISGen01	Major mishaps/accidents/sabotage	Major mishaps/accidents like fire, explosions, earthquakes and flooding during repository operation. Possible decontamination following severe mishap. Ditto sabotage (chemical, physical etc), improper management.
ISGen02	Effects of phased operation	Effects on engineered barriers and geosphere of phased operation, including construction of extensions of the facility.
ISGen03	Incomplete closure	Concerns the effects of an abandoned, not completely sealed repository or open monitoring boreholes.
ISGen04	Monitoring activities	Implications of monitoring activities, including underground monitoring boreholes, on safety after repository closure.
ISGen05	Design deviations – Mishaps	Design deviations due to undetected mishaps during manufacturing, transportation, deposition and repository operations affecting the initial state. This includes e.g. incorrect structural design, deviating material properties, incompletely backfilled or sealed vaults, boreholes and shafts; undesirable or unexpected material left in the vaults.

Other information accessed via the Initial state FEP records in the FEP catalogue is lists of NEA Project FEPs associated with each SR-PSU FEP and if and how these are addressed by the SR-PSU FEP, including the documentation related to the FEP. The FEP tables showing the handling of the NEA Project FEPs associated with SR-PSU Initial state FEPs are provided in Appendix 3.

5.3 Internal process FEPs

All processes included in the SR-PSU process reports are represented by a FEP record in the SR-PSU FEP catalogue. The SR-PSU FEP ID and a reference to the corresponding process description for all process FEPs are given in Table 5-2 (Waste form), Table 5-3 (Concrete and steel packaging), Table 5-4 (BMA barrier), Table 5-5 (BTF barrier), Table 5-6 (Silo barrier), Table 5-7 (BRT barrier), Table 5-8 (BLA barrier), Table 5-9 (Plugs and other closure components) and in Table 5-10 (Geosphere). This information is included in the FEP records in the FEP-catalogue together with text from the process reports describing the process. In addition, each FEP record contains the handling of the process in SR-PSU, as provided in the process tables in Chapter 3 of the Main SR-PSU report (SKB 2014a).

As for the Initial state FEPs, lists of NEA Project FEPs and matrix interactions associated with the SR-PSU Process FEPs are linked to the SR-PSU FEP records as are also tables with documentation of the handling of the linked NEA Project FEPs. FEP tables showing the handling of NEA Project FEPs as documented in the FEP database are provided in Appendices 4 through 12. As stated in Section 4.1, no formal documentation of the handling of each matrix interaction has been made in the FEP records in the SR-PSU FEP catalogue, but the coverage of important interactions is discussed in Section 4.1.

Within a system component, each process is influenced by one or several of the variables describing the state of the component, and the process, in turn, influences one or several of the variables. These couplings within a system component are described by influence tables, one for each process, in the process reports. These influence tables have been included in the FEP database and are accessible via the process FEP records as are also process diagrams that are generated based on the contents of the influence tables. This is further described in Section 5.9.

Table 5-2. SR-PSU process FEPs for the system component Waste form and references to the corresponding process description in the SR-PSU waste form and packaging process report (SKB 2014c). The handling of the FEPs in the assessment is summarised in Appendix F in the SR-PSU Main report (SKB 2014a).

SR-PSU FEP ID	SR-PSU FEP name	Section in SR-PSU process report
WM01	Radioactive decay	3.1.1
WM02	Radiation attenuation/heat generation	3.1.2
WM03	Radiolytic decomposition of organic material	3.1.3
WM04	Water radiolysis	3.1.4
WM05	Heat transport	3.2.1
WM06	Phase changes/freezing	3.2.2
WM07	Water uptake and transport during unsaturated conditions	3.3.1
WM08	Water transport under saturated conditions	3.3.2
WM09	Fracturing	3.4.1
WM10	Advective transport of dissolved species	3.5.1
WM11	Diffusive transport of dissolved species	3.5.2
WM12	Sorption/uptake	3.5.3
WM13	Colloid formation and transport	3.5.4
WM14	Dissolution, precipitation and recrystallisation	3.5.5
WM15	Degradation of organic materials	3.5.6
WM16	Water uptake/swelling	3.5.7
WM17	Microbial processes	3.5.8
WM18	Metal corrosion	3.5.9
WM19	Gas formation and transport	3.5.10
WM20	Speciation of radionuclides	3.6.1
WM21	Transport of radionuclides in the water phase	3.6.2
WM22	Transport of radionuclides in the gas phase	3.6.3

Table 5-3. SR-PSU process FEPs for the system component Concrete and steel packaging and references to the corresponding process description in the SR-PSU waste form and packaging process report (SKB 2014c). The handling of the FEPs in the assessment is summarised in Appendix F in the SR-PSU Main report (SKB 2014a).

SR-PSU FEP ID	SR-PSU FEP name	Section in SR-PSU process report
Pa01	Heat transport	4.1.1
Pa02	Phase changes/freezing	4.1.2
Pa03	Water uptake and transport during unsaturated conditions	4.2.1
Pa04	Water transport under saturated conditions	4.2.2
Pa05	Fracturing/deformation	4.3.1
Pa06	Advective transport of dissolved species	4.4.1
Pa07	Diffusive transport of dissolved species	4.4.2
Pa08	Sorption/uptake	4.4.3
Pa09	Colloid transport and filtering	4.4.4
Pa10	Dissolution, precipitation and recrystallisation	4.4.5
Pa11	Microbial processes	4.4.6
Pa12	Metal corrosion	4.4.7
Pa13	Gas formation and transport	4.4.8
Pa14	Speciation of radionuclides	4.5.1
Pa15	Transport of radionuclides in the water phase	4.5.2
Pa16	Transport of radionuclides in the gas phase	4.5.3

Table 5-4. SR-PSU process FEPs for the system component BMA barriers and references to the corresponding process description in the SR-PSU engineered barrier process report (SKB 2014d). The handling of the FEPs in the assessment is summarised in Appendix F in the SR-PSU Main report (SKB 2014a).

SR-PSU FEP ID	SR-PSU FEP name	Section in SR-PSU process report
BMABa01	Heat transport	5.1.1
BMABa02	Phase changes/freezing	5.1.2
BMABa03	Water uptake and transport during unsaturated conditions	5.2.1
BMABa04	Water transport under saturated conditions	5.2.2
BMABa05	Gas transport/dissolution	5.2.3
BMABa06	Mechanical processes	5.3.1
BMABa07	Advection and dispersion	5.4.1
BMABa08	Diffusion	5.4.2
BMABa09	Sorption on concrete/shotcrete	5.4.3
BMABa10	Sorption on crushed rock backfill	5.4.4
BMABa11	Colloid stability, transport and filtering	5.4.5
BMABa12	Concrete degradation	5.4.6
BMABa13	Aqueous speciation and reactions	5.4.7
BMABa14	Microbial processes	5.4.8
BMABa15	Metal corrosion	5.4.9
BMABa16	Gas formation	5.4.10
BMABa17	Speciation of radionuclides	5.5.1
BMABa18	Transport of radionuclides in the water phase	5.5.2
BMABa19	Transport of radionuclides in the gas phase	5.5.3

Table 5-5. SR-PSU process FEPs for the system component BTF barriers and references to the corresponding process description in the SR-PSU engineered barrier process report (SKB 2014d). The handling of the FEPs in the assessment is summarised in Appendix F in the SR-PSU Main report (SKB 2014a).

SR-PSU FEP ID	SR-PSU FEP name	Section in SR-PSU process report
BTFBa01	Heat transport	6.1.1
BTFBa02	Phase changes/freezing	6.1.2
BTFBa03	Water uptake and transport during unsaturated conditions	6.2.1
BTFBa04	Water transport under saturated conditions	6.2.2
BTFBa05	Gas transport/dissolution	6.2.3
BTFBa06	Mechanical processes	6.3.1
BTFBa07	Advection and dispersion	6.4.1
BTFBa08	Diffusion	6.4.2
BTFBa09	Sorption	6.4.3
BTFBa10	Colloid stability, transport and filtering	6.4.4
BTFBa11	Concrete degradation	6.4.5
BTFBa12	Aqueous speciation and reactions	6.4.6
BTFBa13	Microbial processes	6.4.7
BTFBa14	Metal corrosion	6.4.8
BTFBa15	Gas formation	6.4.9
BTFBa16	Speciation of radionuclides	6.5.1
BTFBa17	Transport of radionuclides in the water phase	6.5.2
BTFBa18	Transport of radionuclides in the gas phase	6.5.3

Table 5-6. SR-PSU process FEPs for the system component Silo barriers and references to the corresponding process description in the SR-PSU engineered barrier process report (SKB 2014d). The handling of the FEPs in the assessment is summarised in Appendix F in the SR-PSU Main report (SKB 2014a).

SR-PSU FEP ID	SR-PSU FEP name	Section in SR-PSU process report
SiBa01	Heat transport	7.1.1
SiBa02	Phase changes/freezing	7.1.2
SiBa03	Water uptake and transport during unsaturated conditions	7.2.1
SiBa04	Water transport under saturated conditions	7.2.2
SiBa05	Gas transport/dissolution	7.2.3
SiBa06	Piping/erosion	7.2.4
SiBa07	Mechanical processes	7.3.1
SiBa08	Advection and dispersion	7.4.1
SiBa09	Diffusion	7.4.2
SiBa10	Sorption (including ion exchange of major ions)	7.4.3
SiBa11	Alteration of impurities	7.4.4
SiBa12	Colloid transport and filtering	7.4.5
SiBa13	Concrete degradation	7.4.7
SiBa14	Dissolution/precipitation	7.4.6
SiBa15	Aqueous speciation and reactions	7.4.8
SiBa16	Osmosis	7.4.9
SiBa17	Montmorillonite transformation	7.4.10
SiBa18	Iron-bentonite interaction	7.4.11
SiBa19	Montmorillonite colloid release	7.4.12
SiBa20	Microbial processes	7.4.13
SiBa21	Cementation in bentonite	7.4.14
SiBa22	Metal corrosion	7.4.15
SiBa23	Gas formation	7.4.16
SiBa24	Speciation of radionuclides	7.5.1
SiBa25	Transport of radionuclides in the water phase	7.5.2
SiBa26	Transport of radionuclides in the gas phase	7.5.3

Table 5-7. SR-PSU process FEPs for the system component BRT barriers and references to the corresponding process description in the SR-PSU engineered barrier process report (SKB 2014d). The handling of the FEPs in the assessment is summarised in Appendix F in the SR-PSU Main report (SKB 2014a).

SR-PSU FEP ID	SR-PSU FEP name	Section in SR-PSU process report
BRTBa01	Heat transport	9.1.1
BRTBa02	Phase changes/freezing	9.1.2
BRTBa03	Water uptake and transport during unsaturated conditions	9.2.1
BRTBa04	Water transport under saturated conditions	9.2.2
BRTBa05	Gas transport/dissolution	9.2.3
BRTBa06	Mechanical processes	9.3.1
BRTBa07	Advection and dispersion	9.4.1
BRTBa08	Diffusion	9.4.2
BRTBa09	Sorption	9.4.3
BRTBa10	Colloid stability, transport and filtering	9.4.4
BRTBa11	Concrete degradation	9.4.5
BRTBa12	Aqueous speciation and reactions	9.4.6
BRTBa13	Microbial processes	9.4.7
BRTBa14	Metal corrosion	9.4.8
BRTBa15	Gas formation	9.4.9
BRTBa16	Speciation of radionuclides	9.5.1
BRTBa17	Transport of radionuclides in the water phase	9.5.2
BRTBa18	Transport of radionuclides in the gas phase	9.5.3

Table 5-8. SR-PSU process FEPs for the system component BLA barriers and references to the corresponding process description in the SR-PSU engineered barrier process report (SKB 2014d). The handling of the FEPs in the assessment is summarised in Appendix F in the SR-PSU Main report (SKB 2014a).

SR-PSU FEP ID	SR-PSU FEP name	Section in SR-PSU process report
BLABa01	Heat transport	8.1.1
BLABa02	Phase changes/freezing	8.1.2
BLABa03	Water uptake and transport during unsaturated conditions	8.2.1
BLABa04	Water transport under saturated conditions	8.2.2
BLABa05	Gas transport/dissolution	8.2.3
BLABa06	Mechanical processes	8.3.1
BLABa07	Advection and dispersion	8.4.1
BLABa08	Diffusion	8.4.2
BLABa09	Sorption	8.4.3
BLABa10	Colloid stability, transport and filtering	8.4.4
BLABa11	Aqueous speciation and reactions	8.4.5
BLABa12	Microbial processes	8.4.6
BLABa13	Degradation of rock bolts, reinforcement and concrete	8.4.7
BLABa14	Speciation of radionuclides	8.5.1
BLABa15	Transport of radionuclides in the water phase	8.5.2
BLABa16	Transport of radionuclides in the gas phase	8.5.3

Table 5-9. SR-PSU process FEPs for the system component Plugs and other closure components and references to the corresponding process description in the SR-PSU engineered barrier process report (SKB 2014d). The handling of the FEPs in the assessment is summarised in Appendix F in the SR-PSU Main report (SKB 2014a).

SR-PSU FEP ID	SR-PSU FEP name	Section in SR-PSU process report
Pg01	Heat transport	10.1.1
Pg02	Phase changes/freezing	10.1.2
Pg03	Water uptake and transport during unsaturated conditions	10.2.1
Pg04	Water transport under saturated conditions	10.2.2
Pg05	Gas transport/dissolution	10.2.3
Pg06	Piping/erosion	10.2.4
Pg07	Mechanical processes	10.3.1
Pg08	Advection and dispersion	10.4.1
Pg09	Diffusion	10.4.2
Pg10	Sorption (including ion exchange of major ions)	10.4.3
Pg11	Alteration of impurities in bentonite	10.4.4
Pg12	Dissolution, precipitation, recrystallisation and clogging in backfill	10.4.5
Pg13	Aqueous speciation and reactions	10.4.6
Pg14	Osmosis	10.4.7
Pg15	Montmorillonite transformation	10.4.8
Pg16	Montmorillonite colloid release	10.4.9
Pg17	Microbial processes	10.4.10
Pg18	Degradation of rock bolts, reinforcements and concrete	10.4.11
Pg19	Speciation of radionuclides	10.5.1
Pg20	Transport of radionuclides in the water phase	10.5.2
Pg21	Transport of radionuclides in the gas phase	10.5.3

Table 5-10. SR-PSU process FEPs for the system component Geosphere and references to the corresponding process description in the SR-PSU geosphere process report (SKB 2014e). The handling of the FEPs in the assessment is summarised in Appendix F in the SR-PSU Main report (SKB 2014a).

SR-PSU FEP ID	SR-PSU FEP name	Section in SR-PSU process report
Ge01	Heat transport	2.1
Ge02	Freezing	2.2
Ge03	Groundwater flow	3.2
Ge04	Gas flow/dissolution	3.3
Ge05	Deformation of intact rock	4.2
Ge06	Displacements along existing fractures	4.3
Ge07	Fracturing	4.4
Ge09	Erosion and sedimentation in fractures	4.5
Ge10	Advective transport/mixing of dissolved species	5.2
Ge11	Diffusive transport in the rock mass	5.3
Ge12	Speciation and sorption	5.4
Ge13	Reactions groundwater/rock matrix	5.5
Ge14	Dissolution/precipitation of fracture-filling minerals	5.6
Ge15	Microbial processes	5.7
Ge16	Degradation of grout	5.8
Ge17	Colloidal processes	5.9
Ge19	Methane hydrate formation	5.10
Ge20	Salt exclusion	5.11
Ge21	Earth currents	5.12
Ge22	Speciation of radionuclides	6.1
Ge23	Transport of radionuclides in the water phase	6.2
Ge24	Transport of radionuclides in the gas phase	6.3

5.4 Variables

These FEPs are the variables needed to describe the evolution of the system components waste form, waste packaging, barriers in the waste vaults (BMA, Silo, etc.) and the geosphere over time. Biosphere FEPs are handled as a separate category in the FEP catalogue, see Section 5.5. Identification of variables has been done in cooperation between FEP coordinators and experts with good knowledge of processes in the different system components with potential importance to post-closure safety. The sets of variables were established in conjunction with the documentation of the processes, since it had to be ensured that the variable sets were suited to describing all conceivable alterations of the system component properties as a result of the long-term, post-closure processes.

The variable FEPs are either related to the initial state of the system components or to the evolution in states as a result of on-going processes. This is also reflected in the NEA Project FEPs and matrix interactions associated with the SR-PSU variables. The documentation of the handling of these aspects linked to the SR-PSU variables is therefore of two kinds, where one relates to the aspects addressed in the description of the initial state and the other to the impact of internal system processes on the state. Documentation relating to the initial state was made by the FEP coordinators (Maria Lindgren, Kemakta, and Kristina Skagius, SKB), whereas documentation of the impact of processes on the state variables were made by Kristina Skagius based on the documented handling of processes provided by the experts developing the process descriptions. As for other FEP records in the SR-PSU FEP catalogue, these tables, together with the documented handling, are accessible via the FEP records. In addition, each variable record contains a reference to the description of the initial state for that variable. For the waste and engineered barriers, this reference is to the appropriate section in the SR-PSU Initial state report (SKB 2014b). For variables in the geosphere system, reference is given to the section in the SR-PSU Main report (SKB 2014a) where the initial state for this variable is addressed.

As for the internal processes, no formal documentation of the handling of matrix interactions associated with the SR-PSU variables has been made.

The SR-PSU FEP identifiers, FEP names and definitions of these variables are given in tables in Appendix 2.

5.5 Biosphere FEPs

Processes and interactions between components in the biosphere that may be important in a safety assessment for radioactive waste disposal are described in a biosphere process report developed for SR-PSU (SKB 2014j). The basis for the descriptions is a biosphere Interaction Matrix that has been used to support the biosphere analyses in SR-PSU and which is a further development of the SAFE biosphere Interaction Matrix (SKB 2001) and the biosphere Interaction Matrix set up for SR-Site (SKB 2010b). In the Interaction Matrix, components of the biosphere are included as elements of the principal diagonal and process interactions between the components as off-diagonal elements in the matrix. Full definitions of the FEPs are provided in the SR-PSU biosphere process report (SKB 2014j) and a detailed description of the handling of the biosphere FEPs in the assessment is given in a separate supporting report (SKB 2014k).

Biosphere FEPs are treated separately in the FEP catalogue for SR-PSU. In the same way as for other system components, there is a FEP record for each process and one for each variable. Beyond this, each subcomponent is also represented by a record in the FEP catalogue.

In total, the biosphere interaction matrix for SR-PSU contains 50 process interactions and 12 system components. For each process interaction in the matrix, a corresponding process FEP record is included in the FEP database. The SR-PSU FEP ID and reference to the corresponding process definition and how it is handled in the assessment are given for all process FEPs in Table 5-11. The NEA Project FEPs that are associated with each of these SR-PSU biosphere FEPs are linked to the appropriate FEP record in the SR-PSU FEP catalogue. In addition, FEP tables with the documented handling of each NEA Project FEP are linked to the SR-PSU FEP records. These FEP tables showing the handling of NEA Project FEPs, as documented in the FEP database, are provided in Appendix 14.

Table 5-11. SR-PSU process FEPs for the biosphere and references to the corresponding process description in the SR-PSU Biosphere process report (SKB 2014j) and to the section in SKB (2014k) where the handling is described. The handling of the FEPs in the assessment is also summarised in Appendix F in the SR-PSU Main report (SKB 2014a).

SR-PSU FEP ID	SR-PSU FEP name	Section in SKB (2014j)	Section in SKB (2014k)
Bio01	Bioturbation	6.1.1	2.4.1
Bio02	Consumption	6.1.2	2.4.2
Bio03	Death	6.1.3	2.4.3
Bio04	Decomposition	6.1.4	2.4.4
Bio05	Excretion	6.1.5	2.4.5
Bio06	Food supply	6.1.6	2.4.6
Bio07	Growth	6.1.7	2.4.7
Bio08	Habitat supply	6.1.8	2.4.8
Bio09	Intrusion	6.1.9	2.4.9
Bio10	Material supply	6.1.10	2.4.10
Bio11	Movement	6.1.11	Excluded[1)]
Bio12	Particle release/trapping	6.1.12	2.4.11
Bio13	Primary production	6.1.13	2.4.12
Bio14	Stimulation/inhibition	6.1.14	2.4.13
Bio15	Uptake	6.1.15	2.4.14
Bio16	Anthropogenic release	6.2.1	2.4.15
Bio17	Material use	6.2.2	2.4.16
Bio18	Species introduction/extermination	6.2.3	2.4.17
Bio19	Water use	6.2.4	2.4.18
Bio20	Change of pressure	6.3.1	Excluded[1)]
Bio21	Consolidation	6.3.2	2.4.19
Bio22	Element supply	6.3.3	2.4.20
Bio23	Loading	6.3.4	Excluded[1)]
Bio24	Phase transitions	6.3.5	2.4.21
Bio25	Physical properties change	6.3.6	2.4.22
Bio26	Reactions	6.3.7	2.4.23
Bio27	Sorption/desorption	6.3.8	2.4.24
Bio28	Water supply	6.3.9	2.4.25
Bio29	Weathering	6.3.10	2.4.26
Bio30	Wind stress	6.3.11	2.4.27
Bio31	Acceleration	6.4.1	2.4.28
Bio32	Convection	6.4.2	2.4.29
Bio33	Covering	6.4.3	2.4.30
Bio34	Deposition	6.4.4	2.4.31
Bio35	Export	6.4.5	2.4.32
Bio36	Import	6.4.6	2.4.33
Bio37	Interception	6.4.7	2.4.34
Bio38	Relocation	6.4.8	2.4.35
Bio39	Resuspension	6.4.9	2.4.36
Bio40	Saturation	6.4.10	2.4.37
Bio41	Radioactive decay	6.5.1	2.4.38
Bio42	Exposure	6.5.2	2.4.39
Bio43	Heat storage	6.5.3	2.4.40
Bio44	Irradiation	6.5.4	Excluded[2)]
Bio45	Light-related processes	6.5.5	2.4.41
Bio46	Radiolysis	6.5.6	Excluded[2)]
Bio47	Radionuclide release	6.5.7	2.4.42
Bio48	Change in rock surface location	6.6.1	2.4.43
Bio49	Sea-level change	6.6.2	2.4.44
Bio50	Thresholding	6.6.3	2.4.45

[1)] Process excluded since it is not important for a low- and intermediate level waste repository located in the Forsmark area, see SKB (2014j, Section 7.2).

[2)] Process excluded since the expected radionuclide levels are too low to affect regolith and water in regolith by irradiation, see SKB (2014j, Section 7.2).

FEP records for the subcomponents of the biosphere, as defined in the biosphere Interaction Matrix, are also included in the FEP catalogue, as are the variables defined for the biosphere system. Inclusion of the subcomponents makes it possible to reproduce the SR-PSU biosphere Interaction Matrix in the FEP database and inclusion of the variables makes it possible to display couplings between the variables and biosphere processes. This is further described in Section 5.9.

The SR-PSU FEPs for the biosphere subcomponents are listed in Table 5-12 and the biosphere variables are defined in Appendix 2.

5.6 External FEPs

External FEPs included in the SR-PSU FEP catalogue are Climate FEPs (Table 5-13), Large-scale geological FEPs (Table 5-14) and FHA FEPs (Table 5-15). In addition, the FEP catalogue contains one single FEP in the category "Other" – Oth01 Meteorite impact.

As with the process FEP records, the external FEP records contain a short description, a brief note on the handling in SR-PSU and references to the SR-PSU reports where the FEP and its handling are described. The two FEPs related to large-scale geological processes are the same as those defined for the spent fuel repository. Therefore, reference to the section in the SR-Site geosphere process report (SKB 2010c) where these processes are described is provided in the SR-PSU FEP record. As described in Section 4.3, lists of NEA Project FEPs associated with the SR-PSU FEPs and tables with notes on how the aspects identified in the NEA Project FEPs are addressed in the SR-PSU FEP are also included in the FEP database and are accessible from the SR-PSU FEP record. Printouts of these FEP tables are provided in Appendix 13.

Table 5-12. SR-PSU FEPs for the subcomponents of the biosphere and references to the corresponding description in the SR-PSU Biosphere process report (SKB 2014j) and to the section in SKB (2014k) where the handling is described.

SR-Site FEP ID	SR-Site FEP name	Section in SKB (2014j)	Section in SKB (2014k)
CompBio01	Geosphere (Boundary condition)	4.11.1	2.2.11
CompBio02	Regolith	4.1	2.2.1
CompBio03	Water in regolith	4.2	2.2.2
CompBio04	Surface water	4.3	2.2.3
CompBio05	Gas and local atmosphere	4.4	2.2.4
CompBio06	Primary producers	4.5	2.2.5
CompBio07	Decomposers	4.6	2.2.6
CompBio08	Filter feeders	4.7	2.2.7
CompBio09	Herbivores	4.8	2.2.8
CompBio10	Carnivores	4.9	2.2.9
CompBio11	Humans	4.10	2.2.10
CompBio12	External conditions (Boundary condition)	4.11.2	2.2.11

Table 5-13. SR-PSU Climate FEPs and references to corresponding descriptions in the SR-PSU Climate report (SKB 2014f). The handling of the FEPs in the assessment is summarised in Table 3-3 in the SR-PSU Main report (SKB 2014a).

SR-PSU FEP ID	SR-PSU FEP name	Section in SR-PSU Climate report
Cli02	Climate forcing	1.3, 3.1
Cli03	Climate evolution	1.3, 3
Cli05	Development of permafrost	2.1
Cli06	Ice-sheet dynamics and hydrology	2.3, 3.3
Cli08	Glacial isostatic adjustment	2.2
Cli09	Shore-level changes	2.2
Cli10	Denudation	2.4

Table 5-14. SR-PSU Large-scale geological FEPs and references to corresponding descriptions in the SR-Site Geosphere process report (SKB 2010c).

SR-PSU FEP ID	SR-PSU FEP name	Section in SR-Site Geosphere process report
LSGe01	Mechanical evolution of the Shield	4.1.2
LSGe02	Earthquakes	4.1.3

Table 5-15. SR-PSU FHA FEPs and references to corresponding descriptions in the SR-PSU FHA report (SKB 2014g). The handling of the FEPs in the assessment is summarised in Table 3-4 in the SR-PSU Main report (SKB 2014a).

SR-PSU FEP ID	SR-PSU FEP name	Section in SR-PSU FHA report
FHA01	State of knowledge	4.4.1
FHA02	Societal development	4.4.2
FHA03	Technical development	4.4.3
FHA04	Heat storage	4.4.4
FHA05	Heat pump system	4.4.5
FHA06	Geothermal energy	4.4.6
FHA07	Heating/cooling plant	4.4.7
FHA08	Drilled well	4.4.8
FHA09	Water management	4.4.9
FHA10	Altered land use	4.4.10
FHA11	Drilling	4.4.11
FHA12	Underground constructions	4.4.12
FHA13	Quarry	4.4.13
FHA14	Landfill	4.4.14
FHA15	Bombing or blasting, explosions and crashes	4.4.15
FHA16	Hazardous waste facility	4.4.16
FHA17	Contamination with chemical substances	4.4.17

5.7 Site-specific factors

The FEP catalogue allows entry of any issue that is, for whatever reason, identified as relevant for the safety assessment. Two site-specific issues have been identified and included as FEPs in the SR-PSU FEP catalogue. The FEP SiteFact02 Construction of nearby rock facilities concerns the impact of future construction of rock facilities like the planned repository for spent nuclear fuel at Forsmark or other underground constructions. Impacts of the planned repository for spent nuclear fuel are not considered in the assessment, since no effects on a closed SFR are expected except possibly for a small hydraulic impact from a spent fuel repository during its operational phase (SKB 2011). Other such potential future events have been considered in the selection and analysis of scenarios related to future human actions, which is reported in Section 5.4 in the SR-PSU FHA report (SKB 2014g).

The FEP SiteFact03 Nearby nuclear power plant concerns the potential impact of the nearby nuclear power plant at Forsmark and, specifically, the power cable to Finland (Fenno-Skan). Corrosion has been observed in down-hole sampling equipment in boreholes at Forsmark, and the effect has been attributed to the influence of electric power cables. Since “Earth currents” is one of the processes included in the SR-PSU Geosphere process report (SKB 2014e) and the impact of earth currents on corrosion rates is addressed in the SR-PSU waste process report (SKB 2014c) and data report (SKB 2014h), it is judged that this site-specific factor is already covered. Therefore, references to these reports are given in the FEP record for SiteFact03.

5.8 Methodology issues

Although not regarded as FEPs in a strict sense, two FEP records to cover methodological issues are included in the FEP catalogue. These are Meth01 "Assessment basis" and Meth02 "Assessment methodology". The basis for including these FEPs and their meanings are discussed in Section 4.5 and this material is not repeated here.

5.9 Couplings included in the SR-PSU catalogue

FEPs are coupled in several ways and on several levels, and the FEP database is used as a tool for documentation and visualisation of couplings between processes via variables and subcomponents. This is further described in the following sections.

5.9.1 Influence tables and process (influence) diagrams

Within a system component, each process is influenced by one or several of the variables describing the state of the component, and the process, in turn, influences one or several of the variables. These couplings within a system component are described by influence tables, one for each process, in the SR-PSU process reports. These influence tables have been included in the SR-PSU FEP catalogue in the SKB FEP database. Based on these influence tables, process diagrams are automatically generated for each process and for each system component in the FEP catalogue. The process diagram for a system component essentially takes the form of a table with the processes as rows and the variables as columns. The table matrix consists of arrows describing the influences between processes and variables.

Both the process diagrams and the underlying influence tables are accessible via the process FEP records in the FEP catalogue. An example is given in Figure 5-2, which shows the process diagram for the waste form process Diffusive transport of dissolved species (WM11). The presence of an arrow or not and its colour are automatically generated based on the contents of the influence tables. A green arrow means that the influence is neglected and a red arrow represents an influence that is handled in SR-PSU. Another way to graphically illustrate these couplings is in the form of an Interaction Matrix, see further Section 5.9.2 below.

5.9.2 Interaction Matrices

Interaction Matrices offer an alternative to process diagrams to illustrate couplings between variables and processes. Interaction Matrices for each system component in the repository, as well as for the geosphere and the biosphere, are included in the FEP database. As for the process diagrams, the Interaction Matrices are automatically generated based on the influence tables imported to the SR-PSU FEP catalogue from the SR-PSU process reports.

The elements of the principal diagonal in the matrix show the variables defined for the system component in question, whereas off-diagonal elements show the internal processes that act directly between two variables in a clock-wise manner. As an example, the interaction matrix for the system component waste form is shown in Figure 5-3. It is not possible to display the whole matrix with all interacting processes at the same time. Therefore, an option has been created that makes it possible to display all interacting processes in any selected matrix element (lower part of Figure 5-3). This more detailed information also shows which processes are handled in the assessment (red text) and which are neglected in the assessment (green text). Further information is given in the instructions on how to navigate in the database that are provided together with the electronic version of the SKB FEP database.

The biosphere consists of many subcomponents (e.g. regolith, water, primary producers). Therefore, the biosphere process report (SKB 2014j) contains an Interaction Matrix with subcomponents as elements of the principal diagonal, in order to highlight where processes of importance for transport and accumulation of radionuclides take place in the biosphere. This biosphere Interaction Matrix is also included in the FEP database, in addition to the aforementioned matrix with the biosphere variables as elements of the principal diagonal, and is described fully in SKB (2014j).

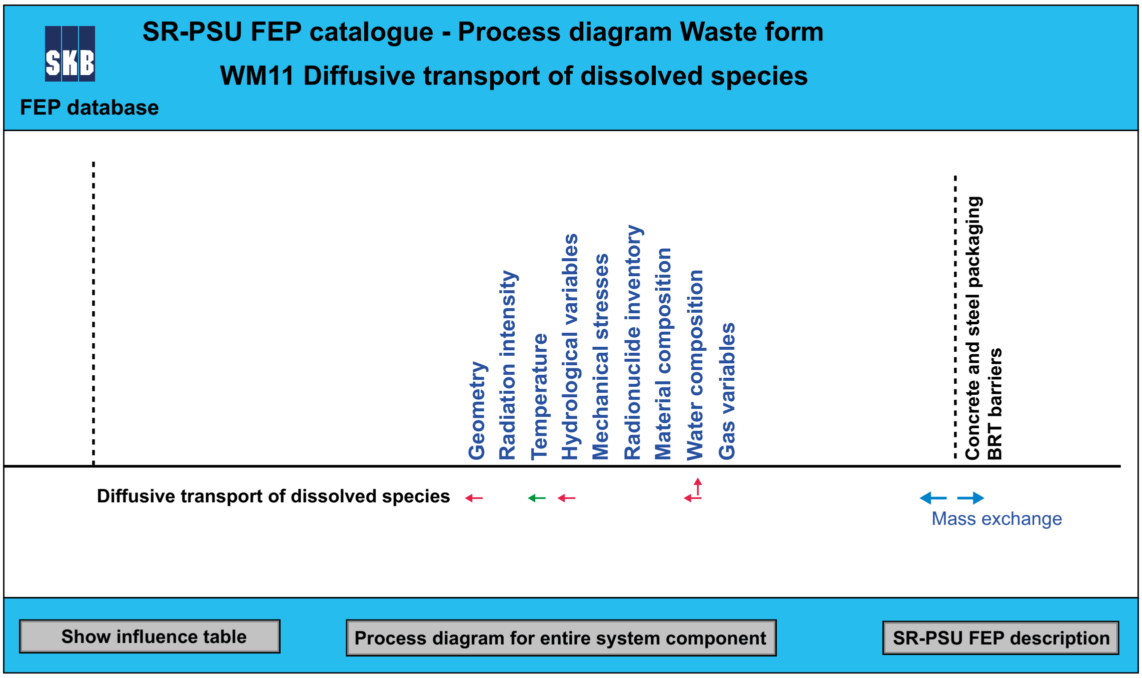


Figure 5-2. *Part of the process diagram for the waste form showing the influences between the process Diffusive transport of dissolved species and the waste form variables. An arrow directed upwards indicates an influence from the process on the variable, whereas an arrow directed to the left indicates an influence from the variable on the process. Red arrows indicate that the influence in question is handled in the assessment, whereas a green arrow indicates that the influence exists but is not assessed.*

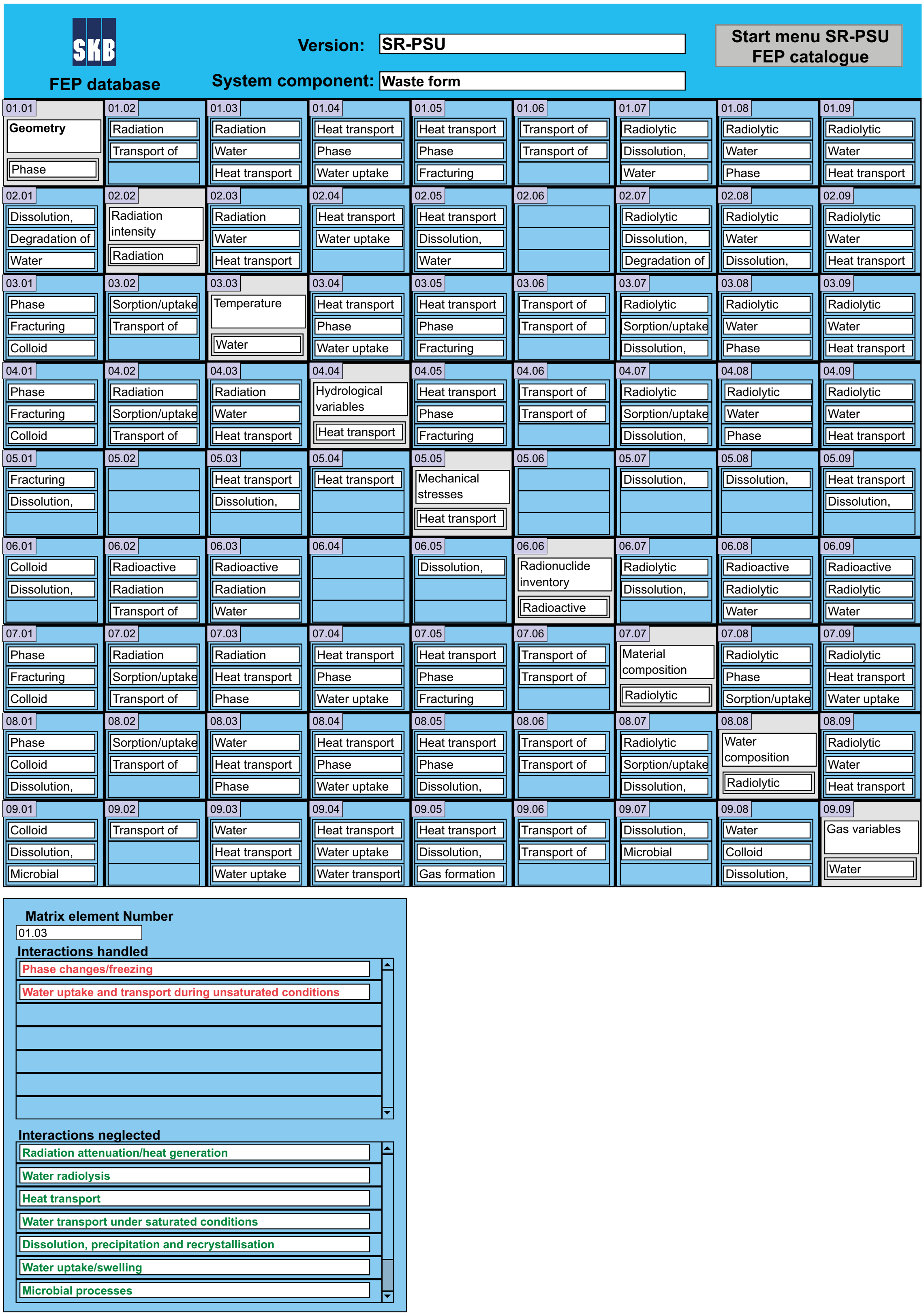


Figure 5-3. *Interaction matrix for the waste form. The elements of the principal diagonal in the matrix show the system component's variables, whereas off-diagonal elements show the internal processes that act directly between two variables. The lower figure shows details for element 01.03 showing processes that act between the variable Geometry and the variable Temperature. Processes in red are handled in the analysis, whereas processes in green are neglected.*

6 Concluding remarks

An SR-PSU FEP catalogue has been established within the framework of the SKB FEP database. The FEP processing work has been conducted in a systematic way, building on the FEP work conducted in earlier safety assessments of the SFR facility, SAR-08 (SKB 2008) and the SAFE project (SKB 2001) and using similar procedures and experience from the work with the set up of the SR-Site and SR-Can FEP catalogues. This, together with the audit against the Project FEPs in the NEA international FEP database and unpublished FEP lists from two low- and intermediate level waste projects as well as the involvement of experts from different disciplines strongly support the view that the PSU FEP catalogue contains all FEPs that need to be handled in the SR-PSU assessment. Therefore, it is concluded that the objectives of the FEP work in SR-PSU have been fulfilled.

References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.se/publications.
In the FEP database, and also in the appendices 3 to 14 to this report, references in the text to SKB reports are given as SKB report numbers.

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SKB, 2014a. Safety analysis for SFR. Long-term safety. Main report for the safety assessment SR-PSU. SKB TR-14-01, Svensk Kärnbränslehantering AB.

SKB, 2014b. Initial state report for the safety assessment SR-PSU. SKB TR-14-02, Svensk Kärnbränslehantering AB.

SKB, 2014c. Waste form and packaging process report for the safety assessment SR-PSU. SKB TR-14-03, Svensk Kärnbränslehantering AB.

SKB, 2014d. Engineered barrier process report for the safety assessment SR-PSU. SKB TR-14-04, Svensk Kärnbränslehantering AB.

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Appendix 1

Result of checking the final content of the SKB FEP database – version SR-PSU

The corresponding check of the SR-Site version of the FEP database is documented in Appendix 1 of the FEP report for SR-Site (SKB 2010a).

1. All NEA Project FEPs in version 2.1 of the NEA FEP database are included in the SR-PSU part of the SKB FEP database.

   Yes.

   Number of records in the NEA Project FEP file PROFEP = 1,671

   Number of records in the SR-PSU file NEA Mapping = 1,671

   No records in the SR-PSU file NEA Mapping with duplicate NEA Project FEP numbers or without NEA Project FEP number found when scrolling through the NEA Project FEP listing in the SR-PSU file NEA Mapping.

2. All Matrix interactions in the SAR-08 repository, geosphere end biosphere matrices are included in the SR-PSU part of the FEP database.

   Yes.

   A comparison with Appendices A and C in the SAR-08 FEP report (SKB 2008) shows:

Number of interactions	SAR-08 FEP report	FEP database
Repository	425	425
Geosphere	325	325
Repository and geosphere	750	750
Biosphere	454	459
Total	1,204	1,209

   The FEP database contains 5 interactions that are not reported in the SAR-08 FEP report (SKB 2008). All these 5 interactions originates from SAFE (SKB 2001) and have in SAFE been assigned the lowest priority (1 = Green).

3. All NEA Project FEPs and Matrix interactions included in the SR-PSU part of the SKB FEP database are flagged as Relevant or Not relevant for the SFR repository.

   Yes.

   Number of records in the NEA Mapping file flagged as Not relevant = 553
   Number of records in the NEA Mapping file flagged as Relevant = 1,118
   Sum of records in the NEA Mapping file flagged as Not relevant or Relevant = 1,671
   Number of Matrix interactions (Repository + Geosphere) mapped to SR-PSU FEPs = 750
   Number of records (interactions) in the Matrix mapping file flagged as Not relevant = 32
   Number of records (interactions) in the Matrix mapping file flagged as Relevant = 718
   Sum of records in the Matrix mapping file flagged as Not relevant or Relevant = 750

4. All Nea Project FEPs and Matrix interactions included in the SR-PSU part of the SKB FEP database and flagged as Not relevant for the SFR repository have a justification documented for their omission.

   Yes.

   Justifications are shown in specific layouts in the NEA Mapping and Matrix Mapping files, respectively.

5. All NEA Project FEPs and Matrix interactions included in the SR-PSU part of the FEP database and flagged as relevant for the SFR repository system are associated with a documented description on their handling in SR-PSU.

   NEA Project FEPs: Yes.

Checked by comparing records in the NEA mapping file flagged as relevant with records in the file used for documenting the handling in SR-PSU.

Matrix interactions: No.

No formal documentation of the handling of Matrix Interactions has been made, since the SAFE and SAR-08 Interaction Matrices were used as input when setting up the SR-PSU FEP catalogue (see Section 4.1).

6. All processes in process reports, defined categories of initial states, defined external factors and defined system variables have a corresponding record in the SR-PSU FEP catalogue.

   Yes.

   List of SR-PSU FEPs in the SR-PSU catalogue compared with lists of contents of the associated reports. All SR-PSU FEP records have a reference to the corresponding section in the associated SR-PSU reports.

Appendix 2

SR-PSU Variable FEPs

Table A2-1. Variable FEPs for the system component "Waste form" and their definition in the SR-PSU FEP catalogue, as provided in the SR-PSU Waste form and packaging process report (SKB 2014c, Section 2.1.2). Descriptions of the initial states are provided in Section 12.1 in the SR-PSU Initial state report (SKB 2014b).

SR-PSU FEP ID	SR-PSU FEP name	SR-PSU definition
VarWM01	Geometry	Volume and dimensions of the waste form and voids inside the waste packaging.
		Porosity and pore characteristics of the waste form.
		Amount and characteristics of fractures in the waste form.
VarWM02	Radiation intensity	Intensity of alpha, beta and gamma radiation.
VarWM03	Temperature	Temperature.
VarWM04	Hydrological variables	Magnitude, direction and distribution of water flow.
		Degree of water saturation.
		Water pressure.
		Aggregation state (water and/or ice).
VarWM05	Mechanical stresses	Stress and strain in waste form.
VarWM06	Radionuclide inventory	Inventory of radionuclides as a function of time within the waste package.
		Type, amount, chemical and physical form.
VarWM07	Material composition	Amount and surface characteristics of the materials inside the waste package (excluding radionuclides).
		Type and amount of chemicals (including decontamination chemicals).
		Type and amount of organic materials and other substances that can be utilised by microbes as nutrients and energy sources.
		Types and amount of microbes and bacteria and other types of biomass.
VarWM08	Water composition	Composition of water including radionuclides.
		Redox, pH, ionic strength, concentration of dissolved species, type and amount of colloids and/or particles, amount and composition of dissolved gas.
		Types and amount of microbes and bacteria and other types of biomass.
		Density and viscosity.
VarWM09	Gas variables	Amount and composition, including radionuclides.
		Volume, pressure and degree of saturation.
		Magnitude, direction and distribution of gas flow.

Table A2-2. Variable FEPs for the system component "Concrete and steel packaging" and their definition in the SR-PSU FEP catalogue, as provided in the SR-PSU Waste form and packaging process report (SKB 2014c, Section 2.2.2). Descriptions of the initial states are provided in Section 12.2 in the SR-PSU Initial state report (SKB 2014b).

SR-PSU FEP ID	SR-PSU FEP name	SR-PSU definition
VarPa01	Geometry	Volume and dimensions of the waste packaging.
		Porosity and pore characteristics of the waste packaging.
		Amount and characteristics of fractures in the waste packaging.
VarPa02	Temperature	Temperature.
VarPa03	Hydrological variables	Magnitude, direction and distribution of water flow.
		Degree of water saturation.
		Water pressure.
		Aggregation state (water and/or ice).
VarPa04	Mechanical stresses	Stress and strain in packaging.
VarPa05	Material composition	Amount, composition and surface characteristics of the materials in the packaging.
		Type and amount of chemicals.
		Extent of cement hydration in concrete.
		Type and amount of organic materials and other substances that can be utilised by microbes as nutrients and energy sources.
VarPa06	Water composition	Composition of water including radionuclides.
		Redox, pH, ionic strength, concentration of dissolved species, type and amount of colloids and/or particles, amount and composition of dissolved gas.
		Types and amount of microbes and bacteria and other types of biomass.
		Density and viscosity.
VarPa07	Gas variables	Amount and composition, including radionuclides.
		Volume, pressure and degree of saturation.
		Magnitude, direction and distribution of gas flow.

Table A2-3. Variable FEPs for the system component "BMA barriers" and their definition in the SR-PSU FEP catalogue, as provided in the SR-PSU Engineered barrier process report (SKB 2014d, Section 4.3). Descriptions of the initial states are provided in Section 12.3 in the SR-PSU Initial state report (SKB 2014b).

SR-PSU FEP ID	SR-PSU FEP name	SR-PSU definition
VarBMA01	Geometry	Volume and dimensions of the barriers.
		Porosity and pore characteristics of the barriers.
VarBMA02	Temperature	Temperature.
VarBMA03	Hydrological variables	Magnitude, direction and distribution of water flow.
		Degree of water saturation.
		Water pressure.
		Aggregation state (water and/or ice).
VarBMA04	Mechanical stresses	Stress and strain in the barriers.
VarBMA05	Material composition	Amount, composition and surface characteristics of the materials in the barriers.
		Type and amount of chemicals.
		Type and amount of organic materials and other substances that can be utilised by microbes as nutrients and energy sources.
		Type and amounts of microbes and bacteria.
VarBMA06	Water composition	Composition of water including radionuclides.
		Redox, pH, ionic strength, concentration of dissolved species, type and amount of colloids and/or particles, amount and composition of dissolved gas.
		Density and viscosity.
		Types and amount of microbes and bacteria and other types of biomass.
VarBMA07	Gas variables	Amount and composition, including radionuclides.
		Volume, pressure and degree of saturation.
		Magnitude, direction and distribution of gas flow.

Table A2-4. Variable FEPs for the system component "BTF barriers" and their definition in the SR-PSU FEP catalogue, as provided in the SR-PSU Engineered barrier process report (SKB 2014d, Section 4.3). Descriptions of the initial states are provided in Section 12.4 in the SR-PSU Initial state report (SKB 2014b).

SR-PSU FEP ID	SR-PSU FEP name	SR-PSU definition
VarBTF01	Geometry	Volume and dimensions of the barriers.
		Porosity and pore characteristics of the barriers.
VarBTF02	Temperature	Temperature.
VarBTF03	Hydrological variables	Magnitude, direction and distribution of water flow.
		Degree of water saturation.
		Water pressure.
		Aggregation state (water and/or ice).
VarBTF04	Mechanical stresses	Stress and strain in the barriers.
VarBTF05	Material composition	Amount, composition and surface characteristics of the materials in the barriers.
		Type and amount of chemicals.
		Type and amount of organic materials and other substances that can be utilised by microbes as nutrients and energy sources.
		Type and amounts of microbes and bacteria.
VarBTF06	Water composition	Composition of water including radionuclides.
		Redox, pH, ionic strength, concentration of dissolved species, type and amount of colloids and/or particles, amount and composition of dissolved gas.
		Density and viscosity.
		Types and amount of microbes and bacteria and other types of biomass.
VarBTF07	Gas variables	Amount and composition, including radionuclides.
		Volume, pressure and degree of saturation.
		Magnitude, direction and distribution of gas flow.

Table A2-5. Variable FEPs for the system component "Silo barriers" and their definition in the SR-PSU FEP catalogue, as provided in the SR-PSU Engineered barrier process report (SKB 2014d, Section 4.3). Descriptions of the initial states are provided in Section 12.5 in the SR-PSU Initial state report (SKB 2014b).

SR-PSU FEP ID	SR-PSU FEP name	SR-PSU definition
VarSi01	Geometry	Volume and dimensions of the barriers.
		Porosity and pore characteristics of the barriers.
VarSi02	Temperature	Temperature.
VarSi03	Hydrological variables	Magnitude, direction and distribution of water flow.
		Degree of water saturation.
		Water pressure.
		Aggregation state (water and/or ice).
VarSi04	Mechanical stresses	Stress and strain in the barriers.
VarSi05	Material composition	Amount, composition and surface characteristics of the materials in the barriers.
		Type and amount of chemicals.
		Type and amount of organic materials and other substances that can be utilised by microbes as nutrients and energy sources.
		Type and amounts of microbes and bacteria.
VarSi06	Water composition	Composition of water including radionuclides.
		Redox, pH, ionic strength, concentration of dissolved species, type and amount of colloids and/or particles, amount and composition of dissolved gas.
		Density and viscosity.
		Types and amount of microbes and bacteria and other types of biomass.
VarSi07	Gas variables	Amount and composition, including radionuclides.
		Volume, pressure and degree of saturation.
		Magnitude, direction and distribution of gas flow.

Table A2-6. Variable FEPs for the system component "BRT barriers" and their definition in the SR-PSU FEP catalogue, as provided in the SR-PSU Engineered barrier process report (SKB 2014d, Section 4.3). Descriptions of the initial states are provided in Section 12.7 in the SR-PSU Initial state report (SKB 2014b).

SR-PSU FEP ID	SR-PSU FEP name	SR-PSU definition
VarBRT01	Geometry	Volume and dimensions of the barriers.
		Porosity and pore characteristics of the barriers.
VarBRT02	Temperature	Temperature.
VarBRT03	Hydrological variables	Magnitude, direction and distribution of water flow.
		Degree of water saturation.
		Water pressure.
		Aggregation state (water and/or ice).
VarBRT04	Mechanical stresses	Stress and strain in the barriers.
VarBRT05	Material composition	Amount, composition and surface characteristics of the materials in the barriers.
		Type and amount of chemicals.
		Type and amount of organic materials and other substances that can be utilised by microbes as nutrients and energy sources.
		Type and amounts of microbes and bacteria.
VarBRT06	Water composition	Composition of water including radionuclides.
		Redox, pH, ionic strength, concentration of dissolved species, type and amount of colloids and/or particles, amount and composition of dissolved gas.
		Density and viscosity.
		Types and amount of microbes and bacteria and other types of biomass.
VarBRT07	Gas variables	Amount and composition, including radionuclides.
		Volume, pressure and degree of saturation.
		Magnitude, direction and distribution of gas flow.

Table A2-7. Variable FEPs for the system component "BLA barriers" and their definition in the SR-PSU FEP catalogue, as provided in the SR-PSU Engineered barrier process report (SKB 2014d, Section 4.3). Descriptions of the initial states are provided in Section 12.6 in the SR-PSU Initial state report (SKB 2014b).

SR-PSU FEP ID	SR-PSU FEP name	SR-PSU definition
VarBLA01	Geometry	Volume and dimensions of the barriers.
		Porosity and pore characteristics of the barriers.
VarBLA02	Temperature	Temperature.
VarBLA03	Hydrological variables	Magnitude, direction and distribution of water flow.
		Degree of water saturation.
		Water pressure.
		Aggregation state (water and/or ice).
VarBLA04	Mechanical stresses	Stress and strain in the barriers.
VarBLA05	Material composition	Amount, composition and surface characteristics of the materials in the barriers.
		Type and amount of chemicals.
		Type and amount of organic materials and other substances that can be utilised by microbes as nutrients and energy sources.
		Type and amounts of microbes and bacteria.
VarBLA06	Water composition	Composition of water including radionuclides.
		Redox, pH, ionic strength, concentration of dissolved species, type and amount of colloids and/or particles, amount and composition of dissolved gas.
		Density and viscosity.
		Types and amount of microbes and bacteria and other types of biomass.
VarBLA07	Gas variables	Amount and composition, including radionuclides.
		Volume, pressure and degree of saturation.
		Magnitude, direction and distribution of gas flow.

Table A2-8. Variable FEPs for the system "Plugs and other closure components" and their definition in the SR-PSU FEP catalogue, as provided in the SR-PSU Engineered barrier process report (SKB 2014d, Section 4.3). Descriptions of the initial states are provided in Section 12.8 in the SR-PSU Initial state report (SKB 2014b).

SR-PSU FEP ID	SR-PSU FEP name	SR-PSU definition
VarPg01	Geometry	Volume and dimensions of the barriers.
		Porosity and pore characteristics of the barriers.
VarPg02	Temperature	Temperature.
VarPg03	Hydrological variables	Magnitude, direction and distribution of water flow.
		Degree of water saturation.
		Water pressure.
		Aggregation state (water and/or ice).
VarPg04	Mechanical stresses	Stress and strain in the barriers.
VarPg05	Material composition	Amount, composition and surface characteristics of the materials in the barriers.
		Type and amount of chemicals.
		Type and amount of organic materials and other substances that can be utilised by microbes as nutrients and energy sources.
		Type and amounts of microbes and bacteria.
VarPg06	Water composition	Composition of water including radionuclides.
		Redox, pH, ionic strength, concentration of dissolved species, type and amount of colloids and/or particles, amount and composition of dissolved gas.
		Density and viscosity.
		Types and amount of microbes and bacteria and other types of biomass.
VarPg07	Gas variables	Amount and composition, including radionuclides.
		Volume, pressure and degree of saturation.
		Magnitude, direction and distribution of gas flow.

Table A2-9. Variable FEPs for the system component "Geosphere" and their definition in the SR-PSU FEP catalogue, as provided in the SR-PSU Geosphere process report (SKB 2014e, Section 1.4.2).

SR-PSU FEP ID	SR-PSU FEP name	SR-PSU definition
VarGe01	Temperature	Temperature in the bedrock as a function of time and space.
VarGe02	Groundwater flow	Groundwater flow as a function of time and space in the geosphere´s fracture system.
VarGe03	Groundwater pressure	Groundwater pressure as a function of time and space in the geospere´s fracture system.
VarGe04	Gas phase flow	Gas phase flow as a function of time and space in the geosphere's fracture system.
VarGe05	Repository geometry	Geometric description of caverns, silo, tunnels, ramps, boreholes etc; i.e. of all excavated volumes.
VarGe06	Fracture and pore geometry	Geometric description of all cavities, from fracture zones to micropores in the rock matrix.
VarGe07	Rock stresses	Rock stresses as a function of time and space.
VarGe08	Matrix minerals	Chemical composition of the rock matrix as a function of (time and) space, i.e. a description of the various minerals that occur and their extent.
VarGe09	Fracture minerals	Chemical composition of the fracture minerals as a function of time and space, i.e. a description of the various fracture-filling minerals that occur. Also the amount and composition of these fracture-filling minerals.
VarGe10	Groundwater composition	Chemical composition of the groundwater as a function of time and space, i.e. redox, pH, ionic strength, concentration of dissolved species, type and amount of colloid particles, amount and composition of dissolved gas, radionuclides, density, viscosity.
VarGe11	Gas composition	Chemical composition of gases in geosphere cavities including any radionuclides located in fractures in the rock and left there at repository closure.
VarGe12	Structural and stray materials	Chemical composition and quantities of grouts and other structural and stray materials injected.
VarGe13	Saturation	Degree of water saturation.

Table A2-10. Variable FEPs for the system component "Biosphere" and their definition in the SR-PSU FEP catalogue, as provided in the SR-PSU Biosphere process report (SKB 2014j, Chapter 5).

SR-PSU FEP ID	SR-PSU FEP name	SR-PSU definition
VarBio01	Geometry	Geometry includes geometric descriptions of the landscape such as topography and bathymetry, depth and volume of regolith, peat, water etc. This feature also includes the geometry of organisms, i.e. their shape, surface area and volume. In addition, geometry includes the amount of a component.
VarBio02	Material composition	Material composition includes chemical composition (e.g. concentration of minerals and nutrients) as well as physical features such as grain size and porosity.
VarBio03	Radionuclide inventory	Radionuclide inventory include radionuclides and their activities in all physical and biological components of the biosphere system in question.
VarBio04	Stage of succession	Stage of succession is a feature used in the biosphere IM to determine the development of ecosystems and transitions from one ecosystem to another. The landscape in Forsmark continuously develops due to ongoing shoreline displacement and associated succession of the ecosystems. Thus, marine ecosystems are typically gradually transformed into lakes which by succession turn into wetland and forests. In addition, wetlands can be drained by humans and used for agriculture. Different process interactions are important for different stages of this ecosystem succession. The biosphere IM is generally applicable to all kinds of ecosystem and the feature 'stage of succession' can be used to evaluate for which ecosystems specific processes may be sufficiently important for them to be taken into account in a safety assessment, i.e. the stage of succession defines whether the ecosystem is a marine basin, lake, stream, forest, wetland, or agricultural land.
VarBio05	Temperature	Temperature is a unique physical property. Temperature has an impact on whether water is in a liquid or solid state and temperature affects living conditions for flora, fauna and humans. In SKB's IM, temperature is restricted to the temperature in the physical component of the system of interest. Temperature is dependent on climate, and local effects of climate on the diagonal elements are associated with this feature, whereas large-scale climate systems and their impacts belong to the diagonal element 'external factors'.
VarBio06	Water composition	Water composition comprises dissolved elements and compounds, colloids and suspended particles (including dead organic matter) in the biosphere components. The content of ions and elements determines e.g. pH-values, salinity, and nutrient concentrations. Thus, water composition is important to the presence and viability of biotic components and process rates. Various transport, chemical and biological processes affect water composition.

Appendix 3

Handling of NEA Project FEPs sorted to PSU Initial State FEPs

Table A3-1. SR-PSU FEP ISGen01 Major mishaps/accidents/sabotage.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.32 Explosions	Explosions are included in the SR-PSU FEP definition.		
A 1.44 Improper operation	See NEA FEP A 1.70.		
A 1.61 Preclosure events	Flooding is included in the SR-PSU FEP definition.		
A 1.70 Sabotage and improper operation	Sabotage, explosions, flooding, fires, terrorist activities, are included in the SR-PSU FEP definition.		
A 2.23 Explosion	Explosions are included in the SR-PSU FEP definition.		
A 2.56 Sabotage	Sabotage is included in the SR-PSU FEP definition.		
H 1.2.7 Flammability	Explosions and fires are included in the SR-PSU FEP definition.		
I 022 Explosions/bombs/ blasting/ collision/impacts/ vibration	Explosions in the repository prior to closure are covered by the SR-PSU FEP definition.		
J 5.05 Chemical sabotage	Sabotage is included in the SR-PSU FEP definition.		
M 2.2.06 Accidents during operation	Accidents are included in the SR-PSU FEP definition.		
M 2.2.07 Sabotage	Sabotage is included in the SR-PSU FEP definition.		
M 2.2.08 Repository flooding during operation	Flooding is included in the SR-PSU FEP definition.		
M 3.3.06 Gas effects	Explosions and fires are included in the SR-PSU FEP definition.		
W 2.027 Gas explosions	Explosions are included in the SR-PSU FEP definition.		

Recorded by: Kristina Skagius **Date:** 2014-04-11
Checked and revised by: Maria Lindgren **Date:** 2014-04-14
Revisions approved by: Not applicable **Date:**

Table A3-2. SR-PSU FEP ISGen01 Major mishaps/accidents/sabotage.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.01 Blasting and vibration	On-going monitoring programme will discover potential impact of blasting and vibration from e.g. construction of SFR extension.		
I 022 Explosions/bombs/ blasting/ collision/impacts/ vibration	On-going monitoring programme will discover potential impact of blasting and vibration from e.g. construction of SFR extension.		

Recorded by: Kristina Skagius **Date:** 2014-04-11
Checked and revised by: Maria Lindgren **Date:** 2014-04-14
Revisions approved by: Not applicable **Date:**

Table A3-3. SR-PSU FEP ISGen03 Incomplete closure.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.45 Incomplete closure	Incomplete closure is included in the SR-PSU FEP definition.		
A 1.70 Sabotage and improper operation	Incomplete closure is included in the SR-PSU FEP definition.		
A 2.70 Vault closure (incomplete)	Incomplete closure is included in the SR-PSU FEP definition.		
I 203 Monitoring shaft (failure to close)	Incomplete closure is included in the SR-PSU FEP definition.		
J 5.02 Non-sealed repository	Incomplete closure is included in the SR-PSU FEP definition.		
M 2.2.09 Abandonment of unsealed repository	Incomplete closure is included in the SR-PSU FEP definition.		
M 2.2.10 Poor closure	Incomplete closure is included in the SR-PSU FEP definition.		
M 2.2.12 Effects of phased operation	Incomplete closure is included in the SR-PSU FEP definition.		
Recorded by: Kristina Skagius			**Date:** 2014-04-11
Checked and revised by: Maria Lindgren			**Date:** 2014-04-14
Revisions approved by: Not applicable			**Date:**

Table A3-4. SR-PSU FEP ISGen04 Monitoring activities.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.56 Monitoring and remedial activities	Monitoring activities are included in the SR-PSU FEP definition.		
J 5.39 Postclosure monitoring	Monitoring activities are included in the SR-PSU FEP definition.	Cables through the buffer/backfill to probes close to the canister are not relevant for SFR.	
K 5.25 Exploratory boreholes (sealing)	Monitoring activities are included in the SR-PSU FEP definition.		
M 2.2.11 Post-closure monitoring	Monitoring activities are included in the SR-PSU FEP definition.		
W 2.011 Postclosure monitoring	Monitoring activities are included in the SR-PSU FEP definition.		
Recorded by: Kristina Skagius			**Date:** 2014-04-11
Checked and revised by: Maria Lindgren			**Date:** 2014-04-14
Revisions approved by: Not applicable			**Date:**

Table A3-5. SR-PSU FEP ISGen05 Design deviations – Mishaps.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.70 Sabotage and improper operation	Issues that are relevant for SFR are mentioned in the SR-PSU FEP definition.		
A 2.47 Open boreholes	Improperly sealed and open boreholes are mentioned in the SR-PSU FEP definition.		
E GEN-35 Fast transport pathways	Unsealed boreholes are mentioned in the SR-PSU FEP definition.		
I 011b Backfill (faulty emplacement)	Faulty emplacement of backfill is mentioned in the SR-PSU FEP definition.		
I 029 Buffer (faulty emplacement)	Faulty emplacement is mentioned in the SR-PSU FEP definition.		The bottom sand/bentonite backfill in the silo is already in place.
I 062a1 Concrete (incorrect structural design)	Design deviations are covered by the SR-PSU FEP definition.		
I 062a2 Concrete (incorrect mix design)	Design deviations are covered by the SR-PSU FEP definition.		
I 062b Concrete (incorrect preparation/emplacement)	Manufacturing deviations are mentioned in the SR-PSU FEP definition.		
I 062f Concrete (poor quality - procurement)	Covered by the SR-PSU FEP definition.		
J 3.1.01 Degradation of the bentonite by chemical reactions	Material deficiencies are included in the SR-PSU FEP definition.		
J 3.2.01.2 Uneven swelling of bentonite	Design and material deficiencies are included in the SR-PSU FEP definition.		
J 3.2.11 Backfill material deficiencies	Material deficiencies are included in the SR-PSU FEP definition.		
J 5.09 Unsealed boreholes and/or shafts	Unsealed boreholes and shafts are included in the SR-PSU FEP definition.		
K 1.26 Handling accidents	Handling accidents are included in the SR-PSU FEP definition.		
K 3.23 Poor emplacement of buffer	Design deviations relevant for SFR are included in the SR-PSU FEP definition.	Emplacement of precompressed bentonite blocks around a canister is not addressed since this is not relevant for SFR.	
K 5.25 Exploratory boreholes (sealing)	Unsealed boreholes are included in the SR-PSU FEP definition.		
M 2.1.08 Poor quality construction	Poor quality construction is covered by the SR-PSU FEP definition.		
M 2.2.02 Inadequate backfill or compaction voidage	An inadequate or badly placed backfill is covered by the SR-PSU FEP definition.		
M 2.2.04 Inadvertent inclusion of undesirable materials	Inclusion of undesirable materials is covered by the SR-PSU FEP definition.		
M 2.2.06 Accidents during operation	Accidents during operation are covered by the SR-PSU FEP definition.		
M 3.3.04 Subsidence/collapse	Design and material deficiencies are included in the SR-PSU FEP definition.		

Recorded by: Kristina Skagius **Date:** 2014-04-11
Checked and revised by: Maria Lindgren **Date:** 2014-04-14
Revisions approved by: Not applicable **Date:**

Appendix 4

Handling of NEA Project FEPs sorted to SR-PSU Waste form processes

Table A4-1. SR-PSU FEP WM01 Radioactive decay.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.65 Radioactive decay	The whole FEP		
E GEN-28 Radioactive decay	Radioactive decay, heat generation, impact on radionuclide inventory.		
E SFR-22 Changes in the radionuclide inventory	Radioactive decay	Migration of radionuclides, which is described in WM21 Transport of radionuclides in the water phase.	
H 1.3.1 Radioactive decay and ingrowth	The whole FEP		
I 045 Progency nuclides (critical radionuclides)	Radioactive decay chains	Assessment of dose is not described in the process, but in the Main report of SR-PSU, TR-14-01.	
J 1.1.02 Radioactive decay; heat	The whole FEP		
K 0.1 Radioactive decay	Radioactive decay	Assessment of dose is not described in the process, but in the Main report of SR-PSU, TR-14-01.	
M 3.4.04 Radioactive decay ingrowth	The whole FEP		
S 005 Changes in radionu-clide inventory	Radioactive decay	Spent fuel, which is not relevant for the SFR waste.	
S 069 Radioactive Decay, fuel	Radioactive decay and heat generation		
Recorded by: Klas Källström			**Date:** 2012-10-14
Checked and revised by: Kristina Skagius			**Date:** 2014-02-19
Revisions approved by: Klas Källström			**Date:** 2014-03-10

Table A4-2. SR-PSU FEP WM02 Radiation attenuation/heat generation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.81 Temperature effects	Heat generation and effect on temperature.	Temperature effect on rate of chemical reactions, because heat arising from decay and attenuation is judged negligible in SFR.	
E GEN-28 Radioactive decay	Heat generation and effect on temperature.	Change in radionuclide inventory, which is addressed in WM01 Radioactive decay.	
E SFR-17 Temperature of the near-field	Heat generation and effect on temperature.	Temperature effect on chemical, microbial and transport properties, because heat arising from decay and attenuation is judged negligible in SFR.	
I 146 Heat generation in IRUS vault(B)	Heat generation and effect on temperature.	Heat generation due to biological decomposition, which is addressed in WM17 Microbial processes.	Heat arising from decay and attenuation is judged negligible in SFR.
I 238 Radiation effects	All		See also WM03 and WM04.
J 1.1.02 Radioactive decay; heat	Heat generation and effect on temperature.	Effects on convective ground water movement, because heat arising from decay and attenuation is judged negligible in SFR.	See also WM08.
K 1.08 Heat output (RN decay heat)	Heat generation and effect on temperature.	Residual heat effects, because heat arising from decay and attenuation is judged negligible in SFR.	The NEA FEP concerns spent fuel.
K 2.11 Radiation shielding	Shielding effect in waste		
K 2.19 Canister temperature	Heat generation and effect on temperature.	Temperature effects on corrosion rate, because heat arising from decay and attenuation is judged negligible in SFR.	
M 3.4.02 Material propertiy changes	All		See also WM03
S 069 Radioactive Decay, fuel	Heat generation and effect on temperature.		Heat arising from decay and attenuation is judged negligible in SFR.
W 2.013 Heat from radioactive decay	Heat generation and effect on temperature.	Effects of extreme temperature increases, because heat arising from decay and attenuation is judged negligible in SFR.	
Recorded by: Klas Källström			**Date:** 2012-10-14
Checked and revised by: Kristina Skagius			**Date:** February 2014
Revisions approved by: Klas Källström			**Date:** 2014-03-10

Table A4-3. SR-PSU FEP WM03 Radiolytic decomposition of organic material.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.64 Radiation damage	Effects of radiation on waste materials.		See also WM04.
A 1.66 Radiolysis	Radiolytic decomposition and formation of gases and degradation products are discussed.		See also WM04.
E SFR-14 Radiation effects in the near-field	Radiolytic decomposition and influences on other processes.		See also WM04.
H 1.1.3 Waste corrosion and solubility and speciation of radionuclides	Impact of radiolytic decomposition on water composition affecting speciation of radionuclides.	Other degradation processes, which are discussed in WM14, WM15, WM17 and WM18.	See also WM20 Speciation of radionuclides.
I 238 Radiation effects	Effects of radiation of bitumen.		
J 1.2.01 Radiolysis	Radiolytic decomposition of water.		The NEA FEP concerns spent fuel.
K 3.19 Radiolysis	Oxidation of bitumen waste matrix.	The oxidation potential of steel and corrosion products are not discussed, but addressed in WM04.	
M 3.2.05 Cellulosis degradation	None.	The FEP has nothing to do with radiolytic decomposition of organic material.	Cellulose degradation considered in WM15.
M 3.4.02 Material propertiy changes	Changes in material properties of bitumen.		
S 069 Radioactive Decay, fuel	Effects of radiation on bituminized waste properties.	Effects of radioactive decay on radionuclide inventory, which is addressed in WM01.	The NEA FEP concerns spent fuel.
W 2.015 Radiological effects on waste	Effects of radiation on bituminized waste properties.		
W 2.053 Radiolysis of cellulose		Gas generation due to radiolysis of cellulose is not addressed. As stated in the FEP description, gas generation from this process is negligible compared with gas generation from other processes, such as metal corrosion.	
Recorded by: Klas Källström			**Date:** 2012-04-18
Checked and revised by: Kristina Skagius			**Date:** February 2014
Revisions approved by: Klas Källström			**Date:** 2014-03-10

Table A4-4. SR-PSU FEP WM04 Water radiolysis.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.64 Radiation damage	Radiolysis products.	Radiolytic decomposition of waste matrices, which are addressed in WM03.	
A 1.66 Radiolysis	Radiolysis products.	Effects on pH and Eh, because the process is assessed as negligible due to the low radiation field.	
E GEN-30 Radiolysis	Radiolysis products.	Impact on redox conditions and radionuclide solubility, because the process is assessed as negligible due to the low radiation field.	
E SFR-11 Gas generation in the repository	Generation of gases.		
E SFR-14 Radiation effects in the near-field	Radiolysis of water.	Radiolytic degradation of organic material, which is addressed in WM03.	
I 238 Radiation effects	Radiolysis products.	Effect on pH and Eh, because the process is assessed as negligible due to the low radiation field.	
J 1.2.01 Radiolysis	Impact of radiolysis on water chemistry.		The NEA FEP concerns spent fuel.
J 1.2.08 Redox potential		Effect on redox potential, because the process is assessed as negligible due to the low radiation field.	The NEA FEP concerns spent fuel.
K 1.23 Radiolysis	Radiolysis of water and gas production.	Effects on Eh, because the process is assessed as negligible due to the low radiation field.	The NEA FEP concerns spent fuel.
K 3.19 Radiolysis	Radiolysis of water and gas production.	Effect on redox potential, because the process is assessed as negligible due to the low radiation field.	The NEA FEP concerns spent fuel.
M 3.4.01 Radiolysis	Radiolysis of water and gas production.	Influence on speciation of radionuclides, because the process is assessed as negligible due to the low radiation field.	The NEA FEP concerns spent fuel.
S 069 Radioactive Decay, fuel	Radiolysis of water.		The NEA FEP concerns spent fuel.
S 071 Radiolysis	Radiolysis of water.	Chemical effects such as pH and Eh, because the process is assessed as negligible due to the low radiation field.	The NEA FEP concerns spent fuel.

Recorded by: Klas Källström **Date:** 2012-04-18
Checked and revised by: Kristina Skagius **Date:** February 2014
Revisions approved by: Klas Källström **Date:** 2014-03-10

Table A4-5. SR-PSU FEP WM05 Heat transport.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E SFR-17 Temperature of the near-field	All aspects of the FEP that relates to the process of heat transport (conduction and convection) are addressed.	Heat generation due to various processes such as cement hydration, radioactive decay and microbially mediated degradation of organic material is mentioned but not discussed in detail. The influence of these processes on heat production is instead handled in each process description separately, through the defined interaction variable "Temperature".	

Recorded by: Magnus Sidborn **Date:** July 2012
Checked and revised by: Kristina Skagius **Date:** February 2014
Revisions approved by: Not applicable **Date:**

Table A4-6. SR-PSU FEP WM06 Phase changes/freezing.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 268 Freeze/thaw cycles	Structural damage of concrete due to periglacial freezing is addressed.	The IRUS repository referred to in the FEP is a near-surface (unsaturated conditions above the groundwater table) facility in Canada exposed to cyclic events of freezing/thawing, whereby the construction is specifically designed to be resistant to such frequent cycles. The SFR repository is placed sufficiently deep to avoid frequent freezing/thawing cycles and any engineering measures to avoid freezing damage are not taken. Structural deterioration due to conditions expected under future periglacial permafrost is addressed, although not specifically due to such frequent cyclic events as those referred to in the FEP.	
J 5.17 Permafrost	Structural deterioration of waste packages as a consequence of freezing under expected periglacial permafrost conditions is addressed.		
S 059 Permafrost	The occurrence and effects of periglacial permafrost on the waste packages is addressed.		

Recorded by: Magnus Sidborn **Date:** July 2012

Checked and revised by: Kristina Skagius **Date:** February 2014

Revisions approved by: Not applicable **Date:**

Table A4-7. SR-PSU FEP WM07 Water uptake and transport during unsaturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.68 Reflooding	Effect on temperature is addressed, but assumed negligible. Pressure build-up during resaturation is addressed.	Possible consequences of pressure build-up on components in the waste form, e.g. cracking, is not mentioned here, but addressed in WM09 Fracturing.	
A 1.88 Unsaturated transport	Unsaturated transport is addressed, although the time to reach full saturation is judged to be relatively short (a few years for BMA, BLA and BTF, and 25-100 years for the Silo).		
E SFR-16 Hydraulic resaturation of the near-field		From FEP: "heterogeneous resaturation will induce complex stress fields in the near-field rock and the engineered barriers (see GEN-36 "Stress field")". This is not addressed since FEP concerns the waste form.	See also NEA FEP A.1.68 above.
H 1.5.3 Unsaturated flow due to gas production	All relevant aspects are addressed.		
J 5.14 Resaturation	All relevant aspects are addressed.		
W 2.041 Wicking	Capillary action is addressed.	The influence of capillary rise on gas production is not addressed here. Gas production is addressed in WM19 Gas formation and transport.	

Recorded by: Magnus Sidborn **Date:** 2012-10-01

Checked and revised by: Kristina Skagius **Date:** February 2014

Revisions approved by: Not applicable **Date:**

Table A4-8. SR-PSU FEP WM08 Water transport under saturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.40 Hydraulic conductivity	All aspects are addressed.		
A 1.41 Hydraulic head	All relevant aspects are addressed.		
E SFR-21 Groundwater movement in the near-field		The effect of gas generation and transport on water transport is not considered here as this issue is addressed in WM07 Water uptake and transport during unsaturated conditions.	
H 1.5.4 Saturated groundwater flow	All relevant aspects are addressed		
Recorded by: Magnus Sidborn			**Date:** 2012-10-03
Checked and revised by: Kristina Skagius			**Date:** February 2014
Revisions approved by: Not applicable			**Date:**

Table A4-9. SR-PSU FEP WM09 Fracturing.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E SFR-13 Mechanical impact on the engineered barriers	Internal and external loads causing mechanical impact and potential fracturing.		
J 2.3.07.1 External stress	External load from e.g. rock fallout on waste containers is identified as a potential cause for fracturing.		
J 3.2.07 Swelling of corrosion products	Formation of corrosion products with higher molecular volume than starting material is identified as a potential cause for fracturing.	Effects on a copper canister and a surrounding bentonite buffer, because they are not relevant for waste in SFR.	See also WM18 Metal corrosion.
M 3.1.02 Non-elastic reponse	Mechanisms leading to fracturing are addressed.		
M 3.3.04 Subsidence/collapse	External load from e.g. rock fallout on waste containers is identified as a potential cause for fracturing.	Total collapse of the waste vaults is not addressed because the process description is restricted to the waste form.	See also BMABa06, BTFBa06, SiBa07, BRTBa06 and BLABa06.
S 004 Cave in	External load from e.g. rock fallout on waste containers is identified as a potential cause for fracturing.	Impact of cave in on other barriers is not addressed because the process description is restricted to the waste form.	See also BMABa06, BTFBa06, SiBa07, BRTBa06 and BLABa06.
S 055 Mechanical impact on canister	Internal and external loads causing mechanical impact and potential fracturing.	Effects of mechanical impact specific for a copper canister with spent fuel.	The NEA FEP concerns spent fuel in a copper canister.
S 100 Volume increase of corrosion products	Formation of corrosion products with higher molecular volume than starting material is identified as a potential cause for fracturing.	Effects on a copper canister and a surrounding bentonite buffer, because they are not relevant for waste in SFR.	See also WM18 Metal corrosion.
W 2.022 Roof falls	External load from e.g. rock fallout on waste containers is identified as a potential cause for fracturing.	Impact of rock fallout on fractures in the surrounding rock is not addressed here, but in Ge07 Fracturing.	
Recorded by: Klas Källström			**Date:** 2012-04-18
Checked and revised by: Kristina Skagius			**Date:** February 2014
Revisions approved by: Klas Källström			**Date:** 2014-03-10

Table A4-10. SR-PSU FEP WM10 Advective transport of dissolved species.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E GEN-10 Radionuclide dispersion	All relevant aspects are addressed.	Aspects of dispersion relevant for field scale only, i.e. dispersive effects due to large-scale geological structures is deemed to be superfluous for this description and is not addressed.	See Ge10 Advective transport/mixing of dissolved species.
Recorded by: Magnus Sidborn			**Date:** 2012-10-01
Checked and revised by: Kristina Skagius			**Date:** February 2014
Revisions approved by: Magnus Sidborn			**Date:** March 2014

Table A4-11. SR-PSU FEP WM11 Diffusive transport of dissolved species.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.27 Diffusion	Contaminant movement due to diffusion through the water and sealing materials is addressed. Diffusion is temperature dependent. Surface effects may be very important in clays.		
A 1.36 Galvanic coupling		Enhanced movement of contaminants due to galvanic coupling with a far ore body is not considered due to the presence of other electrical currents that are deemed to be more significant (arising from e.g. crevice corrosion of steel packaging). Furthermore, galvanic coupling within the repository caverns is neglected on the basis of low consequence to the performance of the disposal system.	
E GEN-09 Diffusion	The issue of quantifying repository-relevant diffusion coefficients for the chemical species of interest is discussed. The influence of porosity, tortuosity and constrictivity on the diffusion coefficients is discussed as well as the influence of temperature, ion–ion and ion–surface interaction effects. Effects due to the electrical double-layer adjacent to mineral surfaces (anion exclusion and enhanced cation diffusion) are considered and their influence by the ionic strength of the porewater is discussed.		
E SFR-09 Diffusion in the near-field	Diffusion in the near-field may occur through water-filled cracks and voids in the mass of the immobilization matrices. Diffusion will be an important process controlling porewater chemistry in the nearfield and the radionuclide release rate to the far-field. Interactions with the porewater's thermal expansion may lead to cracks and fractures that will enhance diffusive transport rates.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 300 Temperature effects (on transport)	Temperature effects on diffusive transport is addressed, but neglected due to the largely isothermal conditions expected at SFR.		
J 3.2.06 Diffusion – surface diffusion	Enhanced cation diffusion and anion exclusion are considered as effects of the presence of an electrical double-layer adjacent to mineral surfaces.		
S 002 Anion-exclusion	Enhanced cation diffusion and anion exclusion are considered as effects of the presence of an electrical double-layer adjacent to mineral surfaces.		
S 024 Diffusion in and through failed canister	Addressed.		
W 2.095 Galvanic coupling		Galvanic coupling within the waste vaults is neglected on the basis of low consequence to the performance of the disposal system.	
W 2.096 Electrophoresis		Because the electrochemical cells that may be established are small, the effect of such cells on the migration of contaminants (for example, by electrophoresis) has also been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.	See also SR-PSU FEP Ge21.

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Checked and revised by: Kristina Skagius **Date:** February 2014
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Table A4-12. SR-PSU FEP WM12 Sorption/uptake.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.73 Sorption	Partitioning of contaminants in water onto substrates, since various sorption/uptake mechanisms are addressed.	Sorption in buffer and backfill not addressed here, but sorption on barrier materials in SFR is addressed in BMABa09, BMABa10, BTFBa09, SiBa10, BRTBa09 and BLABa09.	
A 1.74 Sorption – nonlinear	Taken care of by the description of influence of complexing agents that influence solubility and ability to sorb upon the concrete. For carbonate the precipitation is discussed.	Solubility effects for most of the elements are not discussed, because a vast majority of the RN is present below solubility limits. This however does not take into account stable isotopes of the elements.	
E GEN-34 Radionuclide sorption	Sorption/uptake mechanisms addressed and sorption/uptake of radionuclides on cement considered in the analysis. Sorption of ISA is considered in terms of reducing aqueous concentration.	Sorption of molecules, sorption of ions other than radionuclides and ISA and sorption of colloids is not specifically addressed. Attachment of colloids to material surfaces is addressed in WM13.	
I 300 Termperature effects (on transport)	Impact of temperature on sorption/uptake is addressed but not considered since not enough energy will be generated to be able to increase the temperature.		
J 3.1.02 Saturation of sorption sites	The availability of sorption sites for different materials in the waste form is addressed.	Saturation of sorption sites is not specifically considered, because there will be enough cement material in the cement waste forms to provide sorption sites.	.
J 4.1.04 Sorption	Sorption/uptake mechanisms addressed and sorption/uptake of radionuclides on cement considered in the analysis. Sorption of ISA is considered in terms of reducing aqueous concentration.	Sorption of molecules, sorption of ions other than radionuclides and ISA and sorption of colloids is not specifically addressed. Attachment of colloids to material surfaces is addressed in WM13.	
M 1.6.10 Complexing agents	Influence of organic molecules on sorption/uptake is included in process description.		
S 084 Sorption	Non linear effects and isotopic dilution considered for C-14.	Saturation of sorption sites is not specifically considered, because there will be enough cement material in the cement waste forms to provide sorption sites.	
W 2.061 Actinide sorption	Sorption/uptake mechanisms addressed and sorption/uptake of radionuclides on cement considered in the analysis.		
W 2.062 Kinetics of sorption	Sorption/uptake kinetics is addressed.		

Recorded by: Klas Källström	**Date:** 2012-04-18
Checked and revised by: Kristina Skagius	**Date:** February 2014
Revisions approved by: Klas Källström	**Date:** 2014-03-10

Table A4-13. SR-PSU FEP WM13 Colloid formation and transport.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.63 Psuedo-colloids	Generation of colloids (eigen-colloids) or pseudo-colloids (naturally-occuring particulates) as a result of changes in the vault environment caused by chemical processes, biological processes, and physical agitation are addressed.		Note: In the NEA FEPs *colloids* refer to aggregates of the radionuclide (or contaminant) itself and *pseudo-colloids* refer to naturally occurring colloidal material already present in the groundwater onto which radionuclides may sorb. In the SR-PSU process description, these are referred to as *eigencolloids* and *colloids* respectively.
E SFR-01 Colloid generation in the waste package	Aspects relevant to the waste form are addressed.	Colloid formation due to precipitation of dissolved species (e.g. silica) at the alkaline front (where pH drops) at some distance downstream the repository is not relevant for the waste form and is therefore not addressed here.	
E SFR-15 Radionuclide release from the waste	Aspects relevant to the waste form are addressed.		
I 058 Colloid formation (natural and vault generated)		A general description of the influence on colloid stability by the prevailing redox-conditions is not addressed, except for the possible formation of iron-oxyhydroxide colloids under oxidising conditions.	

Recorded by: Magnus Sidborn **Date:** May 2012
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Table A4-14. SR-PSU FEP WM14 Dissolution, precipitation and recrystallisation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.13 Colloids	Relevant aspects are mentioned with reference to the processes Colloid formation and transport (WM13) and Colloid transport and filtering (Pa09).		
A 1.62 Precipitation and dissolution	All relevant aspects are addressed.		
A 1.77 Speciation	All relevant aspects are addressed.		
E SFR-01 Colloid generation in the waste package	Relevant aspects are mentioned with reference to the processes Colloid formation and transport (WM13) and Colloid transport and filtering (Pa09).		
E SFR-05 Degradation of the concrete packages and the cement matrix	All relevant aspects are addressed.		
E SFR-07 Degradation of the inorganic waste		Degradation of non-metallic inorganic materials (e.g. ceramics) is not addressed. This can be motivated by their low amounts in SFR, and their essentially inert character.	
H 1.1.2 Physico-chemical degradation of concrete	All relevant aspects are addressed.		
H 1.1.3 Waste corrosion and solubility and speciation of radionuclides	All relevant aspects are addressed.		
I 058 Colloid formation (natural and vault generated)	Relevant aspects are mentioned with reference to the processes Colloid formation and transport (WM13) and Colloid transport and filtering (Pa09).		
I 061 Concrete (influence on vault chemistry)	All relevant aspects are addressed.		
I 300 Termperature effects (on transport	All relevant aspects are addressed.		
J 1.2.07 Recrystallization	All relevant aspects are addressed.		
J 3.1.07 Reactions with cement pore water	All relevant aspects are addressed.		
M 3.2.02 Interactions of host materials and ground water with repository materials	All relevant aspects are addressed.		
W 2.060 Kinetics of precipitation and dissolution	All relevant aspects are addressed.		
W 2.073 Concrete hydration	All relevant aspects are addressed.		

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Table A4-15. SR-PSU FEP WM15 Degradation of organic materials.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.13 Colloids		Organic colloids are not addressed here, but in colloid process description, WM 13.	
E SFR-01 Colloid generation in the waste package		Organic colloids are not addressed here, but in colloid process description, WM 13.	
E SFR-06 Degradation of the bitumen matrix	Described.		
E SFR-08 Degradation of the organic waste	Bitumen, ion exchange resins cellulose plastic rubber filter aids etc addressed. Formation of gas mentioned and pointing to process WM19 Gas formation and transport.		
H 1.1.3 Waste corrosion and solubility and speciation of radionuclides	Degradation of organic wastes.	Waste corrosion does not apply to organic material and is described in corrosion processes (WM14 and WM18). Speciation is described in specific process description (WM 20).	
I 044 Chealting agents	Formation of ISA and other chelating agents present in the waste from the beginning is described.		
I 238 Radiation effects		Radiation effects not addressed here but described in radiolytic decomposition of organic material (WM03).	O
I 300 Termperature effects (on transport)	Impact of/on temperature is addressed but not considered since not enough energy will be generated to be able to increase the temperature.		
J 4.1.09 Complexing agents	Effects of humic and fulvic acids are discussed.		
M 1.6.10 Complexing agents	Effect of humic and fulvic acids is discussed.		
M 3.2.05 Cellulosis degradation	Degradation of cellulose and formation of complexing agents are addressed.		
M 3.2.06 Introduced complexing agents and cellulosis	Decontamination liquids and degradation products of organic materials as complexing agents are addressed.		
W 2.068 Organic complexation	Organic materials as complexing agents are addressed.		

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Table A4-16. SR-PSU FEP WM16 Water uptake/swelling.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E SFR-06 Degradation of the bitumen matrix	All relevant aspects are addressed.	The focus of the description is water uptake with resulting swelling of the bitumen matrix. Therefore, chemical degradation under acidic conditions by e.g. sulphuric acid, and microbially-mediated degradation under alkaline conditions and enhanced degradation in the presence of a high radiation field are processes not addressed here. Instead these processes are addressed in "Radiolytic decomposition of organic material" (WM03), "Degradation of organic materials" (WM15), and "Microbial processes"(WM17).	
E SFR-13 Mechanical impact on the engineered barriers	All relevant aspects are addressed.		

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Table A4-17. SR-PSU FEP WM17 Microbial processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.03 Biological activity	All relevant aspects are addressed.		
A 1.53 Methylation	Methylation is addressed.		
E SFL-32 Microbial activity	All relevant aspects are addressed.		
E SFR-01 Colloid generation in the waste package		Impact of microbial processes on colloids is not addressed here, but in WM13 Colloid formation and transport.	
E SFR-11 Gas generation in the repository	Gas generation by microbial processes is addressed.		See also WM19 Gas formation and transport.
H 1.1.3 Waste corrosion and solubility and speciation of radionuclides	Microbial degradation of organic wastes and microbial corrosion of inorganic wastes.		
H 1.2.1 Hydrogen by metal corrosion	Production of hydrogen by corrosion of metals including the effect of corrosion-derived hydrogen on the growth of microbes on concrete.		See also WM18 Metal corrosion and WM19 Gas formation and transport.
H 1.2.2 Methane and carbon dioxide by microbial degradation	Formation of methane and carbon dioxide by microbial degradation, the main controls of the viability of microbes and consequences in terms of carbonation of concrete.		
H 1.2.4 Radioactive gases	Formation of hydrogen, carbon dioxide and methane by microbial processes.	The formation and transport of radioactive gases, C-14 and H-3, is not specifically addressed here, but in WM 19 Gas formation and transport and WM22 Transport of radionuclides in the gas phase.	
I 012 Biological activity (bacteria & microbes)	Biological activity and impact on chemical environment in the vault and other processes influenced by the chemical environment are addressed.		
I 015 Gas generation (CH_4, CO_2, H_2)	Formation of CH_4, CO_2, and H_2 through biological degradation of organic material and impact on vault chemistry are addressed.	Gas generation by metal corrosion and impact of gas generation and transport on contaminant transport are not specifically addressed here, but in WM18 Metal corrosion, WM19 Gas formation and transport, and WM22 Transport of radionuclides in the gas phase.	
I 146 Heat generation in IRUS vault(B)	Heat generation by biological decomposition processes is mentioned.		Heat generation is neglected as the microbial activity is expected to be low as long as hyperalkaline conditions prevail.
J 2.1.10 Microbes	Pre-requisites for microbial activity, types of microbes, their impact on the environment and other processes influenced by the chemical environment are addressed. This includes the formation of complexing agents and various kinds of chelating compounds.	Impact of microbial processes on colloids is not addressed here, but in WM13 Colloid formation and transport.	
K 3.17 Microbial activity	Microbiological activity and growth, and associated production of organic complexants are addressed.	Impact of complexing agents on radionuclide mobility is not specifically addressed here, but in e.g. WM 12 Sorption/uptake and WM20 Speciation of radionuclides.	
M 3.2.07 Microbiological effects	Impact of bacteria on the degradation of metals, concrete and bitumen is addressed.	Impact on degradation of glass is not mentioned, since this relates to vitrified waste which is not relevant for SFR.	
S 010 Colloids/particles in canister		Impact of microbial processes on colloids is not addressed here, but in WM13 Colloid formation and transport.	

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
S 057 Microbial activity	Pre-requisites for microbial activity, types of microbes, their impact on the environment and other processes influenced by the chemical environment are addressed. This includes the formation of complexing agents and various kinds of chelating compounds.	Impact of microbial processes on colloids is not addressed here, but in WM13 Colloid formation and transport.	
W 2.044 Degradation of organic material	Gas generation from microbial degradation of organic materials is addressed.	Gas generation from corrosion and radiolysis is not addressed here, but in e.g. WM19 Gas formation and transport.	
W 2.045 Effect of temperature on microbial gas generation	Impact of temperature on microbial processes is addressed.	Heat generation due to radioactive decay, concrete hydration and aluminium corrosion is not addressed here, but in other process descriptions (WM01, WM14, WM18).	Heat arising from decay, attenuation, etc is judged negligible in SFR.
W 2.046 Effect of pressure on microbial gas generation		Effect of pressure on microbial gas generation is not specifically addressed here. However, gas generation by microbial activity is negligible compared with gas generation from metal corrosion, see WM19.	
W 2.047 Effect of radiation on microbial gas generation	Impact of radiation on microbial processes is addressed.		The radiation intensity is not expected to be high enough to influence microbial processes.
W 2.048 Effect of biofilms on microbial gas generation	The formation of biofilms is addressed.	The effects of biofilms on microbial gas generation and control of microbial population size and effects on radionuclide transport are not specifically addressed. However, biofilms are not expected to be extensive since hyperalkaline conditions will limit microbial activities.	
W 2.076 Microbial growth on concrete	Microbial degradation of concrete is addressed.		
W 2.088 Biofilms	The formation of biofilms is addressed.	The effects of biofilms on radionuclide transport are not specifically addressed. However, biofilms are not expected to be extensive since hyperalkaline conditions will limit microbial activities.	

Recorded by: Birgitta Kalinowski — **Date:** 2012-10-01

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Table A4-18. SR-PSU FEP WM18 Metal corrosion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.30 Electrochemical gradients		Not considered since the effects are difficult to quantify and judged to be small compared to other uncertainties.	
E GEN-13 Electrochemical effects		Not considered since the effects are difficult to quantify and judged to be small compared to other uncertainties.	
E SFR-01 Colloid generation in the waste package			Corrosion is not mentioned in this NEA FEP.
E SFR-07 Degradation of the inorganic waste	Metal corrosion is considered.		
E SFR-11 Gas generation in the repository	Hydrogen production is considered.		
H 1.1.3 Waste corrosion and solubility and speciation of radionuclides	Release of induced activity considered.		See also Speciation of radionuclides WM20.
H 1.1.4 Electrochemical effects of metal corrosion		Not considered since the effects are difficult to quantify and judged to be small compared to other uncertainties.	
H 1.2.1 Hydrogen by metal corrosion	Hydrogen production is considered.		
I 015 Gas generation (CH_4, CO_2, H_2)	Hydrogen production is considered.	CH_4 and CO_2 are produced due to biological activity.	See WM17 Microbial processes.
I 065 Waste container (metal corrosion products)	Influences on water composition are considered.		See also WM12 Sorption/uptake.
I 071 Corrosive chemicals (in vault)	Influences of water composition are considered.	Corrosive chemicals are not specifically addressed since the effects are difficult to quantify and judged to be small compared to other uncertainties.	
I 126 Corrosion (galvanic coupling)		Not considered since the effects are difficult to quantify and judged to be small compared to other uncertainties. The effect of the Fenno-Skan cable is mentioned.	
I 300 Termperature effects (on transport)	Influence of temperature is addressed.		
J 1.2.08 Redox potential	Influence on/of redox potential is considered.		
J 2.1.06.2 Natural telluric electrochemical reactions		Not considered since the effects are difficult to quantify and judged to be small compared to other uncertainties.	
J 2.1.07 Pitting	Pitting is mentioned.		
J 3.2.07 Swelling of corrosion products	Corrosion products with higher molar volume are considered.		Fracturing treated in WM09 Fracturing.
K 2.14 Chemical buffering (canister corrosion products)	Influence on water composition is considered.		
K 2.16 Hydrogen production	Hydrogen production is considered.		
K 2.17 Effect of hydrogen on corrosion		Not considered since the effects are difficult to quantify and judged to be small compared to other uncertainties.	
K 2.18 Corrosion products (physical effects)	Passivation is considered.		
M 3.2.01 Metallic corrosion	All aspects mentioned in the FEP are addressed.		
S 010 Colloids/particles in canister		Not addressed here, but in WM13 Colloid formation and transport.	
S 029 Electrochemical effects/gradients		Not considered since the effects are difficult to quantify and judged to be small compared to other uncertainties.	

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
S 074 Redox front	Redox conditions are addressed.	The front is not discussed; the processes are not described on that detailed level.	
S 100 Volume increase of corrosion products	Corrosion products with higher molar volume are considered.		
W 2.049 Gases from metal corrosion	Hydrogen production is considered.		
W 2.050 Galvanic coupling		The effect of the Fenno-Skan cable is mentioned.	
W 2.051 Chemical effects of corrosion	All aspects mentioned in the FEP are addressed.		
W 2.064 Effect of metal corrosion	The effect on redox conditions is addressed.		
W 2.095 Galvanic coupling		The effect of the Fenno-Skan cable is mentioned.	
W 2.096 Electrophoresis		Not considered since the effects are difficult to quantify and judged to be small compared to other uncertainties.	
Recorded by: Maria Lindgren			**Date:** March 2012
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Revisions approved: Not applicable			**Date:**

Table A4-19. SR-PSU FEP WM19 Gas formation and transport.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.35 Formation of gases	Formation of gas due to corrosion and radiolysis is considered.		
E SFR-11 Gas generation in the repository	Formation of gases due to corrosion, microbial activity and radiolysis is considered.		
H 1.2.1 Hydrogen by metal corrosion	Hydrogen formation due to metal corrosion is considered.	Effect of corrosion-derived hydrogen on the growth of microbes on concrete is not addressed here, but in WM17 Microbial processes.	
H 1.2.8 Thermo-chemical effects		Build–up of gas pressure followed by increase of temperature due to thermal isolation inside the waste packages is not addressed since heat arising from decay, attenuation, etc is judged negligible in SFR.	
J 1.2.02 Hydrogen/oxygen explosions		Not addressed since the probability for obtaining an explosive composition of gaseous oxygen and hydrogen inside the waste form after repository closure is assessed as negligibly low.	
J 1.2.04 Gas generation	Gas formation is considered.		The NEA FEP relates to spent fuel.
K 2.16 Hydrogen production	Formation of gas due to corrosion is considered.		
M 3.2.05 Cellulosis degradation	Formation of gases due to microbial degradation of cellulose is considered.		
Recorded by: Maria Lindgren			**Date:** March 2012
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Table A4-20. SR-PSU FEP WM20 Speciation of radionuclides.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.14 Complexation by organics	Influence of organic complexing agents is addressed.	Humates and fulvates not mentioned explicitly.	
A 1.37 Geochemical pump		Reprecipitation of dissolved radionuclides is not addressed since solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	
A 1.77 Speciation		Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	
E GEN-27 Radionuclide precipitation and dissolution		Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	
E SFR-20 Groundwater chemistry in the near-field	The speciation of redox-sensitive radionuclides considering alterations in water chemistry. Furthermore, speciation is indirectly accounted for in the selection of K_d values.	Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	See also WM21.
H 1.1.3 Waste corrosion and solubility and speciation of radionuclides	The speciation of redox-sensitive radionuclides considering alterations in water chemistry. Furthermore, speciation is indirectly accounted for in the selection of K_d values.	Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	Se also WM12
H 1.5.5 Transport of chemically-active substances into the near-field	All relevant aspects are addressed.		See also WM12, 13, 15 and 17.
H 5.1.3 Incomplete near-field chemical conditioning	All relevant aspects are addressed.		The consequences of incomplete chemical conditioning are treated as an explicit scenario.
I 044 Chealting agents	Influence of organic complexing agents is addressed.		
I 065 Waste container (metal corrosion products)	Impact of metal corrosion on redox potential and speciation is addressed.		See also WM18.
I 233 Source term & solubility limits	The speciation of redox-sensitive radionuclides considering alterations in water chemistry. Furthermore, speciation is indirectly accounted for in the selection of K_d values.	Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	
I 300 Termperature effects (on transport)		Temperature effects on speciation are not addressed because of the largely isothermal conditions expected at SFR.	
J 4.1.09 Complexing agents	Influence of complexing agents is addressed.	Humates and fulvates not mentioned explicitly.	
J 5.04 Decontamination materials left	Decontamination materials are part of the waste and influence of complexing agents is addressed.		
J 5.44 Solubility and precipitation	Impact of aqueous phase composition on speciation is addressed.	Temperature effects on speciation are not addressed because of the largely isothermal conditions expected at SFR.	
K 2.15 Radionuclide sorption and co-precipitation		Sorption onto corrosion products is not addressed here, but in WM12 Sorption/uptake.	Sorption on and co-precipitation with corrosion products are neglected in SFR.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
M 1.6.06 Solubility limit	The speciation of redox-sensitive radionuclides considering alterations in water chemistry. Furthermore, speciation is indirectly accounted for in the selection of K_d values.	Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	
M 1.6.08 Dissolution, precipitation and cristallization	The speciation of redox-sensitive radionuclides considering alterations in water chemistry. Furthermore, speciation is indirectly accounted for in the selection of K_d values.	Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	It is here presumed that this NEA FEP relates to radionuclides.
M 3.2.06 Introduced complexing agents and cellulosis	Influence of complexing agents is discussed.	Bitumen degradation products are not discussed. Bitumen is considered to be chemically stable under the conditions prevailing in SFR.	
S 051 Interaction with corrosion products		Sorption onto corrosion products is not addressed here, but in WM12 Sorption/uptake.	Sorption on and co-precipitation with corrosion products are neglected in SFR.
S 060 Precipitation/dissolution	The speciation of redox-sensitive radionuclides considering alterations in water chemistry. Furthermore, speciation is indirectly accounted for in the selection of K_d values.	Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	.
W 2.056 Speciation	The speciation of redox-sensitive radionuclides considering alterations in water chemistry. Furthermore, speciation is indirectly accounted for in the selection of K_d values.	Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	
W 2.057 Kinetics of speciation	Kinetics of chemical reactions is addressed.		
W 2.066 Reduction-oxidation kinetics	Kinetic constraints in the speciation of redox-sensitive radionuclides are considered.		
W 2.068 Organic complexation	Influence of organic complexing agents is addressed.	Humin, humic, and fulvic acids are not specifically mentioned because solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	Effects on sorption are addressed in WM12.
W 2.069 Organic ligands	See NEA FEP W 2.068	See NEA FEP W 2.068	See NEA FEP W 2.068
W 2.071 Kinetics of organic complexation		Limitation in organic complexation due to kinetics is not addressed. All complexes are considered to be in thermodynamic equilibrium.	

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Table A4-21. SR-PSU FEP WM21 Transport of radionuclides in the water phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.37 Geochemical pump		Re-precipitation of dissolved radionuclides is not addressed since solubility limiting thermodynamics are not accounted for as a retardation mechanism.	See WM20.
A 1.65 Radioactive decay	Radioactive decay, including ingrowth, is addressed.		
E GEN-10 Radionuclide dispersion	Generally treated.		See WM10.
E GEN-13 Electrochemical effects		Transport due to the presence of an electrical field is expected to be negligible in comparison with transport by advection and diffusion.	The same conclusion as in the NEA FEP.
E GEN-28 Radioactive decay	Radioactive decay, including ingrowth, is addressed.		
E SFR-15 Radionuclide release from the waste	All aspects are addressed in this process and in WM21.		See also WM21.
E SFR-22 Changes in the radionuclide inventory	Radioactive decay and radionuclide transport.		
H 5.1.3 Incomplete near-field chemical conditioning		Treated in other SR-PSU FEPs for example WM14 Dissolution, precipitation and recrystallisation, WM18 Metal corrosion, WM20 Speciation of radionuclides.	
I 044 Chealting agents		Impact of complexing agents is addressed in SR-PSU FEP WM12 Sorption/uptake.	
J 2.1.02 Coupled effects (electrophoresis)		Transport due to the presence of an electrical field is expected to be negligible in comparison with transport by advection and diffusion.	
J 2.1.06.2 Natural telluric electrochemical reactions		Transport due to the presence of an electrical field is expected to be negligible in comparison with transport by advection and diffusion.	
J 4.1.09 Complexing agents		Impact of complexing agents is addressed in SR-PSU FEP WM12 Sorption/uptake.	
M 1.6.10 Complexing agents		Impact of complexing agents is addressed in SR-PSU FEP WM12 Sorption/uptake.	
S 061 Preferential pathways in canister		Handled by choosing suitable values of hydraulic conductivity and diffusivity in the modelling of e.g. water flow, concrete degradation and radionuclide transport.	FEP relates to spent fuel canisters.
S 070 Radioactive decay of mobile nuclides	Radioactive decay is considered.	Radiation effects on the water chemistry and properties of the barriers are not addressed because of the low radiation from low- and intermediate level waste.	
S 097 Transport and release of nuclides, failed canister	Most aspects are addressed.	For example, transport induced by electrochemical gradients is not treated because it is expected to be negligible in comparison with advection and diffusion.	This is a general FEP and all aspects are covered by other FEPs.

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Table A4-22. SR-PSU FEP WM22 Transport of radionuclides in the gas phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.65 Radioactive decay	Half-lives of gaseous radionuclides as well as the decay chain for Rn-222 are considered.		
E GEN-28 Radioactive decay	Half-lives of gaseous radionuclides as well as the decay chain for Rn-222 are considered.		
E SFR-15 Radionuclide release from the waste	Gas phase formation and release are considered.		
E SFR-22 Changes in the radionuclide inventory	Changes in inventory of H-3 and Rn-222 are addressed.		See also WM01.
H 1.2.4 Radioactive gases	Gaseous C-14 and tritium as well as other potential radioactive gases are addressed.		
I 127 Gas absorption (^{14}C in CO_2) into concrete walls	CO_2-carbonation by cementitious materials is addressed.		
K 0.3 Gaseous and volatile isotopes	C-14, H-3 and Rn-222 are considered, I-129 mentioned.	Kr-isotopes and Se are not addressed because Kr is not part of the inventory and all found references treating volatile Se relates to other environments than that for long-term disposal of low- and intermediate level waste.	
S 097 Transport and release of nuclides, failed canister	Transport of radionuclides in gas phase is addressed, but neglected in the radionuclide transport calculations.		
W 2.055 Radioactive gases	Radioactive gases carbon dioxide (CO_2) and methane (CH_4) containing C-14, and radon (Rn) are addressed.	Aspects of MgO backfill that will lead to incorporation of carbon dioxide in solid $MgCO_3$ is not relevant for SFR since no MgO backfill will be used.	
W 2.089 Transport of radioactive gases	Transport of radionuclides in gas phase is addressed, but neglected in the radionuclide transport calculations.		

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Revisions approved: Maria Lindgren	**Date:** March 2014

Appendix 5

Handling of NEA Project FEPs sorted to SR-PSU Packaging processes

SR-PSU FEP Pa01 Heat transport

No NEA FEPs associated with this SR-PSU FEP.

Table A5-1. SR-PSU FEP Pa02 Phase changes/freezing.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 268 Freeze/thaw cycles	Structural damage of concrete due to periglacial freezing is addressed.	The IRUS repository referred to in the FEP is a near-surface (unsaturated conditions above the groundwater table) facility in Canada exposed to cyclic events of freezing/thawing, whereby the construction is specifically designed to be resistant to such frequent cycles. The SFR repository is placed sufficiently deep to avoid frequent freezing/thawing cycles and any engineering measures to avoid freezing damage are not taken. Structural deterioration due to conditions expected under future periglacial permafrost is addressed, although not specifically due to such frequent cyclic events as those referred to in the FEP.	
J 5.17 Permafrost	Structural deterioration of waste packages as a consequence of freezing under expected periglacial permafrost conditions is addressed.		
S 059 Permafrost	The occurrence and effects of periglacial permafrost on the waste packages is addressed.		

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Table A5-2. SR-PSU FEP Pa03 Water uptake and transport during unsaturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.68 Reflooding	Effect on temperature is addressed, but assumed negligible. Pressure build-up during resaturation is addressed.	Possible consequences of pressure build-up on components in the waste form and packaging, e.g. cracking, is not mentioned here, but addressed in WM09 Fracturing and Pa05 Fracturing/ deformation.	
A 1.84 Transport in gases or of gases	All relevant aspects are addressed.		
A 1.88 Unsaturated transport	Unsaturated transport is addressed, although the time to reach full saturation is judged to be relatively short (a few years for BMA, BLA and BTF, and 25-100 years for the Silo).		
E SFR-16 Hydraulic resaturation of the near-field		From FEP: “heterogeneous resaturation will induce complex stress fields in the near-field rock and the engineered barriers (see GEN-36 “Stress field”)”. This is not addressed since FEP concerns the waste packaging.	See also NEA FEP A.1.68 above.
H 1.5.3 Unsaturated flow due to gas production	All relevant aspects are addressed.		
J 5.14 Resaturation	All relevant aspects are addressed.		
Recorded by: Magnus Sidborn			**Date:** 2012-10-01
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Revisions approved by: Not applicable			**Date:**

Table A5-3. SR-PSU FEP Pa04 Water transport under saturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.40 Hydraulic conductivity	All relevant aspects are addressed.		
A 1.41 Hydraulic head	All relevant aspects are addressed.		
E SFR-21 Groundwater movement in the near-field		The effect of gas generation and transport on water transport is not considered here as this issue is addressed in WM07 and Pa03 Water uptake and transport during unsaturated conditions.	
H 1.5.4 Saturated groundwater flow	All relevant aspects are addressed.		
Recorded by: Magnus Sidborn			**Date:** 2012-10-03
Checked and revised by: Kristina Skagius			**Date:** February 2014
Revisions approved by: Magnus Sidborn			**Date:** March 2014

Table A5-4. SR-PSU FEP Pa05 Fracturing/deformation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.18 Container failure (long-term)		Failure mechanisms are not addressed since they are not relevant to mechanical failure of the packaging in SFR.	The NEA FEP concerns titanium containers.
A 1.19 Container failure (mechanical processes)		Damage due to hydrostatic pressure or bentonite swelling are not addressed since they are not relevant to mechanical failure of the packaging in SFR.	The NEA FEP concerns titanium containers.
E SFR-13 Mechanical impact on the engineered barriers	Internal and external loads causing mechanical impact and potential fracturing/deformation.		The NEA FEP states that the SFR rock vaults do not have any mechanical barriers which is not true.
I 161 Incomplete filling of containers		Degree of filling not addressed. SKB applies filling rules related to mechanical strength. Furthermore, the packaging is not considered to have any mechanical safety function.	
J 2.3.07.1 External stress	External load from e.g. rock fallout on waste containers is identified as a potential cause for fracturing.		See also WM09. Packaging in i.e. BLA is not regarded to have any mechanical safety function.
J 3.2.07 Swelling of corrosion products	Formation of corrosion products with higher molecular volume than starting material is identified as a potential cause for fracturing.	Effects on a copper canister and a surrounding bentonite buffer, because they are not relevant for waste in SFR.	
M 3.1.02 Non-elastic reponse	Mechanisms leading to fracturing are addressed.		
M 3.3.04 Subsidence/collapse	External load from e.g. rock fallout on waste containers is identified as a potential cause for fracturing.	Total collapse of the waste vaults is not addressed because the process description is restricted to the packaging.	See also BMABa06, BTFBa06, SiBa07 and BLABa06. Packaging in SFR is not regarded to have any mechanical safety function.
S 004 Cave in	External load from e.g. rock fallout on waste containers is identified as a potential cause for fracturing.	Impact of cave in on other barriers than waste packages is not addressed here.	See also BMABa06, BTFBa06, SiBa07 and BLABa06.
S 055 Mechanical impact on canister	Internal and external loads causing mechanical impact and potential fracturing.	Effects of mechanical impact specific for a copper canister with spent fuel.	The NEA FEP concerns spent fuel in a copper canister. Packaging in SFR is not regarded to have any mechanical safety function.
S 100 Volume increase of corrosion products	Formation of corrosion products with higher molecular volume than starting material is identified as a potential cause for fracturing.	Effects on a copper canister and a surrounding bentonite buffer, because they are not relevant for waste packages in SFR.	See also Pa12 Metal corrosion.
W 2.022 Roof falls	External load from e.g. rock fallout on waste containers is identified as a potential cause for fracturing.	Impact of rock fallout on fractures in the surrounding rock is not addressed here, but in Ge07 Fracturing.	

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Table A5-5. SR-PSU FEP Pa06 Advective transport of dissolved species.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E GEN-10 Radionuclide dispersion	All relevant aspects are addressed.	Aspects of dispersion relevant for field scale only, i.e. dispersive effects due to large-scale geological structures is deemed to be superfluous for this description and is not addressed.	See Ge10 Advective transport/mixing of dissolved species.

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Table A5-6. SR-PSU FEP Pa07 Diffusive transport of dissolved species.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.27 Diffusion	Contaminant movement will occur due to diffusion through the water and sealing materials. Diffusion is temperature dependent. Surface effects may be very important in clays.		
A 1.36 Galvanic coupling		Enhanced movement of contaminants due to galvanic coupling with a far ore body is not considered due to the presence of other electrical currents that are deemed to be more significant (arising from e.g. crevice corrosion of steel packaging). Furthermore, galvanic coupling within the repository caverns is neglected on the basis of low consequence to the performance of the disposal system.	
E GEN-09 Diffusion	The issue of quantifying repository-relevant diffusion coefficients for the chemical species of interest is discussed. The influence of porosity, tortuosity and constrictivity on the diffusion coefficients is discussed as well as the influence of temperature, ion–ion and ion–surface interaction effects. Effects due to the electrical double-layer adjacent to mineral surfaces (anion exclusion and enhanced cation diffusion) are considered and their influence by the ionic strength of the porewater is discussed.		
E SFR-09 Diffusion in the near-field	Diffusion in the near-field may occur through water-filled cracks and voids in the mass of the concrete packaging. Diffusion will be an important process controlling porewater chemistry in the near field and the radionuclide release rate to the far-field. Interactions with the porewater's thermal expansion may lead to cracks and fractures that will enhance diffusive transport rates.		
J 3.2.06 Diffusion - surface diffusion	Enhanced cation diffusion and anion exclusion are considered as effects of the presence of an electrical double-layer adjacent to mineral surfaces.		
S 002 Anion-exclusion	Enhanced cation diffusion and anion exclusion are considered as effects of the presence of an electrical double-layer adjacent to mineral surfaces.		
S 024 Diffusion in and through failed canister	Addressed.		
W 2.095 Galvanic coupling		Galvanic coupling within the waste vaults is neglected on the basis of low consequence to the performance of the disposal system.	
W 2.096 Electrophoresis		Because the electrochemical cells that may be established are small, the effect of such cells on the migration of contaminants (for example, by electrophoresis) has also been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.	See also Ge21.

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Table A5-7. SR-PSU FEP Pa08 Sorption/uptake.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.73 Sorption	Partitioning of contaminants in water onto substrates, since various sorption/uptake mechanisms are addressed.	Sorption in buffer and backfill not addressed here, but sorption on barrier materials in SFR is addressed in BMABa09, BMABa10, BTFBa09, SiBa10, BRTBa09 and BLABa09.	See WM12.
A 1.74 Sorption - nonlinear	Taken care of by the description of influence of complexing agents that influence solubility and ability to sorb upon the concrete. For carbonate the precipitation is discussed.	Solubility effects for most of the elements are not discussed, because a vast majority of the RN is present below solubility limits. This however does not take into account stable isotopes of the elements.	See WM12.
E GEN-34 Radionuclide sorption	Sorption/uptake mechanisms addressed and sorption/uptake of radionuclides on cement considered in the analysis. Sorption of ISA is considered in terms of reducing aqueous concentration.	Sorption of molecules, sorption of ions other than radionuclides and ISA and sorption of colloids is not specifically addressed. Attachment of colloids to material surfaces is addressed in Pa09 (and WM13).	See WM12.
J 3.1.02 Saturation of sorption sites	The availability of sorption sites for different materials is addressed.	Saturation of sorption sites is not specifically considered, because there will be enough cement material to provide sorption sites.	See WM12.
J 4.1.04 Sorption	Sorption/uptake mechanisms addressed and sorption/uptake of radionuclides on cement considered in the analysis. Sorption of ISA is considered in terms of reducing aqueous concentration.	Sorption of molecules, sorption of ions other than radionuclides and ISA and sorption of colloids is not specifically addressed. Attachment of colloids to material surfaces is addressed in Pa09 (and WM13).	See WM12.
S 084 Sorption	Non linear effects and isotopic dilution considered for C-14.	Saturation of sorption sites is not specifically considered, because there will be enough cement material in the cement waste forms to provide sorption sites.	See WM12.
W 2.061 Actinide sorption	Sorption/uptake mechanisms addressed and sorption/uptake of radionuclides on cement considered in the analysis.		See WM12.
W 2.062 Kinetics of sorption	Sorption/uptake kinetics is addressed.		See WM12.

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Table A5-8. SR-PSU FEP Pa09 Colloid transport and filtering.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.63 Psuedo-colloids	Generation of colloids (eigen-colloids) or pseudo-colloids (naturally-occuring particu-lates) as a result of changes in the vault environment caused by chemical processes, bio-logical processes, and physical agitation are addressed.		Note: In the FEPs *colloids* refer to aggregates of the radionuclide (or contaminant) itself and *pseudo-colloids* refer to naturally occurring colloidal material already present in the groundwater onto which radionuclides may sorb. In the Process Descrip-tion these are referred to as *eigencolloids* and *colloids* respectively.
E SFR-01 Colloid generation in the waste package	Aspects relevant to the waste form are addressed.	Colloid formation due to precipitation of dissolved species (e.g. silica) at the alkaline front (where pH drops) at some distance downstream the repository is not relevant for the waste packages and is therefore not addressed here.	See WM13.
I 058 Colloid formation (natural and vault generated)		A general description of the influence on colloid stability by the prevailing redox-conditions is not addressed, except for the possible formation of iron-oxyhydroxide colloids under oxidising conditions.	
Recorded by: Magnus Sidborn			**Date:** June 2012
Checked and revised by: Kristina Skagius			**Date:** February 2014
Revisions approved by: Not applicable			**Date:**

Table A5-9. SR-PSU FEP Pa10 Dissolution, precipitation and recrystallisation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.13 Colloids	Relevant aspects are mentioned with reference to the processes Colloid formation and transport (WM13) and Colloid transport and filtering (Pa09).		
A 1.62 Precipitation and dissolution	All relevant aspects are addressed.		
A 1.77 Speciation	All relevant aspects are addressed.		
E SFR-01 Colloid generation in the waste package	Relevant aspects are mentioned with reference to the processes Colloid formation and transport (WM13) and Colloid transport and filtering (Pa09).		
E SFR-05 Degradation of the concrete packages and the cement matrix	All relevant aspects are addressed.		
H 1.1.2 Physico-chemical degradation of concrete	All relevant aspects are addressed.		
I 058 Colloid formation (natural and vault generated)	Relevant aspects are mentioned with reference to the processes Colloid formation and transport (WM13) and Colloid transport and filtering (Pa09).		
I 061 Concrete (influence on vault chemistry)	All relevant aspects are addressed.		
J 1.2.07 Recrystallization	All relevant aspects are addressed.		
J 3.1.07 Reactions with cement pore water	All relevant aspects are addressed.		
M 3.2.02 Interactions of host materials and ground water with repository materials	All relevant aspects are addressed.		
W 2.060 Kinetics of precipitation and dissolution	All relevant aspects are addressed.		
W 2.073 Concrete hydration	All relevant aspects are addressed.		
Recorded by: Magnus Sidborn			**Date:** October 2012
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Table A5-10. SR-PSU FEP Pa11 Microbial processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.03 Biological activity	All relevant aspects are addressed.		See WM17.
A 1.53 Methylation	Methylation is addressed.		See WM17.
E SFL-32 Microbial activity	All relevant aspects are addressed.		See WM17.
E SFR-01 Colloid generation in the waste package		Impact of microbial processes on colloids is not addressed here, but in WM13 Colloid formation and transport.	See WM17.
E SFR-11 Gas generation in the repository	Gas generation by microbial processes is addressed.		See WM17. See also WM19 and Pa13 Gas formation and transport.
H 1.2.1 Hydrogen by metal corrosion	Production of hydrogen by corrosion of metals including the effect of corrosion-derived hydrogen on the growth of microbes on concrete.		See WM17. See also WM18 and Pa12 Metal corrosion and WM19 and Pa13 Gas formation and transport.
H 1.2.3 Gas generation from concrete		Gas generation from microbial growth on concrete is not addressed because it is negligible compared with gas generation from corrosion.	
I 012 Biological activity (bacteria & microbes)	Biological activity and impact on chemical environment in the vault and other processes influenced by the chemical environment are addressed.		See WM17
I 015 Gas generation (CH_4, CO_2, H_2)	Formation of CH_4, CO_2, and H_2 through biological degradation of organic material and impact on vault chemistry are addressed.	Gas generation by metal corrosion and impact of gas generation and transport on contaminant transport are not specifically addressed here, but in WM18 and Pa12 Metal corrosion, WM19 and Pa13 Gas formation and transport, and WM22 and Pa16 Transport of radionuclides in the gas phase.	See WM17
J 2.1.10 Microbes	Pre-requisites for microbial activity, types of microbes, their impact on the environment and other processes influenced by the chemical environment are addressed. This includes the formation of complexing agents and various kinds of chelating compounds.	Impact of microbial processes on colloids is not addressed here, but in WM13 Colloid formation and transport.	See WM17
K 3.17 Microbial activity	Microbiological activity and growth, and associated production of organic complexants are addressed.	Impact of complexing agents on radionuclide mobility is not specifically addressed here, but in e.g. WM 12 (and Pa08) Sorption/uptake and WM20 (and Pa14) Speciation of radionuclides.	See WM17
M 3.2.07 Microbiological effects	Impact of bacteria on the degradation of metals, concrete and bitumen is addressed.	Impact on degradation of glass is not mentioned, since this relates to vitrified waste which is not relevant for SFR.	See WM17
S 057 Microbial activity	Pre-requisites for microbial activity, types of microbes, their impact on the environment and other processes influenced by the chemical environment are addressed. This includes the formation of complexing agents and various kinds of chelating compounds.	Impact of microbial processes on colloids is not addressed here, but in WM13 Colloid formation and transport.	See WM17

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
W 2.044 Degradation of organic material	Gas generation from microbial degradation of organic materials is addressed.	Gas generation from corrosion and radiolysis is not addressed here, but in e.g. WM19 and Pa13 Gas formation and transport.	See WM17
W 2.045 Effect of temperature on microbial gas generation	Impact of temperature on microbial processes is addressed.	Heat generation due to radioactive decay, concrete hydration and aluminium corrosion is not addressed here, but in other process descriptions (WM01, WM14, WM18).	See WM17. Heat arising from decay, attenuation, etc is judged negligible in SFR.
W 2.046 Effect of pressure on microbial gas generation		Effect of pressure on microbial gas generation is not specifically addressed here. However, gas generation by microbial activity is negligible compared with gas generation from metal corrosion.	See WM17.
W 2.048 Effect of biofilms on microbial gas generation	The formation of biofilms is addressed.	The effects of biofilms on microbial gas generation and control of microbial population size and effects on radionuclide transport are not specifically addressed. However, biofilms are not expected to be extensive since hyperalkaline conditions will limit microbial activities.	See WM17.
W 2.076 Microbial growth on concrete	Microbial degradation of concrete is addressed.		See WM17.
W 2.088 Biofilms	The formation of biofilms is addressed.	The effects of biofilms on radionuclide transport are not specifically addressed. However, biofilms are not expected to be extensive since hyperalkaline conditions will limit microbial activities.	See WM17.

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Table A5-11. SR-PSU FEP Pa12 Metal corrosion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.16 Container corrosion products	All relevant aspects for the packaging used in SFR are addressed.	Influence on sorption treated in the Sorption process.	
A 1.18 Container failure (long-term)	All relevant aspects for the packaging used in SFR are addressed.	Corrosion is not as important for a low and intermediate level waste repository as for a high level waste repository and hence not treated in detail.	This NEA FEP concerns spent fuel in containers that shall provide containment of the spent fuel for a very long time period, contradictory to SFR where metal corrosion mainly is an issue for gas formation and mechanical stability.
A 1.21 Containers - partial corrosion	See NEA FEP A 1.18.	See NEA FEP A 1.18.	See NEA FEP A 1.18.
A 1.24 Corrosion	See NEA FEP A 1.18.	See NEA FEP A 1.18.	See NEA FEP A 1.18.
A 1.30 Electrochemical gradients		See NEA FEP A 1.18.	See NEA FEP A 1.18.
A 1.60 Pitting	Mentioned for the corresponding waste form processes to which it is generally referred.		
A 1.86 Uniform corrosion		See NEA FEP A 1.18.	See NEA FEP A 1.18.
E GEN-13 Electrochemical effects		See NEA FEP A 1.18.	See NEA FEP A 1.18.
E SFR-01 Colloid generation in the waste package			Corrosion is not mentioned in this NEA FEP.
E SFR-11 Gas generation in the repository	Hydrogen generation is addressed.		See also Pa13 Gas formation and transport.
H 1.1.1 Container metal corrosion	All relevant aspects are addressed.		
H 1.1.4 Electrochemical effects of metal corrosion		See NEA FEP A 1.18.	See NEA FEP A 1.18.
H 1.2.1 Hydrogen by metal corrosion	Hydrogen generation is addressed.		See also Pa13 Gas formation and transport.
I 015 Gas generation (CH_4, CO_2, H_2)	Hydrogen generation is addressed.	CH_4 and CO_2 are produced due to biological activity.	See also Pa13 Gas formation and transport.
I 062e Concrete (rebar corrosion)	All relevant aspects are addressed.		
I 065 Waste container (metal corrosion products)	Influences on water composition are considered.	Influence on sorption treated in the Sorption process Pa08.	
I 066 Waste container (corrosion/collapse)	Waste container corrosion is addressed.	Container collapse is not specifically addressed because the waste containers in SFR are not considered to have any safety function.	
I 071 Corrosive chemicals (in vault)	Influences of water composition are considered.	Corrosive chemicals are not specifically addressed since the effects are difficult to quantify and judged to be small compared to other uncertainties.	
I 126 Corrosion (galvanic coupling)		See NEA FEP A 1.18.	See NEA FEP A 1.18.
J 1.2.08 Redox potential	Influence on/of redox potential is addressed.		
J 2.1.06.2 Natural telluric electrochemical reactions		See NEA FEP A 1.18.	See NEA FEP A 1.18.
J 2.1.07 Pitting	Addressed in the corresponding waste form process to which the packaging description is generally referring.	See NEA FEP A 1.18.	See NEA FEP A 1.18.
J 3.2.07 Swelling of corrosion products	Corrosion products with higher molar volume are addressed.		
K 2.03 Corrosion on wetting	Corrosion in the presence of water is addressed.		See NEA FEP A 1.18.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
K 2.04 Oxic corrosion	Addressed in the corresponding waste form process to which the packaging description is generally referring.		See WM18.
K 2.05 Microbially-mediated corrosion	Addressed in the corresponding waste form process to which the packaging description is generally referring.		See WM18.
K 2.06 Anoxic corrosion	Addressed in the corresponding waste form process to which the packaging description is generally referring.		See WM18.
K 2.07 Localised corrosion	Addressed in the corresponding waste form process to which the packaging description is generally referring.		See WM18.
K 2.09 Stress corrosion cracking		See NEA FEP A 1.18.	See NEA FEP A 1.18.
K 2.14 Chemical buffering (canister corrosion products)		See NEA FEP A 1.18.	See NEA FEP A 1.18.
K 2.16 Hydrogen production	Hydrogen production addressed here but also in Pa13 Gas formation and transport.		
K 2.17 Effect of hydrogen on corrosion	Corrosion and hydrogen production addressed here but also in Pa13 Gas formation and transport.		
K 2.18 Corrosion products (physical effects)	Addressed in the corresponding waste form process to which the packaging description is generally referring.		
M 3.2.01 Metallic corrosion		See NEA FEP A 1.18.	See NEA FEP A 1.18.
S 029 Electrochemical effects/gradients		Not considered since the effects are difficult to quantify and judged to be small compared to other uncertainties.	
S 074 Redox front	Addressed in the corresponding waste form process to which the packaging description is generally referring.		
S 100 Volume increase of corrosion products	Addressed here but also in Pa13 Gas formation and transport.		
W 2.049 Gases from metal corrosion	Addressed here but also in Pa13 Gas formation and transport.		
W 2.050 Galvanic coupling		See NEA FEP A 1.18.	See NEA FEP A 1.18.
W 2.051 Chemical effects of corrosion	Addressed in the corresponding waste form process to which the packaging description is generally referring.		
W 2.064 Effect of metal corrosion	Addressed in the corresponding waste form process to which the packaging description is generally referring.		
W 2.095 Galvanic coupling		See NEA FEP A 1.18.	See NEA FEP A 1.18.
W 2.096 Electrophoresis		See NEA FEP A 1.18.	See NEA FEP A 1.18.
Recorded by: Maria Lindgren			**Date: October 2012**
Checked and revised by: Kristina Skagius			**Date: 2014-03-06**
Revisions approved by: Maria Lindgren			**Date: March 2014**

Table A5-12. SR-PSU FEP Pa13 Gas formation and transport.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.35 Formation of gases	Formation of gas due to corrosion considered.		
A 1.84 Transport in gases or of gases	Gas transport included.		See also Pa03.
E SFR-11 Gas generation in the repository	Formation of gas due to corrosion considered.		
E SFR-12 Gas flow in the near-field	All aspects relevant for this SR-PSU FEP are addressed.		This NEA FEP relates also to several other SR-PSU FEPs.
H 1.2.1 Hydrogen by metal corrosion	Hydrogen formation due to metal corrosion considered.	Evolved hydrogen may inhibit microbial activity.	See also WM18 Microbial processes.
H 1.2.6 Gas transport	Gas transport addressed.	Gas transport in far-field is not addressed because it is not part of this system component.	
H 1.2.8 Thermo-chemical effects		Build–up of gas pressure followed by increase of temperature due to thermal isolation inside the waste packages are not addressed since heat arising from decay, attenuation, etc is judged negligible in SFR.	
H 1.5.3 Unsaturated flow due to gas production	Gas production is addressed.	Aspects not treated or generally treated in this SR-PSU FEP are treated in Pa03.	
J 1.2.02 Hydrogen/oxygen explosions		Not addressed since the probability for obtaining an explosive composition of gaseous oxygen and hydrogen inside the waste packages after repository closure is assessed as negligibly low.	
J 1.2.04 Gas generation	Formation of gas due to corrosion considered.		
K 2.16 Hydrogen production	Formation of gas due to corrosion considered.		
M 3.3.06 Gas effects	All aspects relevant for this SR-PSU FEP are addressed.	Explosions and fires. The probability is, as in the NEA FEP, assumed to be extremely low during the post-operational period because of the reducing conditions which prevail in the near field.	This NEA FEP relates also to other system components.

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Table A5-13. SR-PSU FEP Pa14 Speciation of radionuclides.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.14 Complexation by organics	Influence of organic complexing agents is addressed.	Humates and fulvates not mentioned explicitly.	See WM20.
A 1.37 Geochemical pump		Reprecipitation of dissolved radionuclides is not addressed since solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	See WM20.
A 1.77 Speciation		Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	See WM20.
E GEN-27 Radionuclide precipitation and dissolution		Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	See WM20.
E SFR-20 Groundwater chemistry in the near-field	The speciation of redox-sensitive radionuclides considering alterations in water chemistry. Furthermore, speciation is indirectly accounted for in the selection of K_d values.	Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	See WM20.
H 1.5.5 Transport of chemically-active substances into the near-field	All relevant aspects are addressed.		See WM20.
H 5.1.3 Incomplete near-field chemical conditioning	All relevant aspects are addressed.		See WM20. The consequences of incomplete chemical conditioning are treated as an explicit scenario.
I 044 Chealting agents	Influence of organic complexing agents is addressed.		See WM20
J 4.1.09 Complexing agents	Influence of complexing agents is addressed.	Humates and fulvates not mentioned explicitly.	See WM20
J 5.44 Solubility and precipitation	Impact of aqueous phase composition on speciation is addressed.	Temperature effects on speciation are not addressed because of the largely isothermal conditions expected at SFR.	See WM20
K 2.15 Radionuclide sorption and co-precipitation		Sorption onto corrosion products is not addressed here, but in Pa08 (and WM12) Sorption/uptake.	See WM20 Sorption on and co-precipitation with corrosion products are neglected in SFR.
M 1.6.08 Dissolution, precipitation and cristallization	The speciation of redox-sensitive radionuclides considering alterations in water chemistry. Furthermore, speciation is indirectly accounted for in the selection of K_d values.	Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	See WM20 It is here presumed that this NEA FEP relates to radionuclides.
S 060 Precipitation/dissolution	The speciation of redox-sensitive radionuclides considering alterations in water chemistry. Furthermore, speciation is indirectly accounted for in the selection of K_d values.	Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	See WM20
W 2.056 Speciation	The speciation of redox-sensitive radionuclides considering alterations in water chemistry. Furthermore, speciation is indirectly accounted for in the selection of K_d values.	Solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	See WM20
W 2.057 Kinetics of speciation	Kinetics of chemical reactions is addressed.		See WM20
W 2.068 Organic complexation	Influence of organic complexing agents is addressed.	Humin, humic, and fulvic acids are not specifically mentioned because solubility limiting thermodynamics are not accounted for as a retardation mechanism. This is explained in the process description.	See WM20 Effects on sorption are addressed in Pa08 (and WM12).
W 2.071 Kinetics of organic complexation		Limitation in organic complexation due to kinetics is not addressed. All complexes are considered to be in thermodynamic equilibrium.	See WM20

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Table A5-14. SR-PSU FEP Pa15 Transport of radionuclides in the water phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.37 Geochemical pump		Re-precipitation of dissolved radionuclides is not addressed since solubility limiting thermodynamics are not accounted for as a retardation mechanism.	See Pa14.
A 1.65 Radioactive decay	Radioactive decay, including ingrowth, is addressed.		
E GEN-10 Radionuclide dispersion	Generally treated.		See Pa06.
E GEN-13 Electrochemical effects		Transport due to the presence of an electrical field is expected to be negligible in comparison with transport by advection and diffusion.	The same conclusion as in the NEA FEP.
E GEN-28 Radioactive decay	Radioactive decay, including ingrowth, is addressed.		
E SFR-18 Radionuclide release from the waste	All aspects are treated in this process and in WM21.		
H 5.1.3 Incomplete near-field chemical conditioning		Treated in other SR-PSU FEPs for example WM14 Dissolution, precipitation and recrystallisation, WM18 Metal corrosion, WM20 Speciation of radionuclides.	
I 044 Chealting agents		Impact of complexing agents is addressed in SR-PSU FEP Pa08 and WM12 Sorption/uptake.	
J 2.1.02 Coupled effects (electrophoresis)		Transport due to the presence of an electrical field is expected to be negligible in comparison with transport by advection and diffusion.	
J 2.1.06.2 Natural telluric electrochemical reactions		Transport due to the presence of an electrical field is expected to be negligible in comparison with transport by advection and diffusion.	
J 4.1.09 Complexing agents		Impact of complexing agents is addressed in SR-PSU FEP Pa08 and WM12 Sorption/uptake.	
S 061 Preferential pathways in canister		Handled by choosing suitable values of hydraulic conductivity and diffusivity in the modelling of e.g. water flow, concrete degradation and radionuclide transport.	FEP relates to spent fuel canisters.
S 070 Radioactive decay of mobile nuclides	Radioactive decay is considered.	Radiation effects on the water chemistry and properties of the barriers are not addressed because of the low radiation from low- and intermediate level waste.	
S 097 Transport and release of nuclides, failed canister	Most aspects are addressed.	For example, transport induced by electrochemical gradients is not treated because it is expected to be negligible in comparison with advection and diffusion.	This is a general FEP and all aspects are covered by other FEPs.

Recorded by: Maria Lindgren	**Date:** October 2012
Checked and revised by: Kristina Skagius	**Date:** 2014-03-06
Revisions approved by: Maria Lindgren	**Date:** March 2014

Table A5-15. SR-PSU FEP Pa16 Transport of radionuclides in the gas phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.65 Radioactive decay	Half-lives of gaseous radionuclides as well as the decay chain for Rn-222 are considered.		
E GEN-28 Radioactive decay	Half-lives of gaseous radionuclides as well as the decay chain for Rn-222 are considered.		
E SFR-18 Radionuclide release from the waste	Transport of radionuclides in gas phase is addressed, but neglected in the radionuclide transport calculations.		This is a general FEP and all aspects have been covered by other FEPs.
I 127 Gas absorption (^{14}C in CO_2) into concrete walls	Addressed in the corresponding waste form process to which the packaging description is generally referring.		See WM22.
K 0.3 Gaseous and volatile isotopes	Addressed in the corresponding waste form process to which the packaging description is generally referring.	Kr-isotopes and Se are not addressed because Kr is not part of the inventory and all found references treating volatile Se relates to other environments than that for long-term disposal of low- and intermediate level waste.	See WM22.
S 097 Transport and release of nuclides, failed canister	Addressed in the corresponding waste form process to which the packaging description is generally referring.		See WM22.
W 2.055 Radioactive gases	Addressed in the corresponding waste form process to which the packaging description is generally referring.	Aspects of MgO backfill that will lead to incorporation of carbon dioxide in solid $MgCO_3$ is not relevant for SFR since no MgO backfill will be used.	See WM22.
W 2.089 Transport of radioactive gases	Transport of radionuclides in gas phase is addressed, but neglected in the radionuclide transport calculations.		

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Appendix 6

Handling of NEA Project FEPs sorted to SR-PSU BMA barrier processes

SR-PSU FEP BMABa01 Heat transport

No NEA FEP associated with this SR-PSU FEP.

Table A6-1. SR-PSU FEP BMABa02 Phase changes/freezing.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 268 Freeze/thaw cycles	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function.	Prior to permafrost, the concrete will not be exposed to freeze-thaw cycles due to the depth of SFR.	
J 5.17 Permafrost	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function.		
S 059 Permafrost	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function. Also, the changes in the hydrological situation are addressed.		

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Table A6-2. SR-PSU FEP BMABa03 Water uptake and transport during unsaturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.68 Reflooding	The special hydraulic conditions during resaturation are discussed.	Temperature, BMA wastes are not significantly heat-generating.	
A 1.84 Transport in gases or of gases	The presence and effect of gases on water flow are accounted for.	Gas transport is addressed in BMABa05.	This FEP refers to the buffer.
A 1.88 Unsaturated transport	The possibility of a prolonged unsaturated period is considered.		
E SFR-16 Hydraulic resaturation of the near-field	Resaturation and the influence of the gas phase are addressed.	The change in redox conditions is addressed in BMABa14 and BMABa15, concrete degradation in BMABa12 and influence of gas production in BMABa05. Thermal effects are not relevant to BMA.	
H 1.5.3 Unsaturated flow due to gas production		Unsaturated groundwater flow due to gas production is considered in SR-PSU FEP BMABa05.	
J 5.14 Resaturation	The special hydraulic conditions during resaturation are discussed.	The change in redox conditions is addressed in BMABa14 and BMABa15.	

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Table A6-3. SR-PSU FEP BMABa04 Water transport under saturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.01 Backfill characteristics	The properties of the backfill are addressed.		
A 1.40 Hydraulic conductivity		Variations in the hydraulic conductivity of the backfill are negligible in comparison with the difference between the concrete and backfill, while the barrier retains its function.	
A 1.41 Hydraulic head	Different hydraulic boundary conditions will be modelled.		
E SFR-21 Groundwater movement in the near-field	Different hydraulic boundary conditions will be modelled.	The influence of gas production, because fully saturated conditions are assumed.	Influence of gas on water transport is addressed in BMABa05.
H 1.5.4 Saturated groundwater flow	Saturated groundwater flow is addressed.		
J 3.2.09 Flow through buffer/backfill		Not addressed, this FEP relates to bentonite, which is not used in the BMA.	
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Table A6-4. SR-PSU FEP BMABa05 Gas transport/dissolution.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.84 Transport in gases or of gases	Transport of gases and the influence of gases on water transport are addressed.		
E SFR-12 Gas flow in the near-field	Gas flow and the consequences of the accumulation of gas pressure in the barriers are addressed.		
H 1.2.6 Gas transport	Gas movement through the barriers is addressed.		
H 1.2.8 Thermo-chemical effects	The effect of gas accumulation is addressed.	Thermal aspects are not considered, as the BMA waste is not heat generating.	
H 1.5.3 Unsaturated flow due to gas production	Unsaturated conditions arising from gas production are addressed.		
M 3.3.06 Gas effects	The effects of gas pressurization are addressed.	Effects on clay are not relevant to the BMA.	
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Table A6-5. SR-PSU FEP BMABa06 Mechanical processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.08 Cave ins	Fallout from the roof and walls of the rock vault is addressed.		
E GEN-03 Cave-in	Fallout from the roof and walls of the rock vault is addressed.		
E SFR-13 Mechanical impact on the engineered barriers	Mechanical impacts on the engineered barriers are addressed.	Fractures due to thermal effects in concrete are addressed in BMABa12.	
H 1.4.2 Vault collapse	Fallout from the roof and walls of the rock vault is addressed. Radionuclide transport is covered indirectly via changes to hydrological variables.		BMA will be backfilled with macadam, which reduces the impact of vault collapse.
J 2.3.07.1 External stress	Fallout from the roof and walls of the rock vault is addressed.	Damage to the waste packages, as falling rocks will hit the macadam backfill and, in any case, the waste packages are not considered to act as a barrier to radionuclide transport.	
J 3.2.07 Swelling of corrosion products	Stresses caused by the corrosion of steel reinforcement are mentioned.		
M 3.1.02 Non-elastic reponse		Not relevant to the BMA.	
M 3.3.04 Subsidence/collapse		Not relevant to BMA due to the macadam backfill used.	This FEP was rejected on the basis of the presence of backfill and appropriate QA.
S 004 Cave in	Fallout from the roof and walls of the rock vault is addressed.		
S 100 Volume increase of corrosion products		Relates specifically to the HLW repository design, not relevant for BMA.	
W 2.022 Roof falls	Fallout from the roof and walls of the rock vault is addressed.		
W 2.035 Mechanical effects of backfill	The mechanical properties of the backfill are mentioned.		

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Table A6-6. SR-PSU FEP BMABa07 Advection and dispersion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.28 Dispersion	Dispersion is addressed.		
E GEN-10 Radionuclide dispersion	Dispersion is addressed in general.	Radionuclide dispersion is addressed directly in BMABa18.	
J 3.2.08 Preferential pathways in the buffer/backfill	Preferential pathways in concrete due to fractures are discussed.		
J 4.1.08 Change of groundwater chemistry in nearby rock		This is handled in the geosphere process report.	See e.g. SR-PSU FEP Ge16.

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Table A6-7. SR-PSU FEP BMABa08 Diffusion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.27 Diffusion	Diffusion and its temperature dependence are addressed.	Surface effects in clays are not relevant for the BMA.	
A 1.36 Galvanic coupling	Electro-osmotic effects are mentioned.		
E GEN-09 Diffusion	Factors affecting diffusion are addressed.	Diffusion in clays is not relevant for the BMA.	
E SFR-09 Diffusion in the near-field	Diffusion and factors affecting diffusion are addressed. The impact of diffusion on water composition is also addressed.		
J 3.2.06 Diffusion - surface diffusion		Surface diffusion in clay materials is not relevant for the BMA.	
S 002 Anion-exclusion	Anion exclusion is addressed.		
W 2.095 Galvanic coupling	Electro-osmotic effects are mentioned.		
W 2.096 Electrophoresis	Electro-osmotic effects are mentioned.		Electrophoresis is expected to have negligible effects, according to the FEP.
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Table A6-8. SR-PSU FEP BMABa09 Sorption on concrete/shotcrete.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.14 Complexation by organics	Complexation by organics is addressed.		Humic acids are addressed in BMABa11.
A 1.73 Sorption	Sorption is defined and the K_d (linear sorption) approach is addressed.		
A 1.74 Sorption - nonlinear		The calculations assume linear sorption.	
E GEN-34 Radionuclide sorption	Radionuclide sorption is addressed.		
I 044 Chealting agents	Complexation by chelating agents is addressed.		
J 3.1.02 Saturation of sorption sites	The effect of the water composition on sorption is addressed.		This FEP relates to clays, and is therefore not entirely relevant to BMA.
J 4.1.04 Sorption	Radionuclide sorption is addressed, and the relevance of oxidation state is mentioned in the handling.		
J 4.1.09 Complexing agents	Complexation by synthetic chelating agents is addressed.	Humic acids are addressed in BMABa11.	
S 084 Sorption	Sorption is addressed, including the factors that affect it.		
W 2.061 Actinide sorption	Actinide sorption is included implicitly.		BMA does not contain a large quantity of actinides.
W 2.062 Kinetics of sorption		The calculations use a K_d approach, which assumes instantaneous sorption/desorption. Colloid concentrations are assumed to be negligible.	
W 2.068 Organic complexation	Complexation by synthetic chelating agents is addressed.	Humic acids are addressed in BMABa11.	
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Table A6-9. SR-PSU FEP BMABa10 Sorption on crushed rock backfill.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.01 Backfill characteristics	The backfill characteristics are addressed.		
A 1.73 Sorption	Sorption is addressed.		
A 1.74 Sorption - nonlinear		The calculations assume linear sorption.	
E GEN-34 Radionuclide sorption	Radionuclide sorption is addressed.		
J 3.1.02 Saturation of sorption sites	The effect of water composition on sorption is addressed.		This FEP relates to clays, and is therefore not relevant to BMA.
J 4.1.04 Sorption	Radionuclide sorption is addressed, and the relevance of oxidation state is mentioned in the handling.		
S 084 Sorption	Sorption is addressed, including the factors that affect it.		
W 2.061 Actinide sorption	Actinide sorption is included implicitly.		BMA does not contain a large quantity of actinides.
W 2.062 Kinetics of sorption	Kinetics are mentioned.	The importance of slow radionuclide desorption kinetics in colloidal transport is not addressed because colloid concentrations are assumed to be negligible.	

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Table A6-10. SR-PSU FEP BMABa11 Colloid stability, transport and filtering.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.63 Psuedo-colloids	Colloid formation, stability and transport are addressed.		
I 058 Colloid formation (natural and vault generated)	Colloid formation and removal mechanisms are addressed.		

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Table A6-11. SR-PSU FEP BMABa12 Concrete degradation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.13 Colloids		Colloid generation is addressed in BMABa11.	
A 1.62 Precipitation and dissolution	Precipitation and dissolution reactions in concrete and the related changes in porosity are addressed.		
A 1.77 Speciation	Solid phase speciation, i.e. mineralogy, is addressed.		Speciation of elements in the solution phase is discussed indirectly.
E GEN-08 Degradation of the rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18. Unsealed vaults and shafts are addressed in the SR-PSU Initial State FEP ISGen05, Design Mishaps.	
H 1.1.2 Physico-chemical degradation of concrete	The physical-chemical degradation of concrete is addressed over the lifetime of the repository.		
I 058 Colloid formation (natural and vault generated)		Colloid formation is addressed in BMABa11.	
I 061 Concrete (influence on vault chemistry)	The influence of the concrete on the chemistry of the vault is addressed.	Low alkalinity concrete is not relevant to BMA.	
I 062e Concrete (rebar corrosion)	The effect of the presence of form rods and fractures on concrete degradation is addressed.	The corrosion process is addressed in BMABa15.	A key reference explores this FEP in detail.
J 1.2.07 Recrystallization	Recrystallization is discussed.		
J 2.3.07.1 External stress	The effects of the presence of form rods and fractures on concrete degradation are discussed.		
J 3.1.07 Reactions with cement pore water	The reactions of concrete with the pore water and the associated changes in pH are addressed.		
M 3.2.02 Interactions of host materials and ground water with repository materials	The effect of groundwater constituents on the concrete are addressed.	The interaction between glass and clays is not relevant to SFR.	
S 021 Degradation of rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18.	
W 2.060 Kinetics of precipitation and dissolution	Precipitation and dissolution kinetics are mentioned.	Radionuclide precipitation is not considered, as it is addressed in BMABa17 and BMABa18.	
W 2.073 Concrete hydration	The heat liberated during concrete hydration is addressed.		
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SR-PSU FEP BMABa13 Aqueous speciation and reactions

No NEA FEP associated with this PSU FEP.

Table A6-12. SR-PSU FEP BMABa14 Microbial processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.03 Biological activity	The effect of microbiological activity on the physical and chemical environment is addressed.		
A 1.53 Methylation	Methylation is discussed.		
E SFL-32 Microbial activity	The effect of microbiological activity on the physical and chemical environment is addressed. Microbial transport through fractures (due to colloidal size) is discussed.		
E SFR-11 Gas generation in the repository	Gas generation during microbial processes is addressed.	The effect of the gas produced on water and gas transport (and therefore radionuclide transport indirectly) is discussed in BMABa05.	
H 1.2.1 Hydrogen by metal corrosion	Microbial respiration of hydrogen is addressed.	Production of hydrogen during metal corrosion is addressed in BMABa15 and BMABa16.	
H 1.2.3 Gas generation from concrete	Gas generation during microbial processes is addressed.	Radiolysis is addressed in BMABa16.	
I 012 Biological activity (bacteria & microbes)	The effect of microbiological activity on the physical and chemical environment is addressed.		
I 015 Gas generation (CH_4, CO_2, H_2)	Gas generation during microbial processes is addressed.	Production of hydrogen during metal corrosion, which is addressed in BMABa15 and BMABa16. The effects of gas generation are discussed in BMABa05.	
J 2.1.10 Microbes	Both the dependence of microbial activity on the physico-chemical conditions and the potential effects of microbial activity are addressed.		
K 3.17 Microbial activity	The production of organic complexing agents is discussed.		
M 3.2.07 Microbiological effects	The influence of microorganisms on material degradation and microbial dependency on nutrients are addressed.		
S 057 Microbial activity	The requirements of microbial growth and microbial adaptation are discussed. The effect of microbiological activity on the physical and chemical environment is addressed.		
W 2.044 Degradation of organic material	The degradation of cement additives is addressed.	The degradation of cellulosic, plastic and other synthetic materials is relevant to the waste form, not the barrier.	
W 2.045 Effect of temperature on microbial gas generation	The relationship between microbial activity and temperature is addressed.		
W 2.046 Effect of pressure on microbial gas generation		As this FEP states, pressure has less influence on microbial than chemical gas generation.	
W 2.048 Effect of biofilms on microbial gas generation		This is not discussed directly, as gas generation will occur predominantly in the waste form.	
W 2.076 Microbial growth on concrete	Microbial growth on concrete and acid production are addressed.		
W 2.088 Biofilms	Biofilms and their formation are discussed. The effect of biofilms on microbial and radionuclide transport is addressed implicitly via the effect of biofilms on water flow and the sorption of radionuclides by microorganisms.		

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Table A6-13. SR-PSU FEP BMABa15 Metal corrosion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.30 Electrochemical gradients		This relates to the waste containers and matrices (E GEN-13 is similar but for metal in the barrier).	
E GEN-08 Degradation of the rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18.	
E GEN-13 Electrochemical effects	Electrochemical effects on the corrosion of the metal components of the barriers are mentioned.		
E GEN-20 Gas generation in the near-field rock	Gas generation in the near field rock is addressed.		
E SFR-11 Gas generation in the repository	Gas generation in the steel components of the barriers is addressed.	The effect of the gas produced on water transport is addressed in BMABa05.	
		Gas production due to microbial processes and radiolysis are discussed in BMABa14 and BMABa16, respectively.	
H 1.1.4 Electrochemical effects of metal corrosion		This is not addressed as the main effect of metal corrosion is to reduce the barrier function.	
H 1.2.1 Hydrogen by metal corrosion	Hydrogen production is addressed.	The role of microbes in enhancing metal corrosion. The high pH of the repository over the relevant timescale is expected to limit microbial activity.	
I 015 Gas generation (CH_4, CO_2, H_2)	Production of hydrogen during metal corrosion is addressed.	Gas generation during microbial processes is addressed in BMABa14. The effects of gas generation are discussed in BMABa05.	
I 062e Concrete (rebar corrosion)	Corrosion of reinforcement bars is addressed.	The effect on concrete degradation is discussed in BMABa12.	
I 071 Corrosive chemicals (in vault)		Corrosive chemicals arise from the waste and will have the greatest influence in the waste form and packaging.	
I 126 Corrosion (galvanic coupling)	Electrochemical effects on the corrosion of the metal components of the barriers are mentioned.		Galvanic coupling is most relevant to the waste form and packaging.
J 1.2.08 Redox potential		Radiolysis is not relevant in BMA.	This is a parameter not a process.
J 2.1.06.2 Natural telluric electrochemical reactions	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
J 3.2.07 Swelling of corrosion products	The larger molar volume of corrosion products is addressed.		
K 2.14 Chemical buffering (canister corrosion products)		This relates to waste packaging.	
M 3.2.01 Metallic corrosion	Corrosion mechanisms are discussed. Chemical influences and hydrogen production are addressed.		
S 021 Degradation of rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18.	
S 029 Electrochemical effects/gradients		This relates to waste packaging.	
S 074 Redox front	The influence of changing redox conditions on metal corrosion is addressed.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
S 100 Volume increase of corrosion products	The larger molar volume of corrosion products is addressed.		
W 2.050 Galvanic coupling	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
W 2.051 Chemical effects of corrosion	The effect of corrosion on the redox potential and gas generation are addressed.		
W 2.064 Effect of metal corrosion	The effect of corrosion on the redox potential is addressed.		
W 2.095 Galvanic coupling	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
W 2.096 Electrophoresis		Effect on ion transport is mentioned in BMABa08.	The FEP explains that the impact of electrophoresis is of low consequence.

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Table A6-14. SR-PSU FEP BMABa16 Gas formation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.35 Formation of gases	Formation of hydrogen during metal corrosion is addressed. Radiolytic and microbial gas formation are mentioned.	The effect of gas accumulation is addressed in BMABa05.	The formation of methane is discussed in more detail in BMABa14.
E SFR-11 Gas generation in the repository	Gas generation during metal corrosion is addressed. Gas formed due to microbial activity is discussed, and radiolysis is mentioned.	The effect of the gas produced on radionuclide transport is discussed in BMABa05.	
H 1.2.1 Hydrogen by metal corrosion	Hydrogen production during metal corrosion is addressed.	Microbial respiration of hydrogen is addressed in BMABa14. The role of microbes in enhancing metal corrosion is not addressed, since the high pH of the repository over the relevant timescale is expected to limit microbial activity.	
H 1.2.8 Thermo-chemical effects	The potential for trapped gas to build pressure is addressed.	The effect of increased gas pressure is addressed in BMABa05. Thermal insulation is not relevant as the BMA waste is not heat generating.	
J 1.2.02 Hydrogen/oxygen explosions		Judged to be of very low probability in BMA due to negligible radiolysis.	
J 1.2.04 Gas generation	Gas generation during metal corrosion is addressed. Gas formed due to microbial activity is discussed, and radiolysis is mentioned.	Gas transport and the effect of gas on water transport are addressed in BMABa05.	

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Table A6-15. SR-PSU FEP BMABa17 Speciation of radionuclides.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.14 Complexation by organics	The cellulose degradation product ISA is mentioned.	Organic complexing agents are addressed in BMABa09 and humic acids in BMAMa11.	
A 1.37 Geochemical pump		This FEP relates to BMABa18.	
A 1.77 Speciation	Speciation is addressed.		
E GEN-27 Radionuclide precipitation and dissolution	Solubility limits are addressed.		Radionuclide solubility limits are not considered in SR-PSU.
E SFR-20 Groundwater chemistry in the near-field		The impact of concrete on the water chemistry is addressed in BMABa12. The removal of oxygen is addressed in BMABa14 and BMABa15. Organic complexing agents are addressed in BMABa09 and the formation of gases in BMABa16.	
H 1.5.5 Transport of chemically-active substances into the near-field	Complexing agents are mentioned.	Colloids are addressed in BMABa11 and microorganisms in BMABa14. Complexing agents are addressed in BMABa09.	
H 5.1.3 Incomplete near-field chemical conditioning		BMA is a multi-barrier system.	
I 044 Chealting agents	The cellulose degradation product ISA is mentioned.	Organic complexing agents are addressed in BMABa09.	
J 4.1.09 Complexing agents	The cellulose degradation product ISA is mentioned.	Organic complexing agents are addressed in BMABa09 and humic acids in BMAMa11.	
J 5.44 Solubility and precipitation	Solubility limits are addressed.		Radionuclide solubility limits are not considered in SR-PSU.
M 1.6.08 Dissolution, precipitation and cristallization	Solubility limits are addressed.		Radionuclide solubility limits are not considered in SR-PSU.
S 060 Precipitation/dissolution	Solubility limits are addressed.		Radionuclide solubility limits are not considered in SR-PSU.
W 2.056 Speciation	Speciation is addressed.		
W 2.057 Kinetics of speciation	Kinetics are addressed relative to transport processes.	In accordance with the FEP, kinetics of speciation reactions are not included in the assessment.	
W 2.068 Organic complexation	The cellulose degradation product ISA is mentioned.	Organic complexing agents are addressed in BMABa09 and humic acids in BMAMa11.	
W 2.071 Kinetics of organic complexation	Kinetics are addressed relative to transport processes.	Kinetics of organic complexation and colloidal effects (e.g. of humic acids) are not included in the assessment.	
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Table A6-16. SR-PSU FEP BMABa18 Transport of radionuclides in the water phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.01 Backfill characteristics	The importance of material characteristics in sorption processes is addressed.		
A 1.22 Convection		Convection is expected to be negligible in the BMA as the wastes are not heat generating.	
A 1.37 Geochemical pump	Included implicitly in the discussion of transport and sorption.	Dissolution and precipitation of radionuclides are not considered in the modelling.	A reference is given to supporting calculations that consider solubility limits.
A 1.65 Radioactive decay	Radioactive decay is addressed.		
E GEN-10 Radionuclide dispersion	Dispersion is addressed.		Dispersion is not included in the calculations as it is less than the numerical dispersion in the modelling.
E GEN-13 Electrochemical effects		The effect on diffusion is mentioned in BMABa08.	
E GEN-28 Radioactive decay	Radioactive decay is addressed.	Heat generation is not relevant in the BMA.	
H 5.1.3 Incomplete near-field chemical conditioning		BMA is a multi-barrier system.	
I 044 Chelating agents		Chelating agents are considered in the selection of the K_d values and organic complexing agents are addressed in BMABa09.	
J 2.1.06.2 Natural telluric electrochemical reactions		The effect on diffusion is mentioned in BMABa08.	
J 3.2.08 Preferential pathways in the buffer/backfill		BMA does not contain bentonite.	
J 4.1.09 Complexing agents		Complexing agents are considered in the selection of the K_d values and are addressed in BMABa09. Humic acids are addressed in BMAMa11.	
S 070 Radioactive decay of mobile nuclides	Radioactive decay is addressed.		
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Table A6-17. SR-PSU FEP BMABa19 Transport of radionuclides in the gas phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.65 Radioactive decay		Radioactive decay is addressed in BMABa18 and also applies here. Decay during transport is not relevant as the gas is assumed to reach the biosphere as soon as it forms.	
E GEN-28 Radioactive decay		Radioactive decay is addressed in BMABa18 and also applies here. Decay during transport is not relevant as the gas is assumed to reach the biosphere as soon as it forms.	
I 127 Gas absorption (^{14}C in CO_2) into concrete walls		Gas is assumed to reach the biosphere as soon as it forms.	
K 0.3 Gaseous and volatile isotopes		Gaseous radionuclides are considered to be ^{14}C, ^{3}H and ^{222}Rn, of which ^{14}C is the most important.	
W 2.055 Radioactive gases	Radioactive gases are addressed.		
W 2.089 Transport of radioactive gases	The transport of radioactive gases is addressed.		

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Appendix 7

Handling of NEA Project FEPs sorted to SR-PSU BTF barrier processes

SR-PSU FEP BTFBa01 Heat transport

No NEA FEP associated with this SR-PSU FEP.

Table A7-1. SR-PSU FEP BTFBa02 Phase changes/freezing.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 268 Freeze/thaw cycles	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function.	Prior to permafrost, the concrete will not be exposed to freeze-thaw cycles due to the depth of SFR.	
J 5.17 Permafrost	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function.		
S 059 Permafrost	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function. Also, the changes in the hydrological situation are addressed.		

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Table A7-2. SR-PSU FEP BTFBa03 Water uptake and transport during unsaturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.68 Reflooding	The special hydraulic conditions during resaturation are discussed.	Temperature, BTF wastes are not significantly heat-generating.	
A 1.84 Transport in gases or of gases	The presence and effect of gases on water flow are accounted for.	Gas transport is addressed in BTFBa05.	This FEP refers to the buffer.
A 1.88 Unsaturated transport	The possibility of a prolonged unsaturated period is considered.		
E SFR-16 Hydraulic resaturation of the near-field	Resaturation and the influence of the gas phase are addressed.	The change in redox conditions is addressed in BTFBa13 and BTFBa14, concrete degradation in BTFBa11 and influence of gas production in BTFBa05. Thermal effects are not relevant to BTF.	
H 1.5.3 Unsaturated flow due to gas production		Unsaturated groundwater flow due to gas production is considered in SR-PSU FEP BTFBa05.	
J 5.14 Resaturation	The special hydraulic conditions during resaturation are discussed.	The change in redox conditions is addressed in BTFBa13 and BTFBa14.	

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Table A7-3. SR-PSU FEP BTFBa04 Water transport under saturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.01 Backfill characteristics	The properties of the backfill are addressed.		
A 1.40 Hydraulic conductivity		Variations in the hydraulic conductivity of the backfill are negligible in comparison with the difference between the concrete and backfill, while the barrier retains its function.	
A 1.41 Hydraulic head	Different hydraulic boundary conditions will be modelled.		
E SFR-21 Groundwater movement in the near-field	Different hydraulic boundary conditions will be modelled.	The influence of gas production, because fully saturated conditions are assumed.	Influence of gas on water transport is addressed in BTFBa05.
H 1.5.4 Saturated groundwater flow	Saturated groundwater flow is addressed.		
J 3.2.09 Flow through buffer/backfill		Not addressed, this FEP relates to bentonite, which is not used in the BTF.	
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Table A7-4. SR-PSU FEP BTFBa05 Gas transport/dissolution.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.84 Transport in gases or of gases	Transport of gases and the influence of gases on water transport are addressed.		
E SFR-12 Gas flow in the near-field	Gas flow and the consequences of the accumulation of gas pressure in the barriers are addressed.		
H 1.2.6 Gas transport	Gas movement through the barriers is addressed.		
H 1.2.8 Thermo-chemical effects	The effect of gas accumulation is addressed.	Thermal aspects are not considered, as the BTF waste is not heat generating.	
H 1.5.3 Unsaturated flow due to gas production	Unsaturated conditions arising from gas production are addressed.		
M 3.3.06 Gas effects	The effects of gas pressurization are addressed.	Effects on clay are not relevant to the BTF.	
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Table A7-5. SR-PSU FEP BTFBa06 Mechanical processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.08 Cave ins	Fallout from the roof and walls of the rock vault is addressed.		
E GEN-03 Cave-in	Fallout from the roof and walls of the rock vault is addressed.		
E SFR-13 Mechanical impact on the engineered barriers	Mechanical impacts on the engineered barriers are addressed.	Fractures due to thermal effects in concrete are addressed in BTFBa11.	
H 1.4.2 Vault collapse	Fallout from the roof and walls of the rock vault is addressed. Radionuclide transport is covered indirectly via changes to hydrological variables.		BTF will be grouted and backfilled with sand, which reduces the impact of vault collapse.
J 2.3.07.1 External stress	Fallout from the roof and walls of the rock vault is addressed.	Damage to the waste packages, as falling rocks will hit the sand backfill.	
J 3.2.07 Swelling of corrosion products	Stresses caused by the corro-sion of steel reinforcement are mentioned.		
M 3.1.02 Non-elastic reponse		Not relevant to the BTF.	
M 3.3.04 Subsidence/ collapse		Not relevant to BTF due to the backfill used.	This FEP was rejected on the basis of the presence of backfill and appropri-ate QA.
S 004 Cave in	Fallout from the roof and walls of the rock vault is addressed.		
S 100 Volume increase of corrosion products		Relates specifically to the HLW reposi-tory design, not relevant for BTF.	
W 2.022 Roof falls	Fallout from the roof and walls of the rock vault is addressed.		
W 2.035 Mechanical effects of backfill	The mechanical properties of the backfill are mentioned.		

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Table A7-6. SR-PSU FEP BTFBa07 Advection and dispersion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.28 Dispersion	Dispersion is addressed.		
E GEN-10 Radionuclide dispersion	Dispersion is addressed in general.	Radionuclide dispersion is addressed directly in BTFBa17.	
J 3.2.08 Preferential pathways in the buffer/ backfill	Preferential pathways in concrete due to fractures are discussed.		
J 4.1.08 Change of groundwater chemistry in nearby rock		This is handled in the geosphere process report.	See e.g. SR-PSU FEP Ge16.

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Table A7-7. SR-PSU FEP BFTBa08 Diffusion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.27 Diffusion	Diffusion and its temperature dependence are addressed.	Surface effects in clays are not relevant for the BTF.	
A 1.36 Galvanic coupling	Electro-osmotic effects are mentioned.		
E GEN-09 Diffusion	Factors affecting diffusion are addressed.	Diffusion in clays is not relevant for the BTF.	
E SFR-09 Diffusion in the near-field	Diffusion and factors affecting diffusion are addressed. The impact of diffusion on water composition is also addressed.		
J 3.2.06 Diffusion - surface diffusion		Surface diffusion in clay materials is not relevant for the BTF.	
S 002 Anion-exclusion	Anion exclusion is addressed.		
W 2.095 Galvanic coupling	Electro-osmotic effects are mentioned.		
W 2.096 Electrophoresis	Electro-osmotic effects are mentioned.		Electrophoresis is expected to have negligible effects, according to the FEP.

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Table A7-8. SR-PSU FEP BTFBa09 Sorption.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.01 Backfill characteristics	The backfill characteristics are addressed.		
A 1.14 Complexation by organics	Complexation by organics is addressed.	Humic acids are addressed in BFTBa10.	
A 1.73 Sorption	Sorption is addressed.		
A 1.74 Sorption - nonlinear		The calculations assume linear sorption.	
E GEN-34 Radionuclide sorption	Radionuclide sorption is addressed.		
I 044 Chealting agents	Complexation by chelating agents is addressed.		
J 3.1.02 Saturation of sorption sites	The effect of water composition on sorption is addressed.		This FEP relates to clays, and is therefore not relevant to BTF.
J 4.1.04 Sorption	Radionuclide sorption is addressed, and the relevance of oxidation state is mentioned in the handling.		
J 4.1.09 Complexing agents	Complexation by synthetic chelating agents is addressed.	Humic acids are addressed in BTFBa10.	
S 084 Sorption	Sorption is addressed, including the factors that affect it.		
W 2.061 Actinide sorption	Actinide sorption is included implicitly.		BTF does not contain a large quantity of actinides.
W 2.062 Kinetics of sorption		The calculations use a K_d approach, which assumes instantaneous sorption/desorption. Colloid concentrations are assumed to be negligible.	
W 2.068 Organic complexation	Complexation by synthetic chelating agents is addressed.	Humic acids are addressed in BTFBa10.	

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Table A7-9. SR-PSU FEP BTFBa10 Colloid stability, transport and filtering.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.63 Psuedo-colloids	Colloid formation, stability and transport are addressed.		
I 058 Colloid formation (natural and vault generated)	Colloid formation and removal mechanisms are addressed.		

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Table A7-10. SR-PSU FEP BTFBa11 Concrete degradation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.13 Colloids		Colloid generation is addressed in BTFBa10.	
A 1.62 Precipitation and dissolution	Precipitation and dissolution reactions in concrete and the related changes in porosity are addressed.		
A 1.77 Speciation	Solid phase speciation, i.e. mineralogy, is addressed.		Speciation of elements in the solution phase is discussed indirectly.
E GEN-08 Degradation of the rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18.	
H 1.1.2 Physico-chemical degradation of concrete	The physical-chemical degradation of concrete is addressed over the lifetime of the repository.		
I 058 Colloid formation (natural and vault generated)		Colloid formation is addressed in BTFBa10.	
I 061 Concrete (influence on vault chemistry)	The influence of the concrete on the chemistry of the vault is addressed.	Low alkalinity concrete is not relevant to BTF.	
I 062e Concrete (rebar corrosion)	The effect of the presence of form rods and fractures on concrete degradation is addressed.	The corrosion process is addressed in BTFBa14.	A key reference explores this FEP in detail.
J 1.2.07 Recrystallization	Recrystallization is discussed.		
J 2.3.07.1 External stress	The effects of the presence of form rods and fractures on concrete degradation are discussed.		
J 3.1.07 Reactions with cement pore water	The reactions of concrete with the pore water and the associated changes in pH are addressed.		
M 3.2.02 Interactions of host materials and ground water with repository materials	The effect of groundwater constituents on the concrete are addressed.	The interaction between glass and clays is not relevant to SFR.	
S 021 Degradation of rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18.	
W 2.060 Kinetics of precipitation and dissolution	Precipitation and dissolution kinetics are mentioned.	Radionuclide precipitation is addressed in to BTFBa16 and BTFBa17.	
W 2.073 Concrete hydration	The heat liberated during concrete hydration is addressed.		

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SR-PSU FEP BTFBa12 Aqueous speciation and reactions

No NEA FEP associated with this PSU FEP.

Table A7-11. SR-PSU FEP BTFBa13 Microbial processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.03 Biological activity	The effect of microbiological activity on the physical and chemical environment is addressed.		
A 1.53 Methylation	Methylation is discussed.		
E SFL-32 Microbial activity	The effect of microbiological activity on the physical and chemical environment is addressed. Microbial transport through fractures (due to colloidal size) is discussed.		
E SFR-11 Gas generation in the repository	Gas generation during microbial processes is addressed.	The effect of the gas produced on water and gas transport (and therefore radionuclide transport indirectly) is discussed in BTFBa05.	
H 1.2.1 Hydrogen by metal corrosion	Microbial respiration of hydrogen is addressed.	Production of hydrogen during metal corrosion is addressed in BTFBa14 and BTFBa15.	
H 1.2.3 Gas generation from concrete	Gas generation during microbial processes is addressed.	Radiolysis is addressed in BTFBa15.	
I 012 Biological activity (bacteria & microbes)	The effect of microbiological activity on the physical and chemical environment is addressed.		
I 015 Gas generation (CH_4, CO_2, H_2)	Gas generation during microbial processes is addressed.	Production of hydrogen during metal corrosion, which is addressed in BTFBa14and BTFBa15. The effects of gas generation are discussed in BTFBa05.	
J 2.1.10 Microbes	Both the dependence of microbial activity on the physico-chemical conditions and the potential effects of microbial activity are addressed.		
K 3.17 Microbial activity	The production of organic complexing agents is discussed.		
M 3.2.07 Microbiological effects	The influence of microorganisms on material degradation and microbial dependency on nutrients are addressed.		
S 057 Microbial activity	The requirements of microbial growth and microbial adaptation are discussed. The effect of microbiological activity on the physical and chemical environment is addressed.		
W 2.044 Degradation of organic material	The degradation of cement additives is addressed.	The degradation of cellulosic, plastic and other synthetic materials is relevant to the waste form, not the barrier.	
W 2.045 Effect of temperature on microbial gas generation	The relationship between microbial activity and temperature is addressed.		
W 2.046 Effect of pressure on microbial gas generation		As this FEP states, pressure has less influence on microbial than chemical gas generation.	
W 2.048 Effect of biofilms on microbial gas generation		This is not discussed directly, as gas generation will occur predominantly in the waste form.	
W 2.076 Microbial growth on concrete	Microbial growth on concrete and acid production are addressed.		
W 2.088 Biofilms	Biofilms and their formation are discussed. The effect of biofilms on microbial and radionuclide transport is addressed implicitly via the effect of biofilms on water flow and the sorption of radionuclides by microorganisms.		

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Table A7-12. SR-PSU FEP BTFBa14 Metal corrosion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.30 Electrochemical gradients		This relates to the waste containers and matrices (E GEN-13 is similar but for metal in the barrier).	
E GEN-08 Degradation of the rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18.	
E GEN-13 Electrochemical effects	Electrochemical effects on the corrosion of the metal components of the barriers are mentioned.		
E GEN-20 Gas generation in the near-field rock	Gas generation in the near field rock is addressed.		
E SFR-11 Gas generation in the repository	Gas generation in the steel components of the barriers is addressed.	The effect of the gas produced on radionuclide transport is addressed in BTFBa 05 and BTFBa17. Gas production due to microbial processes and radiolysis are discussed in BTFBa13 and BTFBa15, respectively.	
H 1.1.4 Electrochemical effects of metal corrosion		This is not addressed as the main effect of metal corrosion is to reduce the barrier function.	
H 1.2.1 Hydrogen by metal corrosion	Hydrogen production is addressed.	The role of microbes in enhancing metal corrosion. The high pH of the repository over the relevant timescale is expected to limit microbial activity.	
I 015 Gas generation (CH_4, CO_2, H_2)	Production of hydrogen during metal corrosion is addressed.	Gas generation during microbial processes is addressed in BTFBa13. The effects of gas generation are discussed in BTFBa05.	
I 062e Concrete (rebar corrosion)	Corrosion of reinforcement bars is included.	The effect on concrete degradation is discussed in BTFBa11.	
I 071 Corrosive chemicals (in vault)		Corrosive chemicals arise from the waste and will have the greatest influence in the waste form and packaging.	
I 126 Corrosion (galvanic coupling)	Electrochemical effects on the corrosion of the metal components of the barriers are mentioned.		Galvanic coupling is most relevant to the waste form and packaging.
J 1.2.08 Redox potential		Radiolysis is not relevant in BTF.	This is a parameter not a process.
J 2.1.06.2 Natural telluric electrochemical reactions	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
J 3.2.07 Swelling of corrosion products	The larger molar volume of corrosion products is addressed.		
K 2.14 Chemical buffering (canister corrosion products)		This relates to waste packaging.	
M 3.2.01 Metallic corrosion	Corrosion mechanisms are discussed. Chemical influences and hydrogen production are addressed.		
S 021 Degradation of rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18.	
S 029 Electrochemical effects/gradients		This relates to waste packaging.	
S 074 Redox front	The influences of changing redox conditions on metal corrosion are addressed.		
S 100 Volume increase of corrosion products	The larger molar volume of corrosion products is addressed.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
W 2.050 Galvanic coupling	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
W 2.051 Chemical effects of corrosion	The effect of corrosion on the redox potential and gas generation are addressed.		
W 2.064 Effect of metal corrosion	The effect of corrosion on the redox potential is addressed.		
W 2.095 Galvanic coupling	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
W 2.096 Electrophoresis		Effect on ion transport is mentioned in BTFBa08.	The FEP explains that the impact of electrophoresis is of low consequence.
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Table A7-13. SR-PSU FEP BTFBa15 Gas formation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.35 Formation of gases	Formation of hydrogen during metal corrosion is addressed. Radiolytic and microbial gas formation are mentioned.	The effect of gas accumulation is addressed in BTFBa05.	The formation of methane is discussed in more detail in BTFBa13.
E SFR-11 Gas generation in the repository	Gas generation during metal corrosion is addressed. Gas formed due to microbial activity is discussed, and radiolysis is mentioned.	The effect of the gas produced on radionuclide transport is discussed in BTFBa05.	
H 1.2.1 Hydrogen by metal corrosion	Hydrogen production during metal corrosion is addressed.	Microbial respiration of hydrogen is addressed in BTFBa13. The role of microbes in enhancing metal corrosion is not addressed, since the high pH of the repository over the relevant timescale is expected to limit microbial activity.	
H 1.2.8 Thermo-chemical effects	The potential for trapped gas to build pressure is addressed.	The effect of increased gas pressure is addressed in BTFBa05. Thermal insulation is not relevant as the BTF waste is not heat generating.	
J 1.2.02 Hydrogen/oxygen explosions		Judged to be of very low probability in BTF due to negligible radiolysis.	
J 1.2.04 Gas generation	Gas generation during metal corrosion is addressed. Gas formed due to microbial activity is discussed, and radiolysis is mentioned.	Gas transport and the effect of gas on water transport are addressed in BTFBa05.	
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Table A7-14. SR-PSU FEP BTFBa16 Speciation of radionuclides.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.14 Complexation by organics	The cellulose degradation product ISA is mentioned.	Organic complexing agents are addressed in BTFBa09.	
A 1.37 Geochemical pump		This FEP relates to BTFBa17.	
A 1.77 Speciation	Speciation is addressed.		
E GEN-27 Radionuclide precipitation and dis-solution	Solubility limits are addressed.		Radionuclide solubility limits are not consid-ered in SR-PSU.
E SFR-20 Groundwater chemistry in the near-field		The impact of concrete on the water chemistry is addressed in BTFBa11. The removal of oxygen is addressed in BTFBa13 and BTFBa14. Organic complexing agents are addressed in BTFBa09 and the formation of gases in BTFBa15.	
H 1.5.5 Transport of chemically-active substances into the near-field	Complexing agents are mentioned.	Colloids are addressed in BTFBa10 and microorganisms in BTFBa13. Complexing agents are addressed in BTFBa09.	
H 5.1.3 Incomplete near-field chemical conditioning		BTF is a multi-barrier system.	
I 044 Chealting agents	The cellulose degradation product ISA is mentioned.	Organic complexing agents are addressed in BTFBa09.	
J 4.1.09 Complexing agents	The cellulose degradation product ISA is mentioned.	Organic complexing agents are addressed in BTFBa09 and humic acids in BTFBa10.	
J 5.44 Solubility and precipitation	Solubility limits are addressed.		Radionuclide solubility limits are not consid-ered in SR-PSU.
M 1.6.08 Dissolution, precipitation and cristal-lization	Solubility limits are addressed.		Radionuclide solubility limits are not consid-ered in SR-PSU.
S 060 Precipitation/dis-solution	Solubility limits are addressed.		Radionuclide solubility limits are not consid-ered in SR-PSU.
W 2.056 Speciation	Speciation is addressed.		
W 2.057 Kinetics of speciation	Kinetics are addressed relative to transport processes.	In accordance with the FEP, kinetics of speciation reactions are not included in the assessment.	
W 2.068 Organic complexation	The cellulose degradation product ISA is mentioned.	Organic complexing agents are addressed in BTFBa09.	
W 2.071 Kinetics of organic complexation	Kinetics are addressed relative to transport processes.	Kinetics of organic complexation and colloidal effects (e.g. of humic acids) are not included in the assessment.	

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Table A7-15. SR-PSU FEP BTFBa17 Transport of radionuclides in the water phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.01 Backfill characteristics	The importance of material characteristics in sorption processes is addressed.		
A 1.22 Convection		Convection is expected to be negligible in the BTF as the wastes are not heat generating.	
A 1.37 Geochemical pump	Included implicitly in the discussion of transport and sorption.	Dissolution and precipitation of radionuclides are not considered.	A reference is given to supporting calculations that consider solubility limits.
A 1.65 Radioactive decay	Radioactive decay is addressed.		
E GEN-10 Radionuclide dispersion	Dispersion is addressed.		Dispersion is not included in the calculations as it is less than the numerical dispersion in the modelling.
E GEN-13 Electrochemical effects		The effect on diffusion is mentioned in BTFBa08.	
E GEN-28 Radioactive decay	Radioactive decay is addressed.	Heat generation is not relevant in the BTF.	
H 5.1.3 Incomplete near-field chemical conditioning		BTF is a highly cementitious vault.	
I 044 Chealting agents		Chelating agents are considered in the selection of the K_d values. Organic complexing agents are addressed in BTFBa09.	
J 2.1.06.2 Natural telluric electrochemical reactions		The effect on diffusion is mentioned in BTFBa08.	
J 3.2.08 Preferential pathways in the buffer/backfill		BTF does not contain bentonite.	
J 4.1.09 Complexing agents		Complexing agents are considered in the selection of the K_d values. Organic complexing agents are addressed in BTFBa09 and humic acids in BTFBa10.	
S 070 Radioactive decay of mobile nuclides	Radioactive decay is addressed.		
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Table A7-16. SR-PSU FEP BTFBa18 Transport of radionuclides in the gas phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.65 Radioactive decay		Radioactive decay is addressed in BTFBa17 and also applies here. Decay during transport is not relevant as the gas is assumed to reach the biosphere as soon as it forms.	
E GEN-28 Radioactive decay		Radioactive decay is addressed in BTFBa17 and also applies here. Decay during transport is not relevant as the gas is assumed to reach the biosphere as soon as it forms.	
I 127 Gas absorption (^{14}C in CO_2) into concrete walls		Gas is assumed to reach the biosphere as soon as it forms.	
K 0.3 Gaseous and volatile isotopes		Gaseous radionuclides are considered to be ^{14}C, ^{3}H and ^{222}Rn, of which ^{14}C is the most important.	
W 2.055 Radioactive gases	Radioactive gases are addressed.		
W 2.089 Transport of radioactive gases	The transport of radioactive gases is addressed.		

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Appendix 8

Handling of NEA Project FEPs sorted to SR-PSU Silo barrier processes

SR-PSU FEP SiBa01 Heat transport

No NEA FEP associated with this SR-PSU FEP.

Table A8-1. SR-PSU FEP SiBa02 Phase changes/freezing.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 268 Freeze/thaw cycles	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function.	Prior to permafrost, the concrete will not be exposed to freeze–thaw cycles due to the depth of SFR.	
I 277 Soil liquefaction (seismic)	.	The Silo is in a rock vault.	
J 5.17 Permafrost	The effects of permafrost on the concrete, bentonite and sand–bentonite mixtures are addressed.		
S 059 Permafrost	The effects of permafrost on the concrete, bentonite and sand–bentonite mixtures are addressed. Also, the changes in the hydrological situation are addressed.		

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Table A8-2. SR-PSU FEP SiBa03 Water uptake and transport during unsaturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.68 Reflooding	The special hydraulic conditions during resaturation are discussed.	Temperature, Silo wastes are not significantly heat-generating.	
A 1.84 Transport in gases or of gases	The presence and effect of gases on water flow are accounted for.	Gas transport is addressed in SiBa05.	
A 1.88 Unsaturated transport	The possibility of a prolonged unsaturated period is addressed.		
E SFR-16 Hydraulic resaturation of the near-field	The resaturation of the Silo is addressed.		
H 1.5.3 Unsaturated flow due to gas production		Unsaturated groundwater flow due to gas production is considered in SiBa05.	
J 5.14 Resaturation	The special hydraulic conditions during resaturation are discussed.	The change in redox conditions is addressed in SiBa20 and SiBa22.	
K 3.03 Bentonite saturation	The resaturation of the bentonite is addressed.		
S 079 Resaturation of bentonite buffer	The resaturation of the bentonite is addressed.		

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Table A8-3. SR-PSU FEP SiBa04 Water transport under saturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.01 Backfill characteristics	The importance of the backfill characteristics is addressed.		
A 1.06 Buffer characteristics	The importance of the buffer characteristics is addressed.		
A 1.40 Hydraulic conductivity	The possibility of preferential flow paths is addressed.		
A 1.41 Hydraulic head	Variations in the hydraulic head are included in the modelling.		
E SFR-16 Hydraulic resaturation of the near-field		Relevant to SiBa03.	
E SFR-21 Groundwater movement in the near-field	Different hydraulic boundary conditions will be modelled. The changes in the hydraulic conductivity of the bentonite and concrete over time are addressed.	The influence of gas production, because fully saturated conditions are assumed. Influence of gas on water transport is addressed in SiBa05.	
H 1.5.4 Saturated groundwater flow	Saturated groundwater flow is addressed.		
K 3.08 Buffer impermeability	The low hydraulic conductivity of bentonite is addressed.		
S 037 Flow through buffer/backfill	Factors affecting flow through the bentonite are addressed.	Influence on copper canister corrosion, as the Silo does not contain HLW.	

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Table A8-4. SR-PSU FEP SiBa05 Gas transport/dissolution.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.84 Transport in gases or of gases	Transport of gases and the influence of gases on water transport are addressed.		
E SFR-12 Gas flow in the near-field	Gas flow and the consequences of the accumulation of gas pressure in the barriers are addressed.		Gas evacuation pipes are present.
H 1.2.6 Gas transport	Gas movement through the barriers is addressed.		
H 1.2.8 Thermo-chemical effects	The effect of gas accumulation is addressed.	Thermal aspects are not considered, as the Silo waste is not heat generating.	Gas evacuation pipes are present.
H 1.5.3 Unsaturated flow due to gas production	Unsaturated conditions arising from gas production are addressed.		
J 3.2.12 Gas transport in bentonite	Gas transport in bentonite is addressed.		
K 3.15 Gas permeability	Gas breakthrough after the build-up of sufficient pressure is addressed.		
M 3.3.06 Gas effects	The effects of gas pressure are addressed.		
S 041 Gas flow and transport, buffer/backfill	Gas flow through the bentonite is addressed.		

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Table A8-5. SR-PSU FEP SiBa06 Piping/erosion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 027 Buffer (channelling)	Piping (channelling) is addressed.		
I 030 Buffer (washout of clay)	The loss of bentonite due to piping and erosion is addressed.		
J 3.2.04 Erosion of buffer/backfill	The effects of flow rate and water composition on erosion are addressed.		
J 3.2.08 Preferential pathways in the buffer/backfill	The effect of the loss of bentonite is addressed.		
J 3.2.09 Flow through buffer/backfill	The effect of piping on water flow is addressed.		
K 3.06 Bentonite erosion	Bentonite erosion is addressed.		
S 025 Dilution of buffer/backfill	The lowering of the bentonite density and its effect on hydraulic properties are addressed.		
S 031 Erosion of buffer/backfill	The effects of flow rate and water composition on erosion are addressed.		
W 2.083 Rinse		Rinse is not relevant to the flow conditions in the Silo.	
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Table A8-6. SR-PSU FEP SiBa07 Mechanical processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.08 Cave ins	Fallout from the roof and walls of the rock vault is addressed.		
A 1.80 Swelling pressure	Impact of swelling pressure on surrounding barriers (concrete and rock).	Impact of swelling pressure on waste packagings since they are not physically in contact.	
E GEN-03 Cave-in	Fallout from the roof and walls of the rock vault is addressed.		
E GEN-36 Stress field	Factors affecting the stress field and its impact are addressed.		
E SFR-13 Mechanical impact on the engineered barriers	Mechanical impacts on the engineered barriers are addressed.	Fractures due to thermal effects in concrete are addressed in SiBa13.	
H 1.4.2 Vault collapse	Fallout from the roof and walls of the rock vault is addressed. Radionuclide transport is covered indirectly via changes to hydrological variables.		The Silo will be backfilled in a way which reduces both the probability and the impact of rock fallout.
I 298 Swelling pressure (clay)	Swelling pressure is addressed.		
J 2.3.07.1 External stress	Fallout from the roof and walls of the rock vault is addressed.	Damage to the waste packages, as falling rocks will hit the backfill and, in any case, the waste packages are not considered to act as a barrier to radionuclide transport.	
J 3.2.01.1 Swelling of bentonite into tunnels and cracks	Bentonite filling void spaces is discussed.		
J 3.2.01.2 Uneven swelling of bentonite	Inhomogeneities in the bentonite filling are discussed.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 3.2.03 Mechanical failure of buffer/backfill	Mechanical failure of the bentonite is addressed.		
J 3.2.07 Swelling of corrosion products	Stresses caused by the corrosion of steel reinforcement are addressed.		
K 3.04 Bentonite swelling pressure	Swelling pressure is addressed.		
K 3.05 Bentonite plasticity	The swelling and self-healing properties of bentonite are addressed.		
K 4.04 Effect of bentonite swelling on EDZ		Effect of swelling on EDZ is not specifically addressed here, but mentioned in the descriptions of the mechanical processes in the geosphere.	See SR-PSU FEPs Ge05, Ge06 and Ge07.
M 3.1.01 Differential elastic response		This relates to thermal expansion, and the Silo wastes are not significantly heat generating.	
M 3.1.02 Non-elastic reponse	Mechanical failure of the bentonite is addressed.		
M 3.3.04 Subsidence/collapse		Not relevant to the Silo due to the backfill used.	This FEP was rejected on the basis of the presence of backfill and appropriate QA.
S 003 Bentonite swelling, buffer	Bentonite swelling, uneven swelling and swelling into voids are addressed.		
S 004 Cave in	Fallout from the roof and walls of the rock vault is addressed.	Effect on the waste packages is addressed in the waste form and packaging process report.	
S 015 Creeping of rock mass, near-field	Creep deformations are addressed.		
S 025 Dilution of buffer/backfill	The lowering of the bentonite density and its effect on hydraulic properties are addressed.		
S 056 Mechanical impact/failure, buffer/backfill	Creep deformations and rock fallout are addressed.		
S 100 Volume increase of corrosion products		Relates specifically to the HLW repository design, not relevant for the Silo.	
W 2.022 Roof falls	Fallout from the roof and walls of the rock vault is addressed.		
W 2.035 Mechanical effects of backfill	The mechanical properties of the backfill are mentioned.		

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Table A8-7. SR-PSU FEP SiBa08 Advection and dispersion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.28 Dispersion	Dispersion is addressed.		
E GEN-10 Radionuclide dispersion	Dispersion is addressed in general.	Radionuclide dispersion is addressed directly in SiBa25.	
J 3.2.08 Preferential pathways in the buffer/backfill	The relationship between geometry and water transport is addressed.		
J 4.1.08 Change of groundwater chemistry in nearby rock		This is handled in the geosphere process report.	
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Table A8-8. SR-PSU FEP SiBa09 Diffusion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.27 Diffusion	Diffusion, its temperature dependence and surface effects in clays are addressed.		
A 1.36 Galvanic coupling	Transport due to the presence of an electrical field is mentioned.		
E GEN-02 Anion exclusion	Anion exclusion is addressed.		
E GEN-09 Diffusion	Factors affecting diffusion are addressed.		
E SFR-09 Diffusion in the near-field	Diffusion and factors affecting diffusion are addressed. The impact of diffusion on water composition is also addressed.		
J 3.2.06 Diffusion - surface diffusion	Surface diffusion is addressed.		
J 4.1.08 Change of groundwater chemistry in nearby rock		This is handled in the geosphere process report.	
K 3.10 Radionuclide retardation		This is addressed in SiBa10.	
K 3.16 Radionuclide transport through buffer	Effective diffusion coefficients are addressed.		
M 1.6.14 Chemical gradients (electrochemical effects, osmosis)	Chemical gradients are addressed.		
S 002 Anion-exclusion	Anion exclusion is addressed.		
S 023 Diffusion	Diffusion, anion exclusion and surface diffusion are addressed.		
W 2.095 Galvanic coupling	Transport due to the presence of an electrical field is mentioned.		
W 2.096 Electrophoresis	Transport due to the presence of an electrical field is mentioned.		The FEP explains that the impact of electrophoresis is of low consequence for diffusion.
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Table A8-9. SR-PSU FEP SiBa10 Sorption (including ion exchange of major ions).

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.01 Backfill characteristics	The backfill characteristics are addressed.		
A 1.06Buffer characteristics	The buffer characteristics are addressed.		
A 1.73 Sorption	Sorption is addressed.		
A 1.74 Sorption - nonlinear		The calculations assume linear sorption.	
E GEN-34 Radionuclide sorption	Radionuclide sorption is addressed.		
I 028b Buffer (quality)	The buffer characteristics are addressed.		
I 182 Buffer (chemical saturation)		The concern relating to large amounts of oil and salts in the wastes is not relevant to Silo wastes.	
J 3.1.02 Saturation of sorption sites	The dependency of the K_d concept on conditions that do not lead to surface saturation is discussed.		Surface saturation is not expected during diffusion-controlled transport through a bentonite barrier.
J 4.1.04 Sorption	Sorption is addressed.		
K 3.10 Radionuclide retardation	Radionuclide retardation processes in the bentonite are addressed.		
M 1.6.07 Sorption	Sorption is addressed.		
M 1.6.14 Chemical gradients (electrochemical effects, osmosis)		The effects of chemical gradients on transport are addressed in SiBa09.	
S 018 Deep saline water intrusion	The relevance of water composition is addressed.		
S 084 Sorption	Sorption is addressed.		
W 2.061 Actinide sorption	Actinide sorption is addressed implicitly.		
W 2.062 Kinetics of sorption	The kinetics of sorption processes is addressed.		
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Table A8-10. SR-PSU FEP SiBa11 Alteration of impurities.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E SFR-24 Evolution of the bentonite layer in the silo	Factors affecting the evolution of the bentonite are addressed.		
I 028a Buffer(degradation)	Factors affecting the degradation of the bentonite are addressed.		
J 3.1.01 Degradation of the bentonite by chemical reactions	Chemical degradation of impurities is addressed.	Montmorillonite degradation is addressed in SiBa17.	
J 3.1.03 Effects of bentonite on groundwater chemistry	Ion exchange properties and reactions are addressed.		
J 3.1.10 Interactions with corrosion products and waste		This refers to the HLW concept and is not relevant to the Silo design.	
K 3.09 Bentonite porewater chemistry	The reactions that control the chemistry of bentonite porewater are addressed.		
S 006 Chemical alteration of buffer/backfill	Chemical alterations of impurities are addressed.	Montmorillonite alterations are addressed in SiBa17.	
S 094 Thermal degradation of buffer/backfill		Temperature gradients will be low in the Silo (cf HLW).	
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Table A8-11. SR-PSU FEP SiBa12 Colloid transport and filtering.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.63 Psuedo-colloids	Colloid formation, stability and transport are addressed.		
E SFR-02 Colloid generation and transport in the shell and grout	Colloid formation, stability and transport are addressed.		
E SFR-10 Colloid filtration in the near-field	Colloid filtration is addressed.		
I 058 Colloid formation (natural and vault generated)	Colloid formation and removal mechanisms are addressed.		
S 096 Transport and release of nuclides, bentonite buffer	Transport of colloids is addressed.	Other transport processes are not relevant in this section.	
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Table A8-12. SR-PSU FEP SiBa13 Concrete degradation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.13 Colloids		Colloid generation is addressed in SiBa12.	
A 1.62 Precipitation and dissolution	Precipitation and dissolution reactions in concrete and the related changes in porosity are addressed.		
A 1.77 Speciation	Solid phase speciation, i.e. mineralogy, is addressed.		Speciation of elements in the solution phase is discussed indirectly.
E GEN-08 Degradation of the rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18. Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05, Design Mishaps.	
E SFR-02 Colloid generation and transport in the shell and grout		Colloid generation and stability are addressed in SiBa12.	
E SFR-03 Degradation of the cement mortar and the silo shell	The degradation of concrete in the Silo is addressed.		
H 1.1.2 Physico-chemical degradation of concrete	The physical-chemical degradation of concrete is addressed over the lifetime of the repository.		
I 058 Colloid formation (natural and vault generated)		Colloid formation is addressed in SiBa12.	
I 061 Concrete (influence on vault chemistry)	The influence of the concrete on the chemistry of the vault is addressed.	Low alkalinity concrete is not relevant to the Silo.	
I 062e Concrete (rebar corrosion)	The effect of the presence of form rods and fractures on concrete degradation is addressed.	The corrosion process is addressed in SiBa22.	A key reference explores this FEP in detail.
J 1.2.07 Recrystallization	Recrystallization is discussed.		
J 2.3.07.1 External stress	The effects of the presence of form rods and fractures on concrete degradation are discussed.		
J 3.1.07 Reactions with cement pore water	The reactions of concrete with the pore water and the associated changes in pH are addressed.		
M 3.2.02 Interactions of host materials and ground water with repository materials	The effect of groundwater constituents on the concrete are addressed.	The interaction between glass and clays is not relevant to SFR.	
S 021 Degradation of rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18.	
W 2.060 Kinetics of precipitation and dissolution	Precipitation and dissolution kinetics are mentioned.	Radionuclide precipitation is addressed in SiBa10.	
W 2.073 Concrete hydration	The heat liberated during concrete hydration is addressed.		

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Table A8-13. SR-PSU FEP SiBa14 Dissolution/precipitation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.13 Colloids		Colloids are addressed in SiBa12.	
A 1.62 Precipitation and dissolution	Precipitation and dissolution are addressed.		Also addressed in SiBa11 and SiBa17.
A 1.77 Speciation		Speciation is addressed in SiBa13, SiBa15 and SiBa24.	
E GEN-08 Degradation of the rock reinforcement and grout		Degradation of the rock reinforcement and grout is addressed in Pg18.	
E SFR-02 Colloid generation and transport in the shell and grout		Colloids are addressed in SiBa12.	
I 058 Colloid formation (natural and vault generated)		Colloids are addressed in SiBa12.	
J 1.2.07 Recrystallization	Recrystallization is mentioned.		
S 021 Degradation of rock reinforcement and grout		Degradation of the rock reinforcement and grout is addressed in Pg18.	
W 2.060 Kinetics of precipitation and dissolution		Kinetics of precipitation are addressed in SiBa13.	

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Table A8-14. SR-PSU FEP SiBa15 Aqueous speciation and reactions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.77 Speciation	Speciation is addressed.		
K 3.09 Bentonite porewater chemistry	Bentonite porewater chemistry is addressed.		

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Table A8-15. SR-PSU FEP SiBa16 Osmosis.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
M 1.6.14 Chemical gradients (electrochemical effects, osmosis)	Chemical gradients and osmosis are addressed.		
W 2.098 Osmotic processes	Osmotic processes are addressed.		

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Table A8-16. SR-PSU FEP SiBa17 Montmorillonite transformation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E SFR-24 Evolution of the bentonite layer in the silo	Montmorillonite transformations and the effect on the barrier are addressed.	Interactions with iron are addressed in SiBa18.	
I 028a Buffer(degradation)	Montmorillonite transformations and the effect on the barrier are addressed.		
I 048 Buffer (degradation by concrete)	The influence of concrete degradation on the montmorillonite is addressed.		
J 3.1.01 Degradation of the bentonite by chemical reactions	Montmorillonite transformations and the effect on the barrier are addressed.		
J 3.2.05 Thermal effects on the buffer material		Thermal effects are not relevant in the Silo.	
K 3.09 Bentonite porewater chemistry	Bentonite porewater chemistry is addressed.		
K 3.12b Mineralogical alteration - long term	The long term mineralogical alterations of montmorillonite are addressed.		
K 3.25 Interaction with cement components	The effect of cement components on montmorillonite transformations is addressed.		
M 3.1.05 Induced chemical changes		Thermal effects are not relevant to the Silo.	
S 006 Chemical alteration of buffer/backfill	Montmorillonite transformations and the effect on the barrier are addressed.	Canister corrosion is not relevant.	
S 094 Thermal degradation of buffer/backfill		Thermal effects are not relevant to the Silo.	

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Table A8-17. SR-PSU FEP SiBa18 Iron–bentonite interaction.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E SFR-24 Evolution of the bentonite layer in the silo	Bentonite transformations resulting from interactions with iron are addressed.	Other transformations are addressed in SiBa17.	
I 028a Buffer(degradation)		This is addressed in SiBa11 and SiBa17.	
J 3.1.01 Degradation of the bentonite by chemical reactions		This is addressed in SiBa11and SiBa17.	
J 3.1.10 Interactions with corrosion products and waste	Bentonite transformations resulting from interactions with iron are addressed.	Other transformations are addressed in SiBa17.	
K 3.09 Bentonite porewater chemistry		This is addressed in SiBa11, SiBa15, SiBa17 and SiBa21.	
K 3.14 Canister/bentonite interaction		This relates to the HLW repository design and is not relevant to the Silo.	
S 006 Chemical alteration of buffer/backfill	Bentonite transformations resulting from interactions with iron are addressed.	Other transformations are addressed in SiBa17. Negligible copper is present in the Silo.	

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Table A8-18. SR-PSU FEP SiBa19 Montmorillonite colloid release.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.13 Colloids	Montmorillonite colloid formation and stability are addressed.	Colloid transport and filtering are addressed in SiBa12.	
A 1.63 Psuedo-colloids	Montmorillonite colloid formation and stability are addressed.	Colloid transport and filtering are addressed in SiBa12.	
A 2.50 Pseudo-colloids	Montmorillonite colloid formation and stability are addressed.	Colloid transport and filtering are addressed in SiBa12.	
I 028a Buffer(degradation)	Buffer degradation as a result of colloid formation is addressed.	Other buffer degradation processes are addressed in SiBa07, SiBa11 and SiBa17.	
I 058 Colloid formation (natural and vault generated)	Montmorillonite colloid formation and stability are addressed.	Colloid transport and filtering are addressed in SiBa12.	
J 3.1.04 Colloid generation - source	Montmorillonite colloid formation and stability are addressed.		
J 3.1.05 Coagulation of bentonite	Coagulation of bentonite is addressed.		
J 3.1.06 Sedimentation of bentonite	Sedimentation of bentonite is discussed.		
K 4.12 Colloids	Montmorillonite colloid formation and stability are addressed.	The formation of other colloids is addressed in SiBa12.	
S 007 Coagulation of bentonite	Coagulation of bentonite is addressed.		
S 009 Colloid generation-source	Montmorillonite colloid formation is addressed.		
S 025 Dilution of buffer/backfill	Loss of the bentonite is addressed.		
S 082 Sedimentation of bentonite	Sedimentation of bentonite is discussed.		
W 2.082 Suspensions of particles		The diffusion-controlled conditions in the Silo are not expected to create particle suspensions.	

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Table A8-19. SR-PSU FEP SiBa20 Microbial processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.03 Biological activity	The effect of microbiological activity on the physical and chemical environment is addressed.		
A 1.53 Methylation	Methylation is discussed.		
E SFL-32 Microbial activity	The effect of microbiological activity on the physical and chemical environment is addressed. Microbial transport through fractures (due to colloidal size) is discussed.		
E SFR-11 Gas generation in the repository	Gas generation during microbial processes is addressed.	The effect of the gas produced on water and gas transport (and therefore radionuclide transport indirectly) is discussed in SiBa05.	
H 1.2.1 Hydrogen by metal corrosion	Microbial respiration of hydrogen is addressed.	Production of hydrogen during metal corrosion is addressed in SiBa22 and SiBa23.	
H 1.2.3 Gas generation from concrete	Gas generation during microbial processes is addressed.	Radiolysis is mentioned in SiBa23 but is negligible in the Silo.	
I 012 Biological activity (bacteria & microbes)	The effect of microbiological activity on the physical and chemical environment is addressed.		
I 015 Gas generation (CH_4, CO_2, H_2)	Gas generation during microbial processes is addressed.	Gas production during metal corrosion is addressed in SiBa22 and SiBa23.	
J 2.1.10 Microbes	Both the dependence of microbial activity on the physico-chemical conditions and the potential effects of microbial activity are addressed.		
K 3.17 Microbial activity	The production of organic complexing agents is discussed.		
M 3.2.07 Microbiological effects	The influence of microorganisms on material degradation and microbial dependency on nutrients are addressed.		
S 044 Gas generation, buffer/backfill	Microbial gas generation is addressed.	Radiolysis is expected to be negligible in the Silo.	
S 057 Microbial activity	The requirements of microbial growth and microbial adaptation are discussed. The effect of microbiological activity on the physical and chemical environment is addressed.		
W 2.044 Degradation of organic material	The degradation of cement additives is addressed.	The degradation of cellulosic, plastic and other synthetic materials is relevant to the waste form, not the barrier.	
W 2.045 Effect of temperature on microbial gas generation	The relationship between microbial activity and temperature is addressed.		
W 2.046 Effect of pressure on microbial gas generation		As this FEP states, pressure has less influence on microbial than chemical gas generation.	
W 2.048 Effect of biofilms on microbial gas generation		This is not discussed directly, as gas generation will occur predominantly in the waste form.	
W 2.076 Microbial growth on concrete	Microbial growth on concrete and acid production are addressed.		
W 2.088 Biofilms	Biofilms and their formation are discussed. The effect of biofilms on microbial and radionuclide transport is addressed implicitly via the effect of biofilms on water flow and the sorption of radionuclides by microorganisms.		

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Table A8-20. SR-PSU FEP SiBa21 Cementation in bentonite.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E SFR-24 Evolution of the bentonite layer in the silo	Factors affecting the evolution of the bentonite are addressed as well as the effect on the barrier function.		See also SiBa11 and SiBa17.
I 028a Buffer(degradation)	Mineral transformations and the effect on the barrier are addressed.		See also SiBa11 and SiBa17.
J 3.1.01 Degradation of the bentonite by chemical reactions	Mineral transformations and the effect on the barrier are addressed.		See also SiBa11 and SiBa17.
K 3.09 Bentonite porewater chemistry	Bentonite porewater chemistry is addressed.		
S 006 Chemical alteration of buffer/backfill	Mineral transformations and the effect on the barrier are addressed.		

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Table A8-21. SR-PSU FEP SiBa22 Metal corrosion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.30 Electrochemical gradients		This relates to the waste containers and matrices (E GEN-13 is similar but for metal in the barrier).	
E GEN-08 Degradation of the rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18.	
E GEN-13 Electrochemical effects	Electrochemical effects on the corrosion of the metal components of the barriers are mentioned.		
E GEN-20 Gas generation in the near-field rock	Gas generation in the near field rock is addressed.		
E SFR-02 Colloid generation and transport in the shell and grout		Colloid formation, stability and transport are addressed in SiBa12.	
E SFR-03 Degradation of the cement mortar and the silo shell		The degradation of concrete in the Silo is addressed in SiBa13.	
E SFR-04 Degradation of steel reinforcements in the silo shell	Degradation of steel reinforcements is addressed.	The effect of steel corrosion on the concrete is mentioned in SiBa13.	
E SFR-11 Gas generation in the repository	Gas generation in the steel components of the barriers is addressed.	The effect of the gas produced on radionuclide transport is addressed in SiBa05 and SiBa26. Gas production due to microbial processes and radiolysis are discussed/mentioned in SiBa20 and SiBa23, respectively.	
H 1.1.4 Electrochemical effects of metal corrosion		This is not addressed as the main effect of metal corrosion is to reduce the barrier function.	
H 1.2.1 Hydrogen by metal corrosion	Hydrogen production is addressed.	The role of microbes in enhancing metal corrosion. The high pH of the repository over the relevant timescale is expected to limit microbial activity.	
I 015 Gas generation (CH_4, CO_2, H_2)	Production of hydrogen during metal corrosion is addressed.	Gas generation during microbial processes is addressed in SiBa20. The effects of gas generation are discussed in SiBa05.	

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 062e Concrete (rebar corrosion)	Corrosion of reinforcement bars is addressed.	The effect on concrete degradation is discussed in SiBa13.	
I 071 Corrosive chemicals (in vault)		Corrosive chemicals arise from the waste and will have the greatest influence in the waste form and packaging.	
I 126 Corrosion (galvanic coupling)	Electrochemical effects on the corrosion of the metal components of the barriers are mentioned.		Galvanic coupling is most relevant to the waste form and packaging.
J 1.2.08 Redox potential		Radiolysis is expected to be negligible in the Silo.	This is a parameter not a process.
J 2.1.06.2 Natural telluric electrochemical reactions	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
J 3.2.07 Swelling of corrosion products	The larger molar volume of corrosion products is addressed.		
K 2.14 Chemical buffering (canister corrosion products)		This relates to waste packaging.	
M 3.2.01 Metallic corrosion	Corrosion mechanisms are discussed. Chemical influences and hydrogen production are addressed.		
S 021 Degradation of rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18.	
S 029 Electrochemical effects/gradients		This relates to waste packaging.	
S 074 Redox front	The influence of changing redox conditions on metal corrosion is addressed.		
S 100 Volume increase of corrosion products	The larger molar volume of corrosion products is addressed.		
W 2.050 Galvanic coupling	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
W 2.051 Chemical effects of corrosion	The effect of corrosion on the redox potential and gas generation are addressed.		
W 2.064 Effect of metal corrosion	The effect of corrosion on the redox potential is addressed.		
W 2.095 Galvanic coupling	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
W 2.096 Electrophoresis		The FEP explains that the electrochemical effects of metal corrosion are of low consequence.	

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Table A8-22. SR-PSU FEP SiBa23 Gas formation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.35 Formation of gases	Formation of hydrogen during metal corrosion is addressed. Radiolytic and microbial gas formation are mentioned.	The effect of gas accumulation is addressed in SiBa05.	The formation of methane is discussed in more detail in SiBa20.
E SFR-11 Gas generation in the repository	Gas generation during metal corrosion is addressed. Gas formed due to microbial activity is discussed, and radiolysis is mentioned.	The effect of the gas produced on radionuclide transport is discussed in SiBa05.	
H 1.2.1 Hydrogen by metal corrosion	Hydrogen production during metal corrosion is addressed.	Microbial respiration of hydrogen is addressed in SiBa20. The role of microbes in enhancing metal corrosion is not addressed, since the high pH of the repository over the relevant timescale is expected to limit microbial activity.	
H 1.2.8 Thermo-chemical effects	The potential for trapped gas to build pressure is addressed.	The effect of increased gas pressure is addressed in SiBa05. Thermal insulation is not relevant as the Silo waste is not heat generating.	
J 1.2.02 Hydrogen/oxygen explosions		Judged to be of very low probability in the Silo due to negligible radiolysis.	
J 1.2.04 Gas generation	Gas generation during metal corrosion is addressed. Gas formed due to microbial activity is discussed, and radiolysis is mentioned.	Gas transport and the effect of gas on water transport are addressed in SiBa05.	
S 044 Gas generation, buffer/backfill		Radiolysis is expected to be negligible in the Silo.	

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Table A8-23. SR-PSU FEP SiBa24 Speciation of radionuclides.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.14 Complexation by organics	Organic complexing agents are mentioned.		
A 1.37 Geochemical pump		This FEP relates to SiBa25.	
A 1.77 Speciation	Speciation is addressed.		
E GEN-27 Radionuclide precipitation and dissolution	Solubility limits are addressed.		Radionuclide solubility limits are not considered in SR-PSU.
E SFR-20 Groundwater chemistry in the near-field	Organic complexing agents are mentioned.	The impact of concrete on the water chemistry is addressed in SiBa13, the removal of oxygen and the formation of other gases are addressed in SiBa20 and SiBa22.	
H 1.5.5 Transport of chemically-active substances into the near-field	Complexing agents are mentioned.	Colloids are addressed in SiBa12 and SiBa19, and microorganisms in SiBa20.	
H 5.1.3 Incomplete near-field chemical conditioning		The Silo is a multi-barrier system.	
I 044 Chealting agents	Complexing agents are mentioned.		
J 4.1.09 Complexing agents	Complexing agents are mentioned.		
J 5.44 Solubility and precipitation	Solubility limits are addressed.		Radionuclide solubility limits are not considered in SR-PSU.
M 1.6.08 Dissolution, precipitation and cristallization	Solubility limits are addressed.		Radionuclide solubility limits are not considered in SR-PSU.
S 060 Precipitation/dissolution	Solubility limits are addressed.		Radionuclide solubility limits are not considered in SR-PSU.
W 2.056 Speciation	Speciation is addressed.		
W 2.057 Kinetics of speciation	Kinetics are addressed relative to transport processes.	In accordance with the FEP, kinetics of speciation reactions are not included in the assessment.	
W 2.068 Organic complexation	Complexing agents are mentioned.		
W 2.071 Kinetics of organic complexation	Kinetics are addressed relative to transport processes.	Kinetics of organic complexation and colloidal effects (e.g. of humic acids) are not included in the assessment.	

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Table A8-24. SR-PSU FEP SiBa25 Transport of radionuclides in the water phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.01 Backfill characteristics	The importance of material characteristics in sorption processes is addressed.		
A 1.06 Buffer characteristics	The buffer characteristics are addressed.		
A 1.22 Convection		Convection is expected to be negligible in the Silo as the wastes are not heat generating.	
A 1.37 Geochemical pump	Included implicitly in the discussion of transport and sorption.	Dissolution and precipitation of radionuclides are not considered in the modelling.	A reference is given to supporting calculations that consider solubility limits.
A 1.65 Radioactive decay	Radioactive decay is addressed.		
E GEN-10 Radionuclide dispersion	Dispersion is addressed.		Dispersion is not included in the calculations as it is less than the numerical dispersion in the modelling.
E GEN-13 Electrochemical effects		The effect on diffusion is mentioned in SiBa09.	
E GEN-28 Radioactive decay	Radioactive decay is addressed.	Heat generation is not relevant in the Silo.	
E SFR-19 Transport and release from the silo	Transport of radionuclides through bentonite in the water phase is addressed.	Transport of gas-phase radionuclides is addressed in SiBa26.	
H 5.1.3 Incomplete near-field chemical conditioning		The Silo is a multi-barrier system.	
I 027 Buffer (channelling)		Piping (channelling) is addressed in SiBa06.	
I 044 Chealting agents		Chelating agents are considered in the selection of the K_d values. Organic complexing agents are addressed in SiBa10.	
J 2.1.06.2 Natural telluric electrochemical reactions		Transport due to the presence of an electrical field is not addressed here, but mentioned in SiBa09.	
J 3.2.08 Preferential pathways in the buffer/backfill		The effect of the loss of bentonite is addressed in SiBa06.	
J 4.1.09 Complexing agents	Organic complexing agents are mentioned.		
K 3.16 Radionuclide transport through buffer	Diffusion-controlled radionuclide transport through the buffer is addressed.		
S 009 Colloid generation-source		Montmorillonite colloid formation is addressed in SiBa19.	
S 070 Radioactive decay of mobile nuclides	Radioactive decay is addressed.		
S 096 Transport and release of nuclides, bentonite buffer	The transport and release of aqueous radionuclide species through the bentonite buffer is addressed.	Colloid formation and stability are addressed in SiBa12 and SiBa19.	

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Table A8-25. SR-PSU FEP SiBa26 Transport of radionuclides in the gas phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.65 Radioactive decay		Radioactive decay is addressed in SiBa25 and also applies here. Decay during transport is not relevant as the gas is assumed to reach the biosphere as soon as it forms.	
E GEN-28 Radioactive decay		Radioactive decay is addressed in SiBa25 and also applies here. Decay during transport is not relevant as the gas is assumed to reach the biosphere as soon as it forms.	
E SFR-19 Transport and release from the silo	The transport and release of gaseous radionuclides is addressed.	Bentonite related gas transport is addressed in SiBa05. Transport of radionuclides through bentonite in the water phase is addressed in SiBa25.	
I 127 Gas absorption (^{14}C in CO_2) into concrete walls		Gas is assumed to reach the biosphere as soon as it forms.	
K 0.3 Gaseous and volatile isotopes		Gaseous radionuclides are considered to be ^{14}C, ^{3}H and ^{222}Rn, of which ^{14}C is the most important.	
S 096 Transport and release of nuclides, bentonite buffer	The transport of radioactive gases is addressed.	The transport of dissolved radionuclides is addressed in SiBa25 and colloid formation and stability in SiBa12 and SiBa19.	
W 2.055 Radioactive gases	Radioactive gases are addressed.		
W 2.089 Transport of radioactive gases	The transport of radioactive gases is addressed.		
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Appendix 9

Handling of NEA Project FEPs sorted to SR-PSU BRT barrier processes

SR-PSU FEP BRTBa01 Heat transport

No NEA FEP associated with this SR-PSU FEP.

Table A9-1. SR-PSU FEP BRTBa02 Phase changes/freezing.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 268 Freeze/thaw cycles	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function.	Prior to permafrost, the concrete will not be exposed to freeze–thaw cycles due to the depth of SFR.	
J 5.17 Permafrost	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function.		
S 059 Permafrost	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function. Also, the changes in the hydrological situation are addressed.		

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Table A9-2. SR-PSU FEP BRTBa03 Water uptake and transport during unsaturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.68 Reflooding	The special hydraulic conditions during resaturation are discussed.	Temperature, BRT wastes are not heat-generating.	BRT is considered to be saturated immediately after closure.
A 1.84 Transport in gases or of gases	The presence and effect of gases on water flow are accounted for.	Gas transport is addressed in BRTBa05.	This FEP refers to the buffer.
A 1.88 Unsaturated transport	The possibility of a prolonged unsaturated period is considered.		BRT is assumed to be saturated immediately after closure.
E SFR-16 Hydraulic resaturation of the near-field	Resaturation and the influence of the gas phase are addressed.	Redox changes are addressed in BRTBa13 and BRTBa14, concrete degradation in BRTBa11 and influence of gas production in BRTBa05. Thermal effects are not relevant to BRT.	
H 1.5.3 Unsaturated flow due to gas production		Unsaturated groundwater flow due to gas production is considered in BRTBa05.	
J 5.14 Resaturation	The special hydraulic conditions during resaturation are discussed.	Redox changes are addressed in BRTBa13 and BRTBa14.	

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Table A9-3. SR-PSU FEP BRTBa04 Water transport under saturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.01 Backfill characteristics	The properties of the backfill are addressed.		
A 1.40 Hydraulic conductivity		Variations in the hydraulic conductivity of the backfill are negligible in comparison with the difference between the concrete and backfill, while the concrete retains its function.	
A 1.41 Hydraulic head	Different hydraulic boundary conditions will be modelled.		
E SFR-21 Groundwater movement in the near-field	Different hydraulic boundary conditions will be modelled.	The influence of gas production, because fully saturated conditions are assumed.	Influence of gas on water transport is addressed in BRTBa05.
H 1.5.4 Saturated groundwater flow	Saturated groundwater flow is addressed.		
J 3.2.09 Flow through buffer/backfill		Not addressed, this FEP relates to bentonite, which is not used in the BRT.	
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Table A9-4. SR-PSU FEP BRTBa05 Gas transport/dissolution.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.84 Transport in gases or of gases	The relatively low resistance to gas flow in the BRT is addressed.		
E SFR-12 Gas flow in the near-field	The relatively low resistance to gas flow in the BRT is addressed.		
H 1.2.6 Gas transport	The relatively low resistance to gas flow in the BRT is addressed.		
H 1.2.8 Thermo-chemical effects	The low likelihood of gas pressurization in the BRT is addressed.	Thermal aspects are not considered, as the BRT waste is not heat generating.	
H 1.5.3 Unsaturated flow due to gas production	The relatively low resistance to gas flow in the BRT is addressed.		
M 3.3.06 Gas effects	The low likelihood of gas pressurization in the BRT is addressed.		
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Table A9-5. SR-PSU FEP BRTBa06 Mechanical processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.08 Cave ins	Fallout from the roof and walls of the rock vault is addressed.		
E GEN-03 Cave-in	Fallout from the roof and walls of the rock vault is addressed.		
E SFR-13 Mechanical impact on the engineered barriers	Mechanical impacts on the engineered barriers are addressed.	Fractures due to thermal effects in concrete are addressed in BRTBa11.	
H 1.4.2 Vault collapse	Fallout from the roof and walls of the rock vault is addressed.		.
J 2.3.07.1 External stress	Fallout from the roof and walls of the rock vault is addressed.	Damage to the waste packages, as falling rocks will hit the macadam backfill and, in any case, the reactor tanks are not considered to act as a barrier to radionuclide transport.	
J 3.2.07 Swelling of corrosion products	Stresses caused by the corrosion of steel reinforcement are mentioned.		
M 3.1.02 Non-elastic reponse		Not relevant to the BRT.	
M 3.3.04 Subsidence/collapse		Not relevant to BRT due to the macadam backfill used.	This FEP was rejected on the basis of the presence of backfill and appropriate QA.
S 004 Cave in	Fallout from the roof and walls of the rock vault is addressed.		
S 100 Volume increase of corrosion products		Relates specifically to the HLW repository design, not relevant for BRT.	
W 2.022 Roof falls	Fallout from the roof and walls of the rock vault is addressed.		
W 2.035 Mechanical effects of backfill	The mechanical properties of the backfill are mentioned.		

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Table A9-6. SR-PSU FEP BRTBa07 Advection and dispersion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.28 Dispersion	Dispersion is addressed.		
E GEN-10 Radionuclide dispersion	Dispersion is addressed in general.		
J 3.2.08 Preferential pathways in the buffer/backfill		Not relevant here as a mixed tank approach is applied.	
J 4.1.08 Change of groundwater chemistry in nearby rock		This is handled in the geosphere process report.	See e.g. SR-PSU FEP Ge16.

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Table A9-7. SR-PSU FEP BRTBa08 Diffusion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.27 Diffusion		The voids of the BRT vaults are assumed to be completely mixed for the safety assessment, with advection dominated flow in and out.	
A 1.36 Galvanic coupling		Not relevant to the handling (see NEA FEP A 1.27).	
E GEN-09 Diffusion		Not relevant to the handling (see NEA FEP A 1.27).	
E SFR-09 Diffusion in the near-field		Not relevant to the handling (see NEA FEP A 1.27).	
J 3.2.06 Diffusion - surface diffusion		Not relevant to the handling (see NEA FEP A 1.27).	
S 002 Anion-exclusion		Not relevant to the handling (see NEA FEP A 1.27).	
W 2.095 Galvanic coupling		Not relevant to the handling (see NEA FEP A 1.27).	
W 2.096 Electrophoresis		Not relevant to the handling (see NEA FEP A 1.27).	

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Table A9-8. SR-PSU FEP BRTBa09 Sorption.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.01 Backfill characteristics	The backfill characteristics are addressed.		
A 1.14 Complexation by organics	Complexation by organics is addressed.	Humic acids are addressed in BRTBa10.	
A 1.73 Sorption	Sorption is defined and the K_d (linear sorption) approach is addressed.		
A 1.74 Sorption - nonlinear		The calculations assume linear sorption.	
E GEN-34 Radionuclide sorption	Radionuclide sorption is addressed.		
I 044 Chealting agents	Complexation by chelating agents is addressed.		
J 3.1.02 Saturation of sorption sites	The effect of the water composition on sorption is addressed.		This FEP relates to clays, and is therefore not entirely relevant to BRT.
J 4.1.04 Sorption	Radionuclide sorption is addressed, and the relevance of oxidation state is mentioned in the handling.		
J 4.1.09 Complexing agents	Complexation by synthetic chelating agents is addressed.	Humic acids are addressed in BRTBa10.	
S 084 Sorption	Sorption is addressed, including the factors that affect it.		
W 2.061 Actinide sorption	Actinide sorption is included implicitly.		The BRT does not contain a large quantity of actinides.
W 2.062 Kinetics of sorption		The calculations use a K_d approach, which assumes instantaneous sorption/desorption. Colloid concentrations are assumed to be negligible.	
W 2.068 Organic complexation	Complexation by synthetic chelating agents is addressed via reference to the BMA (e.g. BMABa09), although no synthetic complexing agents will be deposited in BRT.	Humic acids are addressed in BRTBa10.	

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Table A9-9. SR-PSU FEP BRTBa10 Colloid stability, transport and filtering.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.63 Psuedo-colloids	Colloid formation, stability and transport are addressed.		
I 058 Colloid formation (natural and vault generated)	Colloid formation and removal mechanisms are addressed.		

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Table A9-10. SR-PSU FEP BRTBa11 Concrete degradation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.13 Colloids		Colloid generation is addressed in BRTBa10.	
A 1.62 Precipitation and dissolution	Precipitation and dissolution reactions in concrete and the related changes in porosity are addressed.		
A 1.77 Speciation	Solid phase speciation, i.e. mineralogy, is addressed.		Speciation of elements in the solution phase is discussed indirectly.
E GEN-08 Degradation of the rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18. Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05, Design Mishaps.	
H 1.1.2 Physico-chemical degradation of concrete	The physical-chemical degradation of concrete is addressed over the lifetime of the repository.		
I 058 Colloid formation (natural and vault generated)		Colloid formation is addressed in BRTBa10.	
I 061 Concrete (influence on vault chemistry)	The influence of the concrete on the chemistry of the vault is addressed.	Low alkalinity concrete is not relevant to BRT.	
I 062e Concrete (rebar corrosion)	The effect of the presence of form rods and fractures on concrete degradation is addressed.	The corrosion process is addressed in BRTBa14.	A key reference explores this FEP in detail.
J 1.2.07 Recrystallization	Recrystallization is discussed.		
J 2.3.07.1 External stress	The effects of the presence of form rods and fractures on concrete degradation are discussed.		
J 3.1.07 Reactions with cement pore water	The reactions of concrete with the pore water and the associated changes in pH are addressed.		
M 3.2.02 Interactions of host materials and ground water with repository materials	The effect of groundwater constituents on the concrete are addressed.	The interaction between glass and clays is not relevant to SFR.	
S 021 Degradation of rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18.	
W 2.060 Kinetics of precipitation and dissolution	Precipitation and dissolution kinetics are mentioned.	Radionuclide precipitation is not considered, as it is relevant to BRTBa16 and BRTBa17.	
W 2.073 Concrete hydration	The heat liberated during concrete hydration is addressed.		
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SR-PSU FEP BRTBa12 Aqueous speciation and reactions

No NEA FEP associated with this PSU FEP.

Table A9-11. SR-PSU FEP BRTBa13 Microbial processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.03 Biological activity	The effect of microbiological activity on the physical and chemical environment is addressed.		
A 1.53 Methylation	Methylation is discussed.		
E SFL-32 Microbial activity	The effect of microbiological activity on the physical and chemical environment is addressed. Microbial transport through fractures (due to colloidal size) is discussed.		
E SFR-11 Gas generation in the repository	Gas generation during microbial processes is addressed.		
H 1.2.1 Hydrogen by metal corrosion	Microbial respiration of hydrogen is addressed.	Production of hydrogen during metal corrosion is addressed in BRTBa14and BRTBa15.	
H 1.2.3 Gas generation from concrete	Gas generation during microbial processes is addressed.	Radiolysis is addressed in BRTBa15.	
I 012 Biological activity (bacteria & microbes)	The effect of microbiological activity on the physical and chemical environment is addressed.		
I 015 Gas generation (CH_4, CO_2, H_2)	Gas generation during microbial processes is addressed.	Production of hydrogen during metal corrosion, which is addressed in BRTBa14 and BRTBa15.	
J 2.1.10 Microbes	Both the dependence of microbial activity on the physico-chemical conditions and the potential effects of microbial activity are addressed.		
K 3.17 Microbial activity	The production of organic complexing agents is discussed.		
M 3.2.07 Microbiological effects	The influence of microorganisms on material degradation and microbial dependency on nutrients are addressed.		
S 057 Microbial activity	The requirements of microbial growth and microbial adaptation are discussed. The effect of microbiological activity on the physical and chemical environment is addressed.		
W 2.044 Degradation of organic material	The degradation of cement additives is addressed.	The degradation of cellulosic, plastic and other synthetic materials is relevant to the waste form, not the barrier.	
W 2.045 Effect of temperature on microbial gas generation	The relationship between microbial activity and temperature is addressed.		
W 2.046 Effect of pressure on microbial gas generation		Hyper alkaline conditions (>pH12) are predicted throughout the 100 000 years considered in SR-PSU, thus microbial activity is expected to be negligible.	
W 2.048 Effect of biofilms on microbial gas generation		Hyper alkaline conditions (>pH12) are predicted throughout the 100 000 years considered in SR-PSU, thus microbial activity is expected to be negligible.	
W 2.076 Microbial growth on concrete	Microbial growth on concrete and acid production are addressed.		
W 2.088 Biofilms	Biofilms and their formation are discussed. The effect of biofilms on microbial and radionuclide transport is addressed implicitly via the effect of biofilms on water flow and the sorption of radionuclides by microorganisms.		

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Table A9-12. SR-PSU FEP BRTBa14 Metal corrosion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.30 Electrochemical gradients		This relates to the waste containers and matrices (E GEN-13 is similar but for metal in the barrier).	
E GEN-08 Degradation of the rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18.	
E GEN-13 Electrochemical effects	Electrochemical effects on the corrosion of the metal components of the barriers are mentioned.		
E GEN-20 Gas generation in the near-field rock	Gas generation in the near field rock is addressed.		
E SFR-11 Gas generation in the repository	Gas generation in the steel components of the barriers is addressed.	The effect of the gas produced on radionuclide transport is addressed in BRTBa05 and BRTBa18.	
		Gas production due to microbial processes and radiolysis are expected to be negligible, BRTBa13 and BRTBa15, respectively.	
H 1.1.4 Electrochemical effects of metal corrosion		This is not addressed as the main effect of metal corrosion is to reduce the barrier function.	
H 1.2.1 Hydrogen by metal corrosion	Hydrogen production is addressed.	The role of microbes in enhancing metal corrosion. The high pH of the repository over the relevant timescale is expected to limit microbial activity.	
I 015 Gas generation (CH_4, CO_2, H_2)	Production of hydrogen during metal corrosion is addressed.	Gas generation during microbial processes is addressed in BRTBa13. The effects of gas generation are discussed in BRTBa05.	
I 062e Concrete (rebar corrosion)	Corrosion of reinforcement bars is included.	The effect on concrete degradation is discussed in BRTBa11.	
I 071 Corrosive chemicals (in vault)		There are no corrosive chemicals in the BRT waste.	
I 126 Corrosion (galvanic coupling)	Electrochemical effects on the corrosion of the metal components of the barriers are mentioned.		Galvanic coupling is most relevant to the waste form and packaging.
J 1.2.08 Redox potential		Radiolysis is not relevant in BRT.	This is a parameter not a process.
J 2.1.06.2 Natural telluric electrochemical reactions	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
J 3.2.07 Swelling of corrosion products	The larger molar volume of corrosion products is addressed.		
K 2.14 Chemical buffering (canister corrosion products)		This relates to waste packaging.	
M 3.2.01 Metallic corrosion	Corrosion mechanisms are discussed. Chemical influences and hydrogen production are addressed.		
S 021 Degradation of rock reinforcement and grout		Rock reinforcement and grout degradation are addressed in Pg18.	
S 029 Electrochemical effects/gradients		This relates to waste packaging.	
S 074 Redox front	The influence of changing redox conditions on metal corrosion is addressed.		
S 100 Volume increase of corrosion products	The larger molar volume of corrosion products is addressed.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
W 2.050 Galvanic coupling	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
W 2.051 Chemical effects of corrosion	The effects of corrosion on the redox potential and gas generation are addressed.		
W 2.064 Effect of metal corrosion	The effect of corrosion on the redox potential is addressed.		
W 2.095 Galvanic coupling	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
W 2.096 Electrophoresis		The voids of the BRT vaults are assumed to be completely mixed for the safety assessment, and so this is not relevant.	The FEP explains that the impact of electrophoresis is of low consequence.

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Table A9-13. SR-PSU FEP BRTBa15 Gas formation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.35 Formation of gases	Formation of hydrogen during metal corrosion is addressed. Radiolytic and microbial gas formation are mentioned.	The low likelihood of gas accumulation is addressed in BMABa05.	
E SFR-11 Gas generation in the repository	Gas generation during metal corrosion is addressed. Gas formed due to microbial activity is discussed, and radiolysis is mentioned.	The low resistance to gas flow in the BRT is addressed in BRTBa05.	
H 1.2.1 Hydrogen by metal corrosion	Hydrogen production during metal corrosion is addressed.	Microbial processes that affect or are affected by metal corrosion, since the sustained high pH of the repository is expected to limit microbial activity.	
H 1.2.8 Thermo-chemical effects	The potential for trapped gas to build pressure is addressed.	The low likelihood of gas pressurization in the BRT is addressed in BRTBa05. Thermal insulation is not relevant.	
J 1.2.02 Hydrogen/oxygen explosions		Judged to be of very low probability in BRT due to negligible radiolysis.	
J 1.2.04 Gas generation	Gas generation during metal corrosion is addressed. Gas formed due to microbial activity is discussed, and radiolysis is mentioned.	Gas transport and the low likelihood of gas accumulation are addressed in BMABa05.	

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Table A9-14. SR-PSU FEP BRTBa16 Speciation of radionuclides.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.14 Complexation by organics		Complexing agents are not disposed of in BRT.	
A 1.37 Geochemical pump		This FEP relates to BRTBa17.	
A 1.77 Speciation	Speciation is addressed.		
E GEN-27 Radionuclide precipitation and dissolution	Solubility limits are addressed.		
E SFR-20 Groundwater chemistry in the near-field		The impact of concrete on the water chemistry is addressed in BRTBa11, the removal of oxygen is addressed in BRTBa13 and BRTBa14. Organic complexing agents are addressed in BRTBa09 and the formation of gases in BRTBa15.	
H 1.5.5 Transport of chemically-active substances into the near-field		Complexing agents are not disposed of in BRT. Colloids are addressed in BRTBa10 and microorganisms in BRTBa13.	
H 5.1.3 Incomplete near-field chemical conditioning		BRT contains a large amount of concrete and is a multi-barrier system.	
I 044 Chealting agents		Complexing agents are not disposed of in BRT. Humic acids are addressed in BRTBa10.	
J 4.1.09 Complexing agents		Complexing agents are not disposed of in BRT. Humic acids are addressed in BRTBa10.	
J 5.44 Solubility and precipitation	Solubility limits are addressed.		
M 1.6.08 Dissolution, precipitation and cristallization	Solubility limits are addressed.		
S 060 Precipitation/dissolution	Solubility limits are addressed.		
W 2.056 Speciation	Speciation is addressed.		
W 2.057 Kinetics of speciation	Kinetics are addressed relative to transport processes.	In accordance with the FEP, kinetics of speciation reactions are not included in the assessment.	
W 2.068 Organic complexation		Complexing agents are not disposed of in BRT.	
W 2.071 Kinetics of organic complexation	Kinetics are addressed relative to transport processes.	Complexing agents are not disposed of in BRT. Colloidal effects (e.g. of humic acids) are not included in the assessment.	

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Table A9-15. SR-PSU FEP BRTBa17 Transport of radionuclides in the water phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.01 Backfill characteristics	The importance of material characteristics in sorption processes is addressed.		
A 1.22 Convection		Convection is expected to be negligible in the BRT as the wastes are not heat generating.	
A 1.37 Geochemical pump	Included implicitly in the discussion of transport and sorption.	Dissolution and precipitation of radionuclides are not considered.	A reference is given to supporting calculations that consider solubility limits.
A 1.65 Radioactive decay	Radioactive decay is addressed.		
E GEN-10 Radionuclide dispersion	Dispersion is addressed.		Dispersion is not included in the calculations as it is less than the numerical dispersion in the modelling.
E GEN-13 Electrochemical effects		The voids of the BRT vaults are assumed to be completely mixed for the safety assessment, and so this is not relevant.	
E GEN-28 Radioactive decay	Radioactive decay is addressed.	Heat generation is not relevant in the BRT.	
H 5.1.3 Incomplete near-field chemical conditioning		BRT contains a large amount of concrete and is a multi-barrier system.	
I 044 Chealting agents		Chelating agents are not disposed of in BRT.	
J 2.1.06.2 Natural telluric electrochemical reactions		The voids of the BRT vaults are assumed to be completely mixed for the safety assessment, and so this is not relevant.	
J 3.2.08 Preferential pathways in the buffer/backfill		BRT does not contain bentonite.	
J 4.1.09 Complexing agents		Chelating agents are not disposed of in BRT. Humic acids are addressed in BRTBa10.	
S 070 Radioactive decay of mobile nuclides	Radioactive decay is addressed.		

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Table A9-16. SR-PSU FEP BRTBa18 Transport of radionuclides in the gas phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.65 Radioactive decay		Radioactive decay is addressed in BRTBa17 and also applies here. Decay during transport is not relevant as the gas is assumed to reach the biosphere as soon as it forms.	
E GEN-28 Radioactive decay		Radioactive decay is addressed in BRTBa17 and also applies here. Decay during transport is not relevant as the gas is assumed to reach the biosphere as soon as it forms.	
I 127 Gas absorption (^{14}C in CO_2) into concrete walls		Gas is assumed to reach the biosphere as soon as it forms.	
K 0.3 Gaseous and volatile isotopes		Gaseous radionuclides are considered to be ^{14}C, ^{3}H and ^{222}Rn, of which ^{14}C is the most important.	
W 2.055 Radioactive gases	Radioactive gases are addressed.		
W 2.089 Transport of radioactive gases	The transport of radioactive gases is addressed.		

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Appendix 10

Handling of NEA Project FEPs sorted to SR-PSU BLA barrier processes

SR-PSU FEP BLABa01 Heat transport

No NEA FEP associated with this SR-PSU FEP.

Table A10-1. SR-PSU FEP BLABa02 Phase changes/freezing.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 268 Freeze/thaw cycles	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function.	Prior to permafrost, the concrete will not be exposed to freeze–thaw cycles due to the depth of SFR.	
J 5.17 Permafrost	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function.		
S 059 Permafrost	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function. Also, the changes in the hydrological situation are addressed.		

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Table A10-2. SR-PSU FEP BLABa03 Water uptake and transport during unsaturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.68 Reflooding	The relatively simple resaturation process is addressed.	Temperature, BLA wastes are not heat-generating.	
A 1.84 Transport in gases or of gases	The expected absence of trapped air in BLA is accounted for.		This FEP refers to the buffer.
A 1.88 Unsaturated transport	A prolonged unsaturated period is considered to be unlikely.		
E SFR-16 Hydraulic resaturation of the near-field	Resaturation and the lack of trapped air are addressed.	The change in redox conditions and concrete degradation are addressed in BLABa12 and BLABa13, and the low likelihood of gas accumulation in BLABa05. Thermal effects are not relevant to BLA.	
H 1.5.3 Unsaturated flow due to gas production		The low likelihood of gas accumulation is addressed in BLABa05.	
J 5.14 Resaturation	The relatively simple resaturation process in BLA is addressed.	The change in redox conditions is addressed in BLABa12 and BLABa13. Resaturation is considered to be fast so changes in the chemical conditions will not be handled in this period.	

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Table A10-3. SR-PSU FEP BLABa04 Water transport under saturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.41 Hydraulic head	Different hydraulic boundary conditions will be modelled.		
E SFR-21 Groundwater movement in the near-field	Different hydraulic boundary conditions will be modelled.	The influence of gas production, because fully saturated conditions are assumed. Gases are not expected to become trapped in BLA as there are no engineered barriers.	
H 1.5.4 Saturated ground-water flow	Saturated groundwater flow is addressed.		

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Table A10-4. SR-PSU FEP BLABa05 Gas transport/dissolution.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.84 Transport in gases or of gases	The low resistance to gas flow in the BLA is addressed.		
E SFR-12 Gas flow in the near-field	The low resistance to gas flow in the BLA is addressed.		
H 1.2.6 Gas transport	The low resistance to gas flow in the BLA is addressed.		
H 1.5.3 Unsaturated flow due to gas production	The low resistance to gas flow in the BLA is addressed.		
M 3.3.06 Gas effects	The low likelihood of gas pressurization in the BLA is addressed.		

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Table A10-5. SR-PSU FEP BLABa06 Mechanical processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.08 Cave ins	Fallout from the roof and walls of the rock vault is addressed.		
E GEN-03 Cave-in	Fallout from the roof and walls of the rock vault is addressed.		
E SFR-13 Mechanical impact on the engineered barriers		All, there are no engineered barriers in BLA.	
H 1.4.2 Vault collapse	Fallout from the roof and walls of the rock vault is addressed.	Radionuclide transport, the fallout of pieces of rock is not expected to affect the hydrological variables here.	
J 2.3.07.1 External stress	Fallout from the roof and walls of the rock vault is addressed.	Damage to the waste packages, as the waste packages are not considered to act as a barrier to radionuclide transport.	
J 3.2.07 Swelling of corrosion products		BLA does not have concrete barriers.	
M 3.1.02 Non-elastic reponse		There are no engineered barriers in BLA.	
M 3.3.04 Subsidence/collapse	Fallout from the roof and walls of the rock vault is addressed.		
S 004 Cave in	Fallout from the roof and walls of the rock vault is addressed.		
S 100 Volume increase of corrosion products		Relates specifically to the HLW repository design, not relevant for BLA.	
W 2.022 Roof falls	Fallout from the roof and walls of the rock vault is addressed		
W 2.035 Mechanical effects of backfill		There is no backfill in BLA.	

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Table A10-6. SR-PSU FEP BLABa07 Advection and dispersion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E GEN-10 Radionuclide dispersion	Dispersion is addressed in general.	The voids of the BLA vaults are assumed to be completely mixed for the safety assessment.	
J 4.1.08 Change of groundwater chemistry in nearby rock		This is handled in the geosphere process report.	See e.g. SR-PSU FEP Ge16.

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Table A10-7. SR-PSU FEP BLABa08 Diffusion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.36 Galvanic coupling		The voids of the BLA vaults are assumed to be completely mixed for the SR-PSU, with advection dominated flow in and out.	
E GEN-09 Diffusion		Not relevant to the handling (see NEA FEP A 1.36).	
E SFR-09 Diffusion in the near-field		Not relevant to the handling (see NEA FEP A 1.36).	
J 3.2.06 Diffusion - surface diffusion		Not relevant to the handling (see NEA FEP A 1.36).	
S 002 Anion-exclusion		Not relevant to the handling (see NEA FEP A 1.36).	
W 2.095 Galvanic coupling		Not relevant to the handling (see NEA FEP A 1.36).	
W 2.096 Electrophoresis		Not relevant to the handling (see NEA FEP A 1.36).	
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Table A10-8. SR-PSU FEP BLABa09 Sorption.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.73 Sorption	Sorption is defined and the K_d (linear sorption) approach is addressed.		
A 1.74 Sorption - nonlinear		Sorption is not included in the BLA calculations.	
E GEN-34 Radionuclide sorption	Radionuclide sorption is addressed.		
J 3.1.02 Saturation of sorption sites	The effect of the water composition on sorption is addressed.		
J 4.1.04 Sorption	Radionuclide sorption is addressed, and the relevance of oxidation state is mentioned.		
S 084 Sorption	Sorption is addressed, including the factors that affect it.		
W 2.061 Actinide sorption	Actinide sorption is included implicitly.		
W 2.062 Kinetics of sorption		Sorption is not included in the BLA calculations. Colloids are not included in the assessment.	
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Table A10-9. SR-PSU FEP BLABa10 Colloid transport and filtering.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.63 Psuedo-colloids	Colloid formation, stability and transport are addressed.	Colloids are not handled, as the BLA does not have a barrier function.	
I 058 Colloid formation (natural and vault generated)	Colloid formation and removal mechanisms are addressed.	Colloids are not handled, as the BLA does not have a barrier function.	
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Table A10-10. SR-PSU FEP BLABa11 Aqueous speciation and reactions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.77 Speciation	Chemical speciation is addressed.		

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Table A10-11. SR-PSU FEP BLABa12 Microbial processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.03 Biological activity	The effect of microbiological activity on the physical and chemical environment is addressed.		
A 1.53 Methylation	Methylation is discussed.		
E SFL-32 Microbial activity	The effect of microbiological activity on the physical and chemical environment is addressed. Microbial transport through fractures (due to colloidal size) is discussed.		
E SFR-11 Gas generation in the repository	Gas generation during microbial processes is addressed.	The low likelihood of gas accumulating in BLA (and therefore affecting radionuclide transport) is addressed in BLABa05.	
H 1.2.1 Hydrogen by metal corrosion	Microbial respiration of hydrogen is addressed.	Production of hydrogen during metal corrosion is addressed in BLABa13.	
H 1.2.3 Gas generation from concrete	Gas generation during microbial processes is addressed.	Radiolysis is not relevant to BLA.	
I 012 Biological activity (bacteria & microbes)	The effect of microbiological activity on the physical and chemical environment is addressed.		
I 015 Gas generation (CH_4, CO_2, H_2)	Gas generation during microbial processes is addressed.	Production of hydrogen during metal corrosion, which is addressed in BLABa13 The low likelihood of gas accumulating in BLA is discussed in BLABa05.	
J 2.1.10 Microbes	Both the dependence of microbial activity on the physicochemical conditions and the potential effects of microbial activity are addressed.		
K 3.17 Microbial activity	The production of organic complexing agents is discussed.		
M 3.2.07 Microbiological effects	The influence of microorganisms on material degradation and microbial dependency on nutrients are addressed.		
S 057 Microbial activity	The requirements of microbial growth and microbial adaptation are discussed. The effect of microbiological activity on the physical and chemical environment is addressed.		
W 2.044 Degradation of organic material	The degradation of cement additives is addressed.	The degradation of cellulosic, plastic and other synthetic materials is relevant to the waste form, not the barrier.	
W 2.045 Effect of temperature on microbial gas generation	The relationship between microbial activity and temperature is addressed.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
W 2.046 Effect of pressure on microbial gas generation		As this FEP states, pressure has less influence on microbial than chemical gas generation.	
W 2.048 Effect of biofilms on microbial gas generation		This is not discussed directly, as gas generation will occur predominantly in the waste form.	
W 2.076 Microbial growth on concrete	Microbial growth on concrete and acid production are addressed.		
W 2.088 Biofilms	Biofilms and their formation are discussed. The effect of biofilms on microbial and radionuclide transport is addressed implicitly via the effect of biofilms on water flow and the sorption of radionuclides by microorganisms.		

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Table A10-12. SR-PSU FEP BLABa13 Degradation of rock bolts, reinforcement and concrete.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E GEN-08 Degradation of the rock reinforcement and grout	All.		
E GEN-13 Electrochemical effects	Electrochemical effects on the corrosion of the metal components of the barriers are mentioned.		
E GEN-20 Gas generation in the near-field rock	Gas generation in the near field rock is addressed.		
E SFR-11 Gas generation in the repository	Gas generation in the steel components of the barriers is addressed.		
H 1.1.2 Physico-chemical degradation of concrete	The physical-chemical degradation of concrete is addressed.		
H 1.1.4 Electrochemical effects of metal corrosion		BLA does not have a barrier function.	
H 1.2.1 Hydrogen by metal corrosion	Hydrogen production is addressed.	The role of microbes in enhancing metal corrosion as the BLA does not have a barrier function.	
I 015 Gas generation (CH_4, CO_2, H_2)	Production of hydrogen during metal corrosion is addressed.	Gas generation during microbial processes is addressed in BLABa12. The low likelihood of gas accumulating in BLA is discussed in BLABa05.	
I 058 Colloid formation (natural and vault generated)		Colloids are not handled, as the BLA does not have a barrier function.	
I 061 Concrete (influence on vault chemistry)	The influence of concrete on the chemistry of the vault is addressed.		
I 062e Concrete (rebar corrosion)	Corrosion of reinforcement bars is included.		
I 071 Corrosive chemicals (in vault)		Corrosive chemical do not affect the BLA, as it has no barrier function.	
I 126 Corrosion (galvanic coupling)	Electrochemical effects on the corrosion of the metal components of the barriers are mentioned.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 1.2.07 Recrystallization	Recrystallization is discussed.		
J 1.2.08 Redox potential		Radiolysis is not relevant in BLA.	This is a parameter not a process.
J 2.1.06.2 Natural telluric electrochemical reactions	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
J 3.1.07 Reactions with cement pore water	The reactions of concrete with the pore water and the associated changes in pH are addressed.		
J 3.2.07 Swelling of corrosion products	The larger molar volume of corrosion products is addressed.		
K 2.14 Chemical buffering (canister corrosion products)		This relates to waste packaging.	
M 3.2.01 Metallic corrosion	Corrosion mechanisms are discussed. Chemical influences and hydrogen production are addressed.		
M 3.2.02 Interactions of host materials and ground water with repository materials	The effect of groundwater constituents on the concrete are addressed.	The interaction between glass and clays is not relevant to SFR.	
S 021 Degradation of rock reinforcement and grout		Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05, Design Mishaps.	
S 029 Electrochemical effects/gradients		This relates to waste packaging.	
S 074 Redox front	The influence of changing redox conditions on metal corrosion is addressed.		
S 100 Volume increase of corrosion products	The larger molar volume of corrosion products is addressed.		
W 2.050 Galvanic coupling	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
W 2.051 Chemical effects of corrosion	The effect of corrosion on the redox potential and gas generation are addressed.		
W 2.060 Kinetics of precipitation and dissolution	Precipitation and dissolution kinetics are mentioned.		
W 2.064 Effect of metal corrosion	The effect of corrosion on the redox potential is addressed.		
W 2.095 Galvanic coupling	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
W 2.096 Electrophoresis		The voids of the BLA vaults are assumed to be completely mixed for SR-PSU.	The FEP explains that the impact of electrophoresis is of low consequence.

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Table A10-13. SR-PSU FEP BLABa14 Speciation of radionuclides.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.14 Complexation by organics	The cellulose degradation product ISA is mentioned.		
A 1.77 Speciation	Speciation is addressed.		
E GEN-27 Radionuclide precipitation and dissolution	Solubility limits are addressed.		Radionuclide solubility limits are not considered in SR-PSU.
E SFR-20 Groundwater chemistry in the near-field		The impact of concrete on the water chemistry is addressed in BLABa13, and the formation of gases and removal of oxygen in BLABa12 and BLABa13. Organic complexing agents are not addressed as sorption is not included in the calculations.	
H 1.5.5 Transport of chemically-active substances into the near-field	Complexing agents are mentioned.	Colloids and microbial processes are not handled, as the BLA does not have a barrier function.	
H 5.1.3 Incomplete near-field chemical conditioning		Near-field chemical conditioning is not part of the BLA design.	
I 044 Chealting agents	The cellulose degradation product ISA is mentioned.		
J 4.1.09 Complexing agents	The cellulose degradation product ISA is mentioned.		
J 5.44 Solubility and precipitation	Solubility limits are addressed.		Radionuclide solubility limits are not considered in SR-PSU.
M 1.6.08 Dissolution, precipitation and cristallization	Solubility limits are addressed.		Radionuclide solubility limits are not considered in SR-PSU.
S 060 Precipitation/dissolution	Solubility limits are addressed.		Radionuclide solubility limits are not considered in SR-PSU.
W 2.056 Speciation	Speciation is addressed.		
W 2.057 Kinetics of speciation	Solubility limits are addressed.		Radionuclide solubility limits are not considered in SR-PSU.
W 2.068 Organic complexation	The cellulose degradation product ISA is mentioned.		
W 2.071 Kinetics of organic complexation		Not relevant since sorption is not included in the calculations.	

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Table A10-14. SR-PSU FEP BLABa15 Transport of radionuclides in the water phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.65 Radioactive decay	Radioactive decay is addressed.		
E GEN-10 Radionuclide dispersion	Dispersion is addressed.		The voids of the BLA vaults are assumed to be completely mixed for SR-PSU.
E GEN-13 Electrochemical effects		The voids of the BLA vaults are assumed to be completely mixed for SR-PSU.	
E GEN-28 Radioactive decay	Radioactive decay is addressed.	Heat generation is not relevant in the BLA.	
H 5.1.3 Incomplete near-field chemical conditioning		Near-field chemical conditioning is not part of the BLA design.	
I 044 Chealting agents		Sorption is not included in the calculations.	
J 2.1.06.2 Natural telluric electrochemical reactions		The voids of the BLA vaults are assumed to be completely mixed for SR-PSU.	
J 4.1.09 Complexing agents		Sorption is not included in the calculations.	
S 070 Radioactive decay of mobile nuclides	Radioactive decay is addressed.		
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Table A10-15. SR-PSU FEP BLABa16 Transport of radionuclides in the gas phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.65 Radioactive decay		Radioactive decay is addressed in BLABa15 and also applies here.	
E GEN-28 Radioactive decay		Radioactive decay is addressed in BLABa15 and also applies here.	
K 0.3 Gaseous and volatile isotopes		Gaseous radionuclides are considered to be ^{14}C, ^{3}H and ^{222}Rn, of which ^{14}C is the most important.	
W 2.055 Radioactive gases	Radioactive gases are addressed.		
W 2.089 Transport of radioactive gases	The transport of radioactive gases is addressed.		
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Appendix 11

Handling of NEA Project FEPs sorted to SR-PSU processes for plugs and other closure components

Table A11-1. SR-PSU FEP Pg01 Heat transport.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
S 093 Temperature, tunnel backfill		SFR waste is not heat generating.	

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Table A11-2. SR-PSU FEP Pg02 Phase changes/freezing.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
H 5.1.2 Loss of integrity of shaft or access tunnel seals	Loss of integrity is addressed.	Effect on water flow is addressed in Pg04.	
I 268 Freeze/thaw cycles	Permafrost is considered to lead to widespread cracking of the concrete that results in loss of the barrier function.	Prior to permafrost, the concrete will not be exposed to freeze–thaw cycles due to the depth of SFR.	
I 277 Soil liquefaction		The SFR is constructed from rock.	
J 5.17 Permafrost	The effects of permafrost on the concrete and bentonite are addressed.		
S 059 Permafrost	The effects of permafrost on the concrete and bentonite are addressed. Also, the changes in the hydrological situation are addressed.		

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Table A11-3. SR-PSU FEP Pg03 Water uptake and transport during unsaturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 5.14 Resaturation	The special hydraulic conditions during resaturation are discussed.	The change in redox conditions is addressed in Pg17 and Pg19.	
K 3.03 Bentonite saturation	The resaturation of the bentonite is addressed.		
S 079 Resaturation of bentonite buffer	The resaturation of the bentonite is addressed.		

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Table A11-4. SR-PSU FEP Pg04 Water transport under saturated conditions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.59 Percolation in shafts		Temperature gradients are expected to be small as the SFR waste is not significantly heat generating.	
A 1.72 Seal failure	The degradation of the sealing function of the plugs is addressed.		
A 2.04 Borehole seal failure	The degradation of the sealing function of the plugs is addressed.		
A 2.60 Shaft seal failure	The degradation of the sealing function of the plugs is addressed.		
K 3.08 Buffer imperme-ability	The low hydraulic conductivity of bentonite is addressed.		
S 037 Flow through buffer/backfill	Factors affecting flow through the bentonite are addressed.	Influence on copper canister corro-sion, as the SFR does not contain HLW.	
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Table A11-5. SR-PSU FEP Pg05 Gas transport/dissolution.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 3.2.12 Gas transport in bentonite	Gas transport in bentonite is addressed.		
K 3.15 Gas permeability	Gas breakthrough after the build-up of sufficient pressure is addressed.		
M 3.3.06 Gas effects	The effect of gas pressure is addressed.		
S 041 Gas flow and transport, buffer/backfill	Gas flow through the bentonite is addressed.		
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Table A11-6. SR-PSU FEP Pg06 Piping/erosion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 3.2.04 Erosion of buffer/backfill	The effects of flow rate and water composition on erosion are addressed.		
J 3.2.08 Preferential path-ways in the buffer/backfill	The effect of the loss of bentonite is addressed.		
J 3.2.09 Flow through buffer/backfill	The effect of piping on water flow is addressed.		
J 5.11 Degradation of hole- and shaft seals	The degradation of the sealing function of the plugs is addressed.		
K 3.06 Bentonite erosion	Bentonite erosion is addressed.		
S 025 Dilution of buffer/backfill	The lowering of the bentonite density and its effect on hydraulic properties are addressed.		
S 031 Erosion of buffer/backfill	The effects of flow rate and water composition on erosion are addressed.		
W 2.083 Rinse		Rinse is not relevant to the flow conditions in the plugs.	
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Table A11-7. SR-PSU FEP Pg07 Mechanical processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E GEN-03 Cave-in	The influence of rock fallout on the crushed rock backfill in the tunnels is mentioned. The swelling pressure of the bentonite is addressed in terms of keeping the rock in place.		
H 5.1.2 Loss of integrity of shaft or access tunnel seals		The effect on water transport is addressed in Pg04.	
I 298 Swelling pressure (clay)	Swelling pressure is addressed.		
J 2.3.07.1 External stress	The influence of rock fallout on the crushed rock backfill in the tunnels s mentioned. The swelling pressure of the bentonite is addressed in terms of keeping the rock in place.	Damage to the waste packages, as this is not relevant here.	
J 3.2.01.1 Swelling of bentonite into tunnels and cracks	Bentonite swelling into void spaces is addressed.		
J 3.2.01.2 Uneven swelling of bentonite	Inhomogeneities in the bentonite filling are addressed.		
J 3.2.03 Mechanical failure of buffer/backfill	Mechanical failure of the bentonite is addressed.		
J 3.2.07 Swelling of corrosion products	Stresses caused by the corrosion of steel reinforcement are addressed.		
J 5.11 Degradation of hole- and shaft seals	Degradation of the sealing function of the plugs is addressed.		
K 3.04 Bentonite swelling pressure	Swelling pressure is addressed.		
K 3.05 Bentonite plasticity	The swelling and self-healing properties of bentonite are addressed.		
M 2.1.02 Investigation borelhole seal failure and degradation		Unsealed boreholes are addressed in the Initial State FEP ISGen05, Design Mishaps.	
M 2.1.03 Shaft or access tunnel seal failure and degradation		Unsealed boreholes are addressed in the Initial State FEP ISGen05, Design Mishaps.	
M 3.1.01 Differential elastic response		This relates to thermal expansion, and the SFR wastes are not significantly heat generating.	
M 3.1.02 Non-elastic reponse	Mechanical failure of the bentonite is addressed.		
M 3.3.04 Subsidence/collapse		Not relevant due to the backfill used.	This FEP was rejected on the basis of the presence of backfill and appropriate QA.
S 004 Cave in	Fallout from the roof and walls of the rock vault is addressed.	Effect on the waste packages is not relevant here.	
S 020 Degradation of hole and shaft seals	The degradation of the plugs is addressed.		
S 025 Dilution of buffer/backfill	The lowering of the bentonite density and its effect on hydraulic properties are addressed.		
S 056 Mechanical impact/failure, buffer/backfill	Creep deformations and rock fallout are addressed. The swelling pressure of the bentonite is addressed in terms of keeping the rock in place.		
S 100 Volume increase of corrosion products		Relates specifically to the HLW repository design, not relevant for the closure components.	
W 2.022 Roof falls	Fallout from the roof and walls of the rock vault is addressed. The swelling pressure of the bentonite is addressed in terms of keeping the rock in place.		t
W 2.035 Mechanical effects of backfill	The mechanical properties of the backfill are mentioned.		
W 2.037 Mechanical degradation of seals	The lowering of the bentonite density and its effect on hydraulic properties are addressed.		

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Table A11-8. SR-PSU FEP Pg08 Advection and dispersion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 3.2.08 Preferential pathways in the buffer/backfill	The relationship between geometry and water transport is addressed.		
J 4.1.08 Change of groundwater chemistry in nearby rock		This is handled in the geosphere process report.	See e.g. SR-PSU FEP Ge16.
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Table A11-9. SR-PSU FEP Pg09 Diffusion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 3.2.06 Diffusion - surface diffusion	Surface diffusion is addressed.		
J 4.1.08 Change of groundwater chemistry in nearby rock		This is handled in the geosphere process report.	See e.g. SR-PSU FEP Ge16.
M 1.6.14 Chemical gradients (electrochemical effects, osmosis)	Chemical gradients are addressed.		
S 002 Anion-exclusion	Anion exclusion is addressed.		
S 023 Diffusion	Diffusion, anion exclusion and surface diffusion are addressed.		
W 2.095 Galvanic coupling		Transport due to the presence of an electrical field is not addressed here, but mentioned in SiBa09.	
W 2.096 Electrophoresis		The FEP explains that the impact of electrophoresis is of low consequence for diffusion.	
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Table A11-10. SR-PSU FEP Pg10 Sorption (including ion exchange of major ions).

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 3.1.02 Saturation of sorption sites	The dependency of the K_d concept on conditions that do not lead to surface saturation is discussed.		
J 4.1.04 Sorption	Sorption is addressed.		
M 1.6.07 Sorption	Sorption is addressed.		
M 1.6.14 Chemical gradients (electrochemical effects, osmosis)		The effect of chemical gradients on transport are addressed in Pg09.	
S 018 Deep saline water intrusion	The relevance of water composition is addressed.		
S 084 Sorption	Sorption is addressed.		
W 2.061 Actinide sorption	Actinide sorption is addressed implicitly.		Sorption is neglected in the plugs.
W 2.062 Kinetics of sorption	The kinetics of sorption processes is addressed.		
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Table A11-11. SR-PSU FEP Pg11 Alteration of impurities in bentonite.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.71 Seal evolution	The alteration of impurities is addressed.	Inadequate sealing is addressed in the Initial State FEP ISGen05, Design Mishaps.	
E GEN-07 Degradation of the borehole and shaft seals	The alteration of impurities is addressed.	Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05, Design Mishaps.	
H 5.1.1 Loss of integrity of borehole seals		Unsealed boreholes are addressed in the Initial State FEP ISGen05, Design Mishaps.	
J 3.1.01 Degradation of the bentonite by chemical reactions	The alteration of impurities is addressed.	The degradation of montmorillonite is addressed in Pg15.	
J 3.1.03 Effects of bentonite on groundwater chemistry	The alteration of impurities is addressed.	The degradation of montmorillonite is addressed in Pg15.	
J 5.11 Degradation of hole- and shaft seals	The alteration of impurities is addressed.	Unsealed boreholes and shafts are addressed in the Initial State FEP ISGen05, Design Mishaps.	
M 2.1.02 Investigation borelhole seal failure and degradation		Unsealed boreholes are addressed in the Initial State FEP ISGen05, Design Mishaps.	
M 2.1.03 Shaft or access tunnel seal failure and degradation	The alteration of impurities is addressed.	Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05, Design Mishaps.	
S 006 Chemical alteration of buffer/backfill	The alteration of impurities is addressed.	The degradation of montmorillonite is addressed in Pg15.	
S 020 Degradation of hole and shaft seals	The alteration of impurities is addressed.	Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05, Design Mishaps.	
S 094 Thermal degradation of buffer/backfill		Temperature gradients will be low in the closure components (cf HLW).	
W 2.074 Chemical degradation of seals	The alteration of impurities is addressed.	Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05, Design Mishaps.	

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Table A11-12. SR-PSU FEP Pg12 Dissolution, precipitation, recrystallisation and clogging in backfill.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.71 Seal evolution		This process relates to the backfill, not the seals. Inadequate sealing is addressed in the Initial State FEP ISGen05 Design Mishaps.	
E GEN-07 Degradation of the borehole and shaft seals		This process relates to the backfill, not the seals.	
H 1.1.2 Physico-chemical degradation of concrete	The physico-chemical degradation of concrete is addressed.		
H 5.1.1 Loss of integrity of borehole seals		This process relates to the backfill, not the seals.	
H 5.1.2 Loss of integrity of shaft or access tunnel seals		This process relates to the backfill, not the seals. Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05 Design Mishaps.	
I 058 Colloid formation (natural and vault generated)		Colloids are addressed in Pg16.	
I 061 Concrete (influence on vault chemistry)	The influence of concrete on the water chemistry is addressed.		
J 1.2.07 Recrystallization	Recrystallisation is discussed.		
J 3.1.07 Reactions with cement pore water	The reactions of concrete with the pore water and the associated changes in pH are addressed.		
M 2.1.02 Investigation borelhole seal failure and degradation		Unsealed boreholes are addressed in the Initial State FEP ISGen05 Design Mishaps.	
M 2.1.03 Shaft or access tunnel seal failure and degradation		This process relates to the backfill, not the seals. Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05 Design Mishaps.	
M 3.2.02 Interactions of host materials and ground water with repository materials	The effect of groundwater constituents on the concrete are addressed.	The interaction between glass and clays is not relevant to SFR.	
S 020 Degradation of hole and shaft seals		This process relates to the backfill, not the seals. Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05 Design Mishaps.	
W 2.060 Kinetics of precipitation and dissolution	Precipitation and dissolution kinetics are mentioned.	Radionuclide solubility limits are addressed in Pg19.	
W 2.073 Concrete hydration	The heat liberated during concrete hydration is addressed.		
W 2.074 Chemical degradation of seals		This process relates to the backfill, not the seals. Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05 Design Mishaps.	

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SR-PSU FEP Pg13 Aqueous speciation and reactions

No NEA FEP associated with this PSU FEP.

Table A11-13. SR-PSU FEP Pg14 Osmosis.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
M 1.6.14 Chemical gradients (electrochemical effects, osmosis)	Chemical gradients and osmosis are addressed.		
W 2.098 Osmotic processes	Osmotic processes are addressed.		

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Table A11-14. SR-PSU FEP Pg15 Montmorillonite transformation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.71 Seal evolution	Montmorillonite transformations are addressed.	Inadequate sealing is addressed in the Initial State FEP ISGen05 Design Mishaps.	
E GEN-07 Degradation of the borehole and shaft seals	Montmorillonite transformations are addressed.	Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05 Design Mishaps.	
H 5.1.1 Loss of integrity of borehole seals		Unsealed boreholes are addressed in the Initial State FEP ISGen05 Design Mishaps.	
I 048 Buffer (degradation by concrete)	The influence of concrete degradation on the montmorillonite is addressed.		
J 3.1.01 Degradation of the bentonite by chemical reactions	Montmorillonite transformations and the effect on water flow are addressed.		
J 3.2.05 Thermal effects on the buffer material		Thermal effects are not relevant in SFR.	
J 5.11 Degradation of hole- and shaft seals	Montmorillonite transformations are addressed.	Unsealed boreholes are addressed in the Initial State FEP ISGen05 Design Mishaps.	
K 3.12b Mineralogical alteration - long term	The long term mineralogical alterations of montmorillonite are addressed.		
K 3.25 Interaction with cement components	The effect of cement components on montmorillonite transformations is addressed.		
M 2.1.02 Investigation borelhole seal failure and degradation		Unsealed boreholes are addressed in the Initial State FEP ISGen05 Design Mishaps.	
M 2.1.03 Shaft or access tunnel seal failure and degradation		Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05 Design Mishaps.	
S 006 Chemical alteration of buffer/backfill	Montmorillonite transformations and the effect on the plugs are addressed.	Canister corrosion is not relevant.	
S 020 Degradation of hole and shaft seals	Montmorillonite transformations and the effect on the plugs are addressed.	Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05 Design Mishaps.	
S 094 Thermal degradation of buffer/backfill		Thermal effects are not relevant to SFR.	
W 2.074 Chemical degradation of seals	Montmorillonite transformations and the effect on the plugs are addressed.	Inadequate sealing is addressed in the Initial State FEP ISGen05 Design Mishaps.	

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Table A11-15. SR-PSU FEP Pg16 Montmorillonite colloid release.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 058 Colloid formation (natural and vault generated)	Montmorillonite colloid formation and stability are addressed.		
J 3.1.04 Colloid generation - source	Montmorillonite colloid formation and stability are addressed.		
J 3.1.05 Coagulation of bentonite	Coagulation of bentonite is addressed.		
J 3.1.06 Sedimentation of bentonite	Sedimentation of bentonite is discussed.		
S 007 Coagulation of bentonite	Coagulation of bentonite is addressed.		
S 009 Colloid generation-source	Montmorillonite colloid formation is addressed.		
S 025 Dilution of buffer/backfill	Loss of the bentonite is addressed.		
S 082 Sedimentation of bentonite	Sedimentation of bentonite is discussed.		
W 2.082 Suspensions of particles		The low water flow (diffusion-controlled in the bentonite) is not expected to create particle suspensions.	
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Table A11-16. SR-PSU FEP Pg17 Microbial processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
H 5.1.1 Loss of integrity of borehole seals	The influence of microorganisms on material degradation is addressed.	Unsealed boreholes are addressed in the Initial State FEP ISGen05 Design Mishaps.	
I 270 Seeds in vault/wate		Fungi are aerobic, and aerobic conditions are not expected to persist for a significant time.	
J 2.1.10 Microbes	Both the dependence of microbial activity on the physico-chemical conditions and the potential effects of microbial activity are addressed.		
K 3.17 Microbial activity	The production of organic complexing agents is discussed.		
M 3.2.07 Microbiological effects	The influence of microorganisms on material degradation and microbial dependency on nutrients are addressed.		
S 044 Gas generation, buffer/backfill	Microbial gas generation is addressed.	Radiolysis will be negligible in the plugs.	
S 057 Microbial activity	The requirements of microbial growth and microbial adaptation are discussed. The effect of microbiological activity on the physical and chemical environment is addressed.		
W 2.044 Degradation of organic material	The degradation of cement additives is addressed.	The degradation of cellulosic, plastic and other synthetic materials is not relevant to the plugs.	
W 2.045 Effect of temperature on microbial gas generation	The relationship between microbial activity and temperature is addressed.		
W 2.046 Effect of pressure on microbial gas generation		As this FEP states, pressure has less influence on microbial than chemical gas generation.	
W 2.048 Effect of biofilms on microbial gas generation		This is not discussed directly, as gas generation will occur predominantly in the waste form.	
W 2.076 Microbial growth on concrete	Microbial growth on concrete and acid production are addressed.		
W 2.088 Biofilms	Biofilms and their formation are discussed.		
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Table A11-17. SR-PSU FEP Pg18 Degradation of rock bolts, reinforcements and concrete.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.71 Seal evolution	The degradation of concrete is addressed in general.	Inadequate sealing is addressed in the Initial State FEP ISGen05 Design Mishaps.	
E GEN-07 Degradation of the borehole and shaft seals	The degradation of concrete is addressed in general.	Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05 Design Mishaps.	
E GEN-08 Degradation of the rock reinforcement and grout	Degradation of the rock reinforcement and grout are addressed.		
H 1.1.4 Electrochemical effects of metal corrosion		This is not addressed as the main effect of metal corrosion is to enhance water flow.	
H 5.1.1 Loss of integrity of borehole seals	The degradation of concrete is addressed in general.	Unsealed boreholes are addressed in the Initial State FEP ISGen05 Design Mishaps.	
H 5.1.2 Loss of integrity of shaft or access tunnel seals	The degradation of concrete is addressed in general.	Inadequate sealing is addressed in the Initial State FEP ISGen05 Design Mishaps.	
I 062e Concrete (rebar corrosion)	Corrosion of reinforcement bars is addressed.		
I 071 Corrosive chemicals (in vault)		Corrosive chemicals arise from the waste and will have the greatest influence in the waste form and packaging.	
J 1.2.08 Redox potential		Radiolysis is not relevant in the closure components.	This is a parameter not a process.
J 2.1.06.2 Natural telluric electrochemical reactions	The potential influence of natural telluric currents and induced currents from electrical conductors on metal corrosion are mentioned.		
J 3.2.07 Swelling of corrosion products	The larger molar volume of corrosion products is addressed.	Stresses caused by the degradation of metal components is addressed in Pg07.	
K 2.14 Chemical buffering (canister corrosion products)		This relates to waste packaging.	
M 3.2.01 Metallic corrosion	Corrosion mechanisms are discussed. Chemical influences and hydrogen production are addressed.		
S 020 Degradation of hole and shaft seals	The degradation of concrete is addressed in general.	Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05 Design Mishaps.	
S 021 Degradation of rock reinforcement and grout	Degradation of the rock reinforcement and grout are addressed.		
S 029 Electrochemical effects/gradients		This relates to waste packaging.	
S 074 Redox front	The influence of changing redox conditions on metal corrosion is addressed.		
S 100 Volume increase of corrosion products		Relates specifically to the HLW repository design, not relevant for SFR.	
W 2.050 Galvanic coupling	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
W 2.051 Chemical effects of corrosion	The effect of corrosion on the redox potential and gas generation are addressed.		
W 2.064 Effect of metal corrosion	The effect of corrosion on the redox potential is addressed.		
W 2.074 Chemical degradation of seals	The degradation of concrete is addressed in general.	Unsealed vaults and shafts are addressed in the Initial State FEP ISGen05 Design Mishaps.	
W 2.095 Galvanic coupling	The potential influence of natural telluric currents and induced currents from electrical conductors are mentioned.		
W 2.096 Electrophoresis		The FEP explains that the impact of electrophoresis is of low consequence.	

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Table A11-18. SR-PSU FEP Pg19 Speciation of radionuclides.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 4.1.09 Complexing agents	Complexing agents are mentioned.		
J 5.44 Solubility and precipitation	Solubility limits are addressed.		
M 1.6.08 Dissolution, precipitation and cristal-lization	Solubility limits are addressed.		
S 060 Precipitation/ dissolution	Solubility limits are addressed.		
W 2.056 Speciation	Speciation is addressed.		
W 2.057 Kinetics of speciation	Kinetics are addressed relative to transport processes.		
W 2.068 Organic complexation	Complexing agents are mentioned.		
W 2.071 Kinetics of organic complexation	Kinetics are addressed relative to transport processes.		

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Table A11-19. SR-PSU FEP Pg20 Transport of radionuclides in the water phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.04 Borehole seal failure		The plugs are not included in the radionu-clide transport modelling.	The effect of the plugs on the water flux in SFR is addressed in Pg04.
A 2.60 Shaft seal failure		The plugs are not included in the radionu-clide transport modelling.	The effect of the plugs on the water flux in SFR is addressed in Pg04.
J 2.1.06.2 Natural telluric electrochemical reactions		The plugs are not included in the radionu-clide transport modelling.	
J 3.2.08 Preferential pathways in the buffer/ backfill		The plugs are not included in the radionu-clide transport modelling.	The effect of the plugs on the water flux in SFR is addressed in Pg04.
J 4.1.09 Complexing agents		The plugs are not included in the radionu-clide transport modelling.	
S 009 Colloid generation-source		The plugs are not included in the radionu-clide transport modelling.	
S 070 Radioactive decay of mobile nuclides		The plugs are not included in the radionu-clide transport modelling.	
S 099 Transport and release of nuclides, tunnel backfill		The plugs are not included in the radionu-clide transport modelling.	The effect of the plugs on the water flux in SFR is addressed in Pg04

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Table A11-20. SR-PSU FEP Pg21 Transport of radionuclides in the gas phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 127 Gas absorption (^{14}C in CO_2) into concrete walls		The plugs are not included in the radionuclide transport modelling.	
K 0.3 Gaseous and volatile isotopes		The plugs are not included in the radionuclide transport modelling.	
S 099 Transport and release of nuclides, tunnel backfill		The plugs are not included in the radionuclide transport modelling.	
W 2.055 Radioactive gases		The plugs are not included in the radionuclide transport modelling.	
W 2.089 Transport of radioactive gases		The plugs are not included in the radionuclide transport modelling.	
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Appendix 12

Handling of NEA Project FEPs sorted to PSU Geosphere processes

Table A12-1. SR-PSU FEP Ge01 Heat transport.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.69 Unsaturated rock	Relevant aspects addressed.		See SR-PSU FEP Ge03.
E GEN-38 Temperature of the far-field	Thermal gradients in rock.	Non-heat generating waste, hence no influence from repository.	Aspects of mechanical stress considered in SR-PSU FEP Ge07.
K 5.13 Geothermal regime	Thermal gradients in rock.		Same as K 6.13.
K 6.13 Geothermal regime	Thermal gradients in rock.		Same as K 5.13.
S 091 Temperature, far-field	Thermal gradients in rock.	Non-heat generating waste, hence no influence from repository.	See also SR-PSU FEP Ge03.
S 092 Temperature, near-field rock	Thermal gradients in rock.	Non-heat generating waste, hence no influence from repository.	See also SR-PSU FEP Ge03.
Recorded by: Teresita Morales, Magnus Sidborn			**Date:** 2014-07-02
Checked and revised by: Kristina Skagius			**Date:** 2014-08-27
Revisions approved by: Teresita Morales			**Date:** 2014-09-24

Table A12-2. SR-PSU FEP Ge02 Freezing.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E GEN-26 Permafrost	Permafrost and its impacts are described.		See also SR-PSU FEP Ge03.
E GEN-38 Temperature of the far-field	Thermal gradients in rock.	Non-heat generating waste, hence no influence from repository.	Aspects of mechanical stress considered in Ge07.
H 3.1.2 Climate change: Natural	Climate change is addressed.		
I 268 Freeze/thaw cycles	Freezing and thawing and effects are addressed.		
J 5.17 Permafrost	Permafrost and its impacts are described.		
K 10.13 Permafrost	Permafrost and its impacts are described.		See also SR-PSU FEP Ge03.
K 10.16 Ice sheet effects (loading, melt water recharge)		Effects of ice-sheet advance over permafrost are not specifically addressed here, but in SR-PSU FEPs Cli06 and Ge03.	
S 059 Permafrost	Permafrost and its impacts are described.		See also SR-PSU FEP Ge03.
S 091 Temperature, far-field	Coupling between freezing and temperature is addressed.		
Recorded by: Teresita Morales			**Date:** 2014-08-26
Checked and revised by: Kristina Skagius			**Date:** 2014-08-27
Revisions approved by: Teresita Morales			**Date:** 2014-09-24

Table A12-3. SR-PSU FEP Ge03 Groundwater flow.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.12 Climate change	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
A 1.41 Hydraulic head	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
A 1.67 Recharge groundwater	Addressed in the process report.		See SR-PSU FEP Ge10.
A 1.68 Reflooding	Saturation addressed in the process report but not in the modelling.		Details in SKB R-13-25.
A 2.01 Blasting and vibration	The EDZ is addressed in the process report but not in the modelling.		
A 2.04 Borehole seal failure		Flow in open boreholes is not addressed here, but is covered by the SR-PSU initial state FEP ISGen05 Design deviations – Mishaps.	
A 2.06 Cavitation		Is considered not to be an issue for crystalline rock.	
A 2.13 Damaged zone	The EDZ is addressed in the process report but not in the modelling.		See NEA FEP A 2.01.
A 2.15 Dewatering	Saturation addressed in the process report but not in the modelling.		Details in SKB R-13-25.
A 2.17 Discharge zones	Hydrologic cycle addressed in the process report and discharged zones part of the modelling.		Details in SKB R-13-25.
A 2.22 Erosion		Not addressed in the process report but erosion and accumulation are considered in the landscape evolution.	See also SR-PSU Climate FEP Cli10.
A 2.27 Gases and gas transport	Addressed in the process report but not considered in the modelling.		
A 2.28 Geothermal gradient effects	Addressed in the process report and considered in the permafrost modelling.		Details in SKB R-13-25.
A 2.30 Glaciation	Addressed in the process report but not considered in the modelling.		Details in SKB R-13-25.
A 2.35 Hydraulic properties - evolution	Addressed in the process report but not considered in the modelling.		
A 2.57 Salinity effects on flow	Addressed in the process report but not considered in the modelling.		
A 2.59 Sea level change	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
A 2.60 Shaft seal failure	Not addressed in the process report but handled in the near-field modelling.		Details in SKB TR-13-08.
A 2.69 Unsaturated rock	Saturation addressed in the process report but not in the modelling.		Details in SKB R-13-25.
A 2.73 Wells	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
A 2.74 Wells (high-demand)		This FEP is not relevant for the site considered.	
E GEN-06 Groundwater salinity changes	Addressed in the process report but not considered in the modelling.		See NEA FEP A 2.57.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E GEN-12 Earth tides		Not addressed in the process report since this occurs on a much shorter time scale than the time scales relevant to the repository performance.	
E GEN-15 Excavation effects on the near field rock	The EDZ is addressed in the process report but not in the modelling.		See NEA FEP A 2.01.
E GEN-16 External flow boundary conditions	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
E GEN-21 Glaciation	Addressed in the process report but not considered in the modelling.		Details in SKB R-13-25.
E GEN-23 Groundwater flow	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
E GEN-26 Permafrost	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
E GEN-29 Erosion and weathering		Not addressed in the process report but erosion and accumulation are considered in the landscape evolution.	See also SR-PSU Biosphere FEP Bio29 and Climate FEP Cli10.
E GEN-32 Hydraulic resaturation of the near-field rock	Saturation addressed in the process report but not in the modelling.		
E GEN-33 Sea level changes	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
E GEN-35 Fast transport pathways	Not addressed in the process report but considered in the modelling.		Details in SKB R-13-25.
E GEN-37 Surface water chemistry		Not addressed because this FEP is not relevant for the site considered.	
H 1.5.1 Desaturation (pumping) effects	Open repository addressed in the process report but not in the modelling.		Details in SKB R-13-25.
H 1.5.2 Disturbed zone (hydromechanical) effect	The EDZ is addressed in the process report but not in the modelling.		See NEA FEP A 2.01
H 1.5.3 Unsaturated flow due to gas production	Addressed in the process report but not considered in the modelling.		
H 1.5.4 Saturated groundwater flow	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
H 2.2.1 Changes in geometry and driving forces of the flow system	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
H 2.2.2 Rock property changes	Addressed in the process report and considered in the permafrost modelling.		Details in SKB R-13-25.
H 2.3.7 Far-field transport: Changes in groundwater chemistry and flow direction	Addressed in the process report.		See also SR-PSU FEP Ge10.
H 2.3.11 Far-field transport: Gas induced groundwater transport	Addressed in the process report but not considered in the modelling.		
H 2.4.1 Generalised denudation		Not addressed in the process report but denudation is considered in the landscape evolution.	See SR-PSU FEP Cli10.
H 2.4.2 Localised denudation		Not addressed in the process report but denudation is considered in the landscape evolution.	See SR-PSU FEP Cli10.
H 3.1.2 Climate change: Natural	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
H 4.1.1 Groundwater discharge to soils and surface waters	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
H 5.1.2 Loss of integrity of shaft or access tunnel seals	Not addressed in the process report but considered in the near-field modelling.		Details in SKB TR-13-08.
I 022 Explosions/bombs/ blasting/collision/ impacts/ vibration		This FEP is not relevant for the site considered.	
I 049 Climate change	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
I 085a Dams (filling, draining)		This FEP is not relevant for the site considered.	
I 143 Groundwater (redirection of)	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
I 266 Sea level (rising)	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
J 4.2.02.1 Excavation/ backfilling effects on nearby rock	Addressed in the process report but not considered in the modelling.		
J 4.2.03 Extreme channel flow of oxidants and nuclides		Extreme channel flow is not addressed in the process report. Moderate channeling is mimicked by spatially varying the properties of discrete features such as deformation zones and discrete fractures.	Details in SKB R-13-25.
J 4.2.06 Faulting	Addressed in the process report but not considered in the modelling.		
J 4.2.07 Thermo-hydro-mechanical effects	Addressed in the process report and considered in the permafrost modelling.		Details in SKB R-13-25.
J 5.01 Saline (or fresh) groundwater intrusion	Addressed in the process report but not considered in the modelling.		
J 5.14 Resaturation	Saturation addressed in the process report but not in the modelling.		
J 5.16 Uplift and subsidence	Addressed in the process report and considered in the permafrost modelling.		Details in SKB R-13-25.
J 5.27 Human induced actions on groundwater recharge	Addressed in the process report and considered in the modelling.		Details in SKB TR-14-08.
J 5.31 Change in sealevel	Addressed in the process report and considered in the permafrost modelling.		Details in SKB R-13-25.
J 5.42 Glaciation	Addressed in the process report but not considered in the modelling.		Details in SKB R-13-25.
J 6.13 Geothermally induced flow		This FEP is not relevant for this kind of repository.	
J 7.07 Human induced changes in surface hydrology	Addressed in the process report and considered in the modelling.		Details in SKB TR-14-08.
K 4.01 Excavation-disturbed zone (EDZ)	The EDZ is addressed in the process report but not in the modelling.		See NEA FEP A 2.01.
K 4.03 Desaturation/ resaturation of EDZ	The EDZ is addressed in the process report but not in the modelling.		See NEA FEP A 2.01.
K 4.07 Water flow at the bentonite–host rock interface		This FEP is not relevant for this kind of repository.	

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
K 4.08 Radionuclide migration		This FEP is not relevant for this kind of repository.	
K 5.11 Intrusion of saline groundwater	Addressed in the process report but not considered in the modelling.		Details in SKB R-13-25.
K 5.12 Density-driven groundwater flow (thermal)	Addressed in the process report and considered in the permafrost modelling.		Details in SKB R-13-25.
K 5.17 Gas pressure effects	Addressed in the process report but not considered in the modelling.		
K 5.18 Hydraulic gradient changes (magnitude, direction)	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
K 6.11 Intrusion of saline groundwater	Addressed in the process report but not considered in the modelling.		Details in SKB R-13-25.
K 6.12 Density-driven groundwater flows (thermal)	Addressed in the process report and considered in the permafrost modelling.		Details in SKB R-13-25.
K 6.17 Gas pressure effects	Addressed in the process report but not considered in the modelling.		
K 6.18 Hydraulic gradient changes (magnitude, direction)	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
K 7.11 Erosion		Not addressed in the process report but erosion and accumulation are considered in the landscape evolution.	See SR-PSU FEP Cli10.
K 7.13 Density-driven groundwater flows (temperature/salinity differences)	Addressed in the process report but not considered in the modelling.		
K 9.06 Stress changes - hydrogeological effect	Addressed in the process report but not considered in the modelling.		
K 9.07 Erosion/denuda-tion		Not addressed in the process report but erosion/denudation is considered in the landscape evolution.	See e.g. SR-PSU FEP Cli10 and Bio29.
K 10.13 Permafrost	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
K 10.16 Ice sheet effects (loading, melt water recharge)	Addressed in the process report but not considered in the modelling.		Details in SKB R-13-25.
M 1.2.11 Rock hetero-geneity	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
M 1.3.01 Precipitation, temperature and soil water balance	Addressed in the process report but variations considered less important than shoreline displacement.		
M 1.4.03 River, stream, channel erosion		Not addressed in the process report but erosion/denudation is considered in the landscape evolution.	See e.g. SR-PSU FEP Bio38.
M 1.5.03 Recharge to ground water	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
M 1.5.04 Ground water discharge	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
M 1.5.05 Ground water flow	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
M 1.5.07 Saline or freshwater intrusion	Addressed in the process report but not considered in the modelling.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
M 2.1.05 Dewatering of host rock	Saturation addressed in the process report but not in the modelling.		
S 001 Alteration/weathering of flow paths	Addressed in the process report but not considered in the modelling.		
S 018 Deep saline water intrusion	Addressed in the process report but not considered in the modelling.		
S 028 Earth tides		Not addressed in the process report since this occurs on a much shorter time scale than the time scales relevant to the repository performance.	
S 032 Excavation effects on nearby rock	The EDZ is addressed in the process report but not in the modelling.		See NEA FEP A 2.01.
S 033 External flow boundary conditions	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
S 036 Faulting	Addressed in the process report but not considered in the modelling.		
S 047 Glaciation	Addressed in the process report but not considered in the modelling.		Details in SKB R-13-25.
S 049 Groundwater flow	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
S 059 Permafrost	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
S 078 Resaturation, near-field rock	Saturation addressed in the process report but not in the modelling.		
S 081 Sea level changes	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
S 086 Stress field	Addressed in the process report but not considered in the modelling.		
S 091 Temperature, far-field	Addressed in the process report and considered in the permafrost modelling.		Details in SKB R-13-25.
S 092 Temperature, near-field rock	Addressed in the process report and considered in the permafrost modelling.		Details in SKB R-13-25.
W 1.009 Changes in fracture properties	Addressed in the process report but not considered in the modelling.		
W 1.022 Fracture infills	Addressed in the process report but not considered in the modelling.		
W 1.025 Fracture flow	Addressed in the process report and considered in the permafrost modelling.		Details in SKB R-13-25.
W 1.026 Density effects on groundwater flow	Addressed in the process report and considered in the permafrost modelling.		Details in SKB R-13-25.
W 1.028 Thermal effects on groundwater flow	Addressed in the process report and considered in the permafrost modelling.		Details in SKB R-13-25.
W 1.029 Saline intrusion	Addressed in the process report but not considered in the modelling.		
W 1.030 Freshwater intrusion	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
W 1.031 Hydrological response to earth-quakes	Addressed in the process report but not considered in the modelling.		
W 1.034 Saline intrusion	Addressed in the process report but not considered in the modelling.		
W 1.035 Freshwater intrusion	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
W 1.053 Groundwater discharge	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
W 1.056 Changes in groundwater recharge and discharge	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
W 2.018 Disturbed rock zone	The EDZ is addressed in the process report but not in the modelling.		See NEA FEP A 2.01.
W 2.042 Fluid flow due to gas production	Addressed in the process report but not considered in the modelling.		
W 3.031 Natural borehole fluid flow	Addressed in the process report and considered in the modelling.		Details in SKB R-13-25.
W 3.033 Flow through undetected boreholes		This FEP is not relevant for the site considered.	
W 3.035 Borehole-induced mineralization		Not addressed in the process report because this effect is considered to be small and localized.	
W 3.036 Borehole-induced geochemical changes		Not addressed in the process report because this effect is considered to be small and localized.	

Recorded by: Magnus Odén, Sven Follin, Jan-Olof Selroos **Date:** 2014-03-26
Checked and revised by: Kristina Skagius **Date:** 2014-04-03
Revisions approved by: Teresita Morales **Date:** 2014-06-16

Table A12-4. SR-PSU FEP Ge04 Gas flow/dissolution.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.68 Reflooding	All relevant aspects addressed.		See also SR-PSU FEP Ge03.
A 2.15 Dewatering	All relevant aspects addressed.		See also SR-PSU FEP Ge03.
A 2.27 Gases and gas transport	All relevant aspects addressed.		See also SR-PSU FEP Ge03.
A 2.69 Unsaturated rock	All relevant aspects addressed.		See also SR-PSU FEP Ge03.
E GEN-15 Excavation effects on the near field rock	All relevant aspects addressed.		See also SR-PSU FEP Ge03. Gases accumulated in the EDZ during the operational phase and their influence on groundwater chemistry is expected to be short-term after closure.
E GEN-18 Gas flow in the far-field	All relevant aspects addressed.	Impact on radionuclide transport is not addressed here, but in SR-PSU FEP Ge24.	
E GEN-19 Gas generation in the far-field	Gas generation by radiolysis is addressed and is expected to be negligible due to the low radioactivity of SFR wastes.	Microbially mediated gas production is not addressed here, but in SR-PSU FEP Ge15.	
E GEN-20 Gas generation in the near-field rock	Gas generation by radiolysis is addressed and is expected to be negligible due to the low radioactivity of SFR wastes.	Microbially mediated gas production is not addressed here, but in SR-PSU FEP Ge15.	Gas generated in the repository volume including generation from steel corrosion is addressed in SR-PSU FEPs BMABa15, BTFBa14, SiBa22, BRTBa14 and BLABa13.
E GEN-23 Groundwater flow	All relevant aspects addressed.		See also SR-PSU FEP Ge03.
E GEN-32 Hydraulic resaturation of the near-field rock	All relevant aspects addressed.		See also SR-PSU FEP Ge03.
H 1.2.6 Gas transport	All relevant aspects addressed.		
H 1.5.1 Desaturation (pumping) effects	All relevant aspects addressed.		See also SR-PSU FEP Ge03.
H 1.5.3 Unsaturated flow due to gas production	All relevant aspects addressed.		See also SR-PSU FEP Ge03.
H 2.1.9 Effects of natural gases	All relevant aspects addressed.	Clathrates are not addressed here, but in SR-PSU FEP Ge19.	
H 2.3.11 Far-field transport: Gas induced groundwater transport	Gas-induced changes in groundwater flow are addressed in the process description.		See also SR-PSU FEP Ge03.
H 4.1.3 Gas discharge	All relevant aspects addressed.		See also SR-PSU FEP Ge24.
J 5.14 Resaturation	All relevant aspects addressed.		See also SR-PSU FEP Ge03.
J 5.22 Accumulation of gases under permafrost	All relevant aspects addressed.	Clathrates are not addressed here, but in SR-PSU FEP Ge19. Accumulation of other gasses at permafrost is not discussed, as gas production has essentially ceased at such times, and as natural gasses exist at very small concentrations.	
J 5.43 Methane intrusion	All relevant aspects addressed.	Clathrates are not addressed here, but in SR-PSU FEP Ge19.	
J 6.02 Gas transport	All relevant aspects addressed.	Radionuclide transport in the gas phase is not addressed here, but in SR-PSU FEP Ge24.	
K 4.03 Desaturation/ resaturation of EDZ	All relevant aspects addressed.		See also SR-PSU FEP Ge03.
K 5.17 Gas pressure effects	All relevant aspects addressed.		See also SR-PSU FEP Ge03.
K 5.24 Geogas	All relevant aspects addressed.	Transport of radionuclides by ascending bubbles is not addressed here, but in SR-PSU FEP Ge24.	
K 6.17 Gas pressure effects	All relevant aspects addressed.		See also SR-PSU FEP Ge03.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
K 6.24 Geogas	All relevant aspects addressed.	Transport of radionuclides by ascending bubbles is not addressed here, but in SR-PSU FEP Ge24.	
M 1.2.13 Natural gas intrusion	All relevant aspects addressed.		
M 1.6.04 Gas mediated transport		Gas mediated transport is not addressed here, but in SR-PSU FEP Ge24.	The NEA FEP concerns transport in clay.
M 2.1.05 Dewatering of host rock	All relevant aspects addressed.	Irreversible modifications of host rock clay because of dewatering are not addressed since SFR is located in crystalline rock.	
M 3.3.06 Gas effects	All relevant aspects addressed.	Fires and explosions are not addressed here, but in SR-PSU FEP ISGen01.	
S 042 Gas flow and transport, near-field rock/far-field	All relevant aspects addressed.		
S 043 Gas generation and gas sources, far-field	All relevant aspects addressed.	Microbially mediated gas generation and clathrates are not addressed here but in SR-PSU FEPs Ge15 and Ge19, respectively.	
S 046 Gas generation, near-field rock	All relevant aspects addressed.		See also SR-PSU FEP Ge15.
S 048 Groundwater chemistry	All relevant aspects addressed.	Microbially mediated gas generation is addressed in SR-PSU FEP Ge15. Other processes affecting groundwater chemistry are addressed elsewhere, e.g. in SR-PSU FEP Ge14.	
S 059 Permafrost	All relevant aspects addressed.	Clathrates are not addressed here, but in SR-PSU FEP Ge19. Accumulation of other gasses at permafrost is not discussed, as gas production has essentially ceased at such times, and as natural gasses exist at very small concentrations.	
S 078 Resaturation, near-field rock	All relevant aspects addressed.		See also SR-PSU FEP Ge03.
W 1.032 Natural gas intrusion	All relevant aspects addressed.		
W 2.042 Fluid flow due to gas production	All relevant aspects addressed.		See also SR-PSU FEP Ge03.

Recorded by: Martin Löfgren — **Date:** 2012-05-18
Checked and revised by: Kristina Skagius — **Date:** 2014-08-27
Revisions approved by: Teresita Morales — **Date:** 2014-09-04

Table A12-5. SR-PSU FEP Ge05 Deformation of intact rock.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.08 Cave ins	All relevant aspects addressed.		See also SR-PSU FEP Ge06.
E GEN-05 Creeping of the rock mass	All relevant aspects addressed.		
E GEN-15 Excavation effects on the near field rock	All relevant aspects addressed.		
J 4.2.02.1 Excavation/ backfilling effects on nearby rock	All relevant aspects addressed.		
J 4.2.07 Thermo-hydro-mechanical effects	All relevant aspects addressed.		See also SR-PSU FEP Ge03.
M 3.3.02 Changes in in-situ stress field	All relevant aspects addressed.		
M 3.3.04 Subsidence/ collapse	All relevant aspects addressed.		
S 004 Cave in	All relevant aspects addressed.		See also SR-PSU FEP Ge06.
S 086 Stress field	All relevant aspects addressed.		
W 2.035 Mechanical effects of backfill	All relevant aspects addressed.		
Recorded by: Eva Hakami			**Date:** February 2014
Checked and revised by: Kristina Skagius			**Date:** 2014-08-28
Revisions approved by: Teresita Morales			**Date:** 2014-09-17

Table A12-6. SR-PSU FEP Ge06 Displacement along existing fractures.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.08 Cave ins	All relevant aspects addressed.		
A 1.29 Earthquakes	All relevant aspects addressed.		
A 2.21 Earthquakes	All relevant aspects addressed.		
A 2.24 Faulting	All relevant aspects addressed.		
A 2.30 Glaciation	All relevant aspects addressed.		
A 3.045 Earthquakes	All relevant aspects addressed.		
E GEN-03 Cave-in	All relevant aspects addressed.		
E GEN-05 Creeping of the rock mass	All relevant aspects addressed.		
E GEN-14 Enhanced rock fracturing	All relevant aspects addressed.		See also SR-PSU FEP Ge07.
E GEN-15 Excavation effects on the near field rock	All relevant aspects addressed.		
E GEN-17 Faulting	All relevant aspects addressed.		
H 2.1.7 Faulting/fracturing	All relevant aspects addressed.		
J 4.2.01 Mechanical failure of repository	All relevant aspects addressed.		
J 4.2.02.1 Excavation/ backfilling effects on nearby rock	All relevant aspects addressed.		
J 4.2.06 Faulting	All relevant aspects addressed.		
J 4.2.07 Thermo-hydro-mechanical effects	All relevant aspects addressed.		
J 5.15 Earthquakes	All relevant aspects addressed.		
J 5.42 Glaciation	All relevant aspects addressed.		
K 9.06 Stress changes - hydrogeological effects	All relevant aspects addressed.		
M 1.2.09 Fault activation	All relevant aspects addressed.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
M 3.1.03 Host rock fracture aperture changes	All relevant aspects addressed.		
M 3.3.02 Changes in in-situ stress field	All relevant aspects addressed.		
M 3.3.04 Subsidence/collapse	All relevant aspects addressed.		
S 004 Cave in	All relevant aspects addressed.		
S 036 Faulting	All relevant aspects addressed.		
S 047 Glaciation	All relevant aspects addressed.		
S 086 Stress field	All relevant aspects addressed.		
W 1.010 Formation of new faults	All relevant aspects addressed.		
W 1.011 Fault movement	All relevant aspects addressed.		
W 2.035 Mechanical effects of backfill	All relevant aspects addressed.		

Recorded by: Eva Hakami	**Date:** November 2013
Checked and revised by: Kristina Skagius	**Date:** 2014-08-28
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Table A12-7. SR-PSU FEP Ge07 Fracturing.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.08 Cave ins	All relevant aspects addressed.		
A 2.01 Blasting and vibration	All relevant aspects addressed.		
A 2.13 Damaged zone	All relevant aspects addressed.		
A 2.21 Earthquakes	All relevant aspects addressed.		
A 2.30 Glaciation	All relevant aspects addressed.		
E GEN-03 Cave-in	All relevant aspects addressed.		
E GEN-05 Creeping of the rock mass	All relevant aspects addressed.		
E GEN-14 Enhanced rock fracturing	All relevant aspects addressed.		
H 1.4.2 Vault collapse	All relevant aspects addressed.		
H 1.5.2 Disturbed zone (hydromechanical) effects	All relevant aspects addressed.		
H 2.1.7 Faulting/fracturing	All relevant aspects addressed.		
I 022 Explosions/bombs/ blasting/collision/impacts/ vibration		Human interaction FEPs not addressed here, but in SR-PSU FEP FHA15.	
J 4.2.02.1 Excavation/ backfilling effects on nearby rock	All relevant aspects addressed.		
J 4.2.07 Thermo-hydro-mechanical effects	All relevant aspects addressed.		
J 4.2.08 Enhanced rock fracturing	All relevant aspects addressed.		
J 5.42 Glaciation	All relevant aspects addressed.		
K 4.01 Excavation-disturbed zone (EDZ)	All relevant aspects addressed.		
M 3.3.04 Subsidence/ collapse	All relevant aspects addressed.		
M 3.3.05 Fracturing	All relevant aspects addressed.		
S 004 Cave in	All relevant aspects addressed.		
S 030 Enhanced rock fracturing	All relevant aspects addressed.		
S 032 Excavation effects on nearby rock	All relevant aspects addressed.		
S 036 Faulting	All relevant aspects addressed.		
S 047 Glaciation	All relevant aspects addressed.		
S 086 Stress field	All relevant aspects addressed.		
W 1.008 Formation of fractures	All relevant aspects addressed.		
W 2.018 Disturbed rock zone	All relevant aspects addressed.		
W 2.019 Excavation-induced changes in stress	All relevant aspects addressed.		
W 2.022 Roof falls	All relevant aspects addressed.		

Recorded by: Eva Hakami **Date:** November 2013
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Revisions approved by: Teresita Morales **Date:** 2014-09-04

Table A12-8. SR-PSU FEP Ge09 Erosion/sedimentation in fractures.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.06 Cavitation	All relevant aspects addressed.		
J 3.1.06 Sedimentation of bentonite	Sedimentation in general is addressed.		

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Table A12-9. SR-PSU FEP Ge10 Advective transport/mixing of dissolved species.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.28 Dispersion	All relevant aspects are addressed.		
A 1.67 Recharge groundwater	All relevant aspects are addressed.		
A 2.11 Convection	All relevant aspects are addressed.		
A 2.18 Dispersion	All relevant aspects are addressed.		
A 2.53 Recharge groundwater	All relevant aspects are addressed.		
E GEN-06 Groundwater salinity changes	The aspects relevant for advective transport of solutes (including salinity) are addressed.	The FEP concerns many effects that may result from salinity changes affecting e.g. flow paths, bentonite swelling, metal degradation and radionuclide solubility. These effects are not addressed specifically in the process description for advection.	Salinity changes and their influence on groundwater chemistry are addressed and modelled in SKB R-13-30 (cited in the process description for advection).
E GEN-10 Radionuclide dispersion	All relevant aspects are addressed.		See also SR-PSU FEP Ge23.
E GEN-12 Earth tides		Earth tides are not addressed for advection. Firstly since they relate to groundwater flow (see Ge03) and only influences advective transport indirectly. Secondly earth tides occur on a very short timescale as compared to the time scales relevant to the repository performance.	
E GEN-22 Far-field groundwater chemistry	The aspects relevant for advective transport of solutes are addressed.	The FEP concerns many effects that may result from changes in groundwater chemistry. These effects are not addressed specifically in the process description for advection.	See also e.g. SR-PSU FEPs Ge13 and Ge14.
E GEN-24 Interfaces between different waters	The aspects relevant for advective transport of solutes are addressed.	The FEP concerns chemical reactions that may occur at interfaces between waters with different compositions. These effects are not specifically addressed in the process description for advection.	The groundwater chemistry evolution is addressed and modelled in SKB R-13-30 (cited in the process description for advection).
E GEN-37 Surface water chemistry	The aspects relevant for advective transport of solutes are addressed.	The FEP concerns the surface water control on groundwater chemistry. Several aspects in the FEP are related to water-rock interactions (see SR PSU FEPs Ge13 and Ge14), and aqueous chemical reactions which are not addressed in the process description for advection.	The groundwater chemistry evolution is addressed and modelled in SKB R-13-30 (cited in the process description for advection).
E SFL-38 Redox fronts	The aspects relevant for advective transport of solutes are addressed.	The FEP concerns chemical reactions that may occur at interfaces between waters with different redox potential. These effects are not specifically addressed in the process description for advection.	The groundwater chemistry evolution is addressed and modelled in SKB R-13-30 (cited in the process description for advection). Water–rock reactions are addressed in SR-PSU FEPs Ge13 and Ge14.
E SFR-23 Groundwater chemistry in the near-field rock	The aspects relevant for advective transport of solutes are addressed.	The FEP describes many chemical reactions that contribute to the groundwater chemistry evolution in the near-field rock. These are not addressed specifically in the process description for advection.	The groundwater chemistry evolution is addressed and modelled in SKB R-13-30 (cited in the process description for advection).
H 2.3.3 Far-field transport: Hydrodynamic dispersion	All relevant aspects are addressed.		
H 2.3.7 Far-field transport: Changes in groundwater chemistry and flow direction	Aspects relevant for advective transport of solutes are addressed.	The FEP concerns uncertainties in groundwater chemistry (see SR-PSU FEPs Ge13 and Ge14), and groundwater flow (see Ge03).	The groundwater chemistry evolution is addressed and modelled in SKB R-13-30 (cited in the process description for advection). For groundwater flow, see SR-PSU FEP Ge03.
I 040 Farfield chemical interactions	Aspects relevant for advective transport of solutes are addressed.	Chemical reactions and their influence on e.g. sorption properties are not addressed in the process description for advection.	See also SR-PSU FEPs Ge12, Ge13, and Ge14.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 4.1.08 Change of groundwater chemistry in nearby rock	Aspects relevant for advective transport of solutes are addressed.	FEP concerns only chemical reactions with construction material, backfill and other man-made materials, and does not relate to advection as a process. Furthermore these reactions have limited relevance for the geosphere.	
J 4.2.03 Extreme channel flow of oxidants and nuclides	Aspects relevant for advective transport of solutes are addressed.		For flow channeling, see SR-PSU FEP Ge03.
J 5.01 Saline (or fresh) groundwater intrusion		The effect by salinity gradients on ground-water flow is not addressed here, but in SR-PSU FEP Ge03.	
J 6.04 Dispersion	All relevant aspects are addressed.		
K 5.08 Groundwater chemistry	Aspects relevant for advective transport of solutes are addressed.	Chemical reactions and their influence on e.g. sorption properties are not addressed here, but in SR-PSU FEPs Ge12, Ge13 and Ge14.	
K 5.11 Intrusion of saline groundwater	Aspects relevant for advective solute trans-port (including species affecting salinity) are addressed.		A saline–freshwater interface is not expected at SFR and the aspects of the FEP are therefore judged not to be relevant for SR-PSU.
K 6.08 Groundwater chemistry	Aspects relevant for advective transport of solutes are addressed.	Chemical reactions and their influence on e.g. sorption properties are not addressed here, but in SR-PSU FEPs Ge12, Ge13 and Ge14.	
K 6.11 Intrusion of saline groundwater	Aspects relevant for advective solute trans-port (including species affecting salinity) are addressed.		A saline–freshwater interface is not expected at SFR and the aspects of the FEP are therefore judged not to be relevant for SR-PSU.
K 7.08 Groundwater chemistry	Aspects relevant for advective transport of solutes are addressed.	Chemical reactions and their influence on e.g. sorption properties are not addressed here, but in SR-PSU FEPs Ge12, Ge13 and Ge14.	
M 1.5.08 Effects at saline–freshwater interface	Aspects relevant for advective solute trans-port (including species affecting salinity) are addressed.	The chemical activity of the waters at a saline–freshwater interface and their influ-ences on e.g. the migration of radionuclides are not addressed in the process descrip-tion for advection.	A saline–freshwater interface is not expected at SFR and the aspects of the FEP are therefore judged not to be relevant for SR-PSU.
M 1.6.01 Advection and dispersion	All relevant aspects are addressed.		
S 018 Deep saline water intrusion	Aspects relevant for advective solute trans-port (including species affecting salinity) are addressed.	The effect by salinity gradients on ground-water flow is not addressed here, but in SR-PSU FEP Ge03.	A saline–freshwater interface is not expected at SFR and the aspects of the FEP are therefore judged not to be relevant for SR-PSU.
S 026 Dispersion	All relevant aspects are addressed.		
S 048 Groundwater chemistry	Aspects relevant for advective solute trans-port are addressed.	Chemical reactions and their influence on e.g. sorption properties are not addressed here, but in SR-PSU FEPs Ge12, Ge13 and Ge14.	
S 052 Interface differ-ent waters	Aspects relevant for advective solute trans-port are addressed.	Chemical reactions, e.g. colloid formation, at interfaces between different waters are not addressed in the process description for advection. Colloid formation is addressed in SR-PSU FEP Ge17.	
W 3.035 Borehole-induced mineralization		Groundwater flow is addressed in SR-PSU FEP GE03. Effects on solute transport by human activities such as drilling or excava-tion is addressed in the descriptions of future human actions (SR-PSU FHA FEPs).	
W 3.036 Borehole-induced geochemical changes		Groundwater flow is addressed in SR-PSU FEP GE03. Effects on solute transport by human activities such as drilling or excava-tion is addressed in the descriptions of future human actions (SR-PSU FHA FEPs).	

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Table A12-10. SR-PSU FEP Ge11 Diffusive transport in the rock mass.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.16 Diffusion	All relevant aspects are addressed.		
A 2.41 Matrix diffusion	All relevant aspects are addressed.		Unlike the FEP, we may need to consider transverse diffusion (in the matrix).
E GEN-01 Alteration and weathering along flow paths	All relevant aspects are addressed.		
E GEN-02 Anion exclusion	All relevant aspects are addressed.		
E GEN-09 Diffusion	All relevant aspects are addressed.		
E GEN-12 Earth tides		Earth tides in the rock matrix are not addressed, as the host rock matrix is through to be too rigid, the rock matrix permeability too low, and the cyclic pattern too fast to affect solute exchange between rock matrix and groundwater. Only cyclic stress pattern in the longer time perspectives (glacial cycle) is discussed.	
E GEN-25 Matrix diffusion	All relevant aspects are addressed.		The statement "Field studies indicate that the volume of rock available for matrix diffusion is actually only a small proportion of the total volume and possibly restricted to a volume of rock just a few centimetres thick adjacent to the advecting fractures" is disagreed upon, on the basis of more recent information.
E SFR-23 Groundwater chemistry in the near-field rock	All relevant aspects are addressed.		
H 2.3.2 Far-field transport: Diffusion	All relevant aspects are addressed.		
J 3.2.06 Diffusion - surface diffusion	All relevant aspects are addressed.		
J 4.1.05 Matrix diffusion	All relevant aspects are addressed.		
K 5.06 Matrix diffusion	All relevant aspects are addressed.		
K 6.05 Radionuclide transport through MWCF	All relevant aspects are addressed.		
K 6.06 Matrix diffusion	All relevant aspects are addressed.		
K 6.11 Intrusion of saline groundwater		Site-specific FEP with no direct bearing on the process.	
M 1.6.02 Diffusion	All relevant aspects are addressed.		
M 1.6.03 Matrix diffusion	All relevant aspects are addressed.		
S 001 Alteration/ weathering of flow paths	All relevant aspects are addressed.		
S 002 Anion-exclusion	All relevant aspects are addressed.		
S 023 Diffusion	All relevant aspects are addressed.		
S 028 Earth tides		Earth tides in the rock matrix are not addressed, as the host rock matrix is through to be too rigid, the rock matrix permeability too low, and the cyclic pattern too fast to affect solute exchange between rock matrix and groundwater. Only cyclic the stress pattern in the longer time perspectives (glacial cycle) is discussed.	
S 054 Matrix diffusion	All relevant aspects are addressed.		
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Table A12-11. SR-PSU FEP Ge12 Speciation and sorption.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.58 Saturation	Not mentioned explicitly, but implicit in handling of sorption and discussion of competitive effects of sorption.		
A 2.62 Sorption	All relevant aspects are addressed.		
A 2.63 Sorption - nonlinear	All relevant aspects are addressed.		
A 2.64 Speciation	All relevant aspects are addressed.		
E GEN-01 Alteration and weathering along flow paths	All relevant aspects are addressed.		
E GEN-04 Colloid behaviour in the host rock	All relevant aspects are addressed.		
E GEN-22 Far-field groundwater chemistry	All relevant aspects are addressed.		
E GEN-31 Radionuclide reconcentration	Mentioned briefly in the process description. Implicit in assignment of differing K_d values for alkaline affected zone (i.e. as a spatially dynamic process).	Reconcentration/remobilsation of radionuclides as a temporally dynamic process is specifically excluded within SR-PSU.	
E GEN-34 Radionuclide sorption	All relevant aspects are addressed.		
H 2.3.5 Far-field transport: Sorption including ion-exchange	All relevant aspects are addressed.		
H 2.3.6 Far-field transport: Changes in sorptive surfaces	All relevant aspects are addressed.		
H 2.3.7 Far-field transport: Changes in groundwater chemistry and flow direction	All relevant aspects are addressed.		
I 040 Farfield chemical interactions	All relevant aspects are addressed.		
J 3.1.02 Saturation of sorption sites	Not mentioned explicitly, but implicit in handling of sorption and discussion of competitive effects of sorption.		
J 4.1.04 Sorption	All relevant aspects are addressed.		
J 4.1.06 Reconcentration	Mentioned briefly in the process description. Implicit in assignment of differing K_d values for alkaline affected zone (i.e. as a spatially dynamic process).	Reconcentration/remobilsation of radionuclides as a temporally dynamic process is specifically excluded within SR-PSU.	
J 7.05 Isotopic dilution	Mentioned with regard to C-14. Implicit in discussion of background concentration ranges for sorbing solutes.		
K 5.07 Mineralogy	All relevant aspects are addressed.		
K 5.08 Groundwater chemistry	All relevant aspects are addressed.		
K 5.09 Sorption	All relevant aspects are addressed.		
K 5.10 Non-linear sorption	Non-linear sorption is implicit in discussion of sorption as a process and selection of conservative K_d values.		Not addressed in terms of specific sorption isotherm descriptions as in FEP.
K 5.21 Organics	All relevant aspects are addressed.		
K 5.22 Microbial activity		Not specifically addressed here, but in SR-PSU FEPs Ge13, Ge14, and Ge15.	

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
K 6.07 Mineralogy	Discussed in terms of specific mineral phase composition of rock.		Not addressed in terms of rock nomenclature according to FEP.
K 6.08 Groundwater chemistry	All relevant aspects are addressed.		
K 6.09 Sorption	All relevant aspects are addressed.		
K 6.10 Non-linear sorption	Non-linear sorption is implicit in discussion of sorption as a process and selection of conservative K_d values.		Not addressed in terms of specific sorption isotherm descriptions as in FEP.
K 6.21 Organics	All relevant aspects are addressed.		
K 7.08 Groundwater chemistry	All relevant aspects are addressed.		
K 7.09 Radionuclide sorption	All relevant aspects are addressed.		
M 1.2.11 Rock heterogeneity	Mineralogical heterogeneity discussed in terms of sorptivity of individual mineral phases.	Flowpath heterogeneity is not addressed here, but in SR-PSU FEP Ge23.	
S 001 Alteration/weathering of flow paths	All relevant aspects are addressed.		
S 018 Deep saline water intrusion	Implicit in selection of K_d values for conservatively saline conditions (i.e. cation exchanging radionuclides).	Deep saline intrusion not handled specifically as a process.	
S 048 Groundwater chemistry	All relevant aspects are addressed.		
S 073 Reconcentration	Mentioned briefly in the process description. Implicit in assignment of differing K_d values for alkaline affected zone (i.e. as a spatially dynamic process).	Reconcentration/remobilsation of radionuclides as a temporally dynamic process is specifically excluded within SR-PSU.	
S 084 Sorption	All relevant aspects are addressed.		
W 2.061 Actinide sorption	All relevant aspects are addressed.		Actinides not given special treatment relative to other radionuclides.
W 2.062 Kinetics of sorption		Chemical kinetics of sorption not considered relevant for modelling of far-field sorption processes. Sorption by cation exchange and surface complexation is assumed to be fast and reversible relative to timescale of transport. Diffusive exchange with the rock matrix is assumed to dominate as a kinetic process.	

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Table A12-12. SR-PSU FEP Ge13 Reactions groundwater/rock matrix.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.11 Chemical kinetics	All relevant aspects are addressed.		
A 2.53 Recharge groundwater	All relevant aspects are addressed.		
E GEN-01 Alteration and weathering along flow paths	All relevant aspects are addressed.		
E GEN-22 Far-field ground-water chemistry	All relevant aspects are addressed.		
E GEN-37 Surface water chemistry	All relevant aspects are addressed.		
E SFL-38 Redox fronts	All relevant aspects are addressed.		
H 2.2.2 Rock property changes	All relevant aspects are addressed.		
H 2.3.7 Far-field transport: Changes in groundwater chemistry and flow direction	All relevant aspects are addressed.		
I 040 Farfield chemical interactions	All relevant aspects are addressed.		
J 6.06 Weathering of flow paths	All relevant aspects are addressed.		
K 4.05 Geochemical alteration	All relevant aspects are addressed.		
K 4.06 Groundwater chemistry	All relevant aspects are addressed.		
K 5.07 Mineralogy	All relevant aspects are addressed.		
K 5.08 Groundwater chemistry	All relevant aspects are addressed.		
K 5.20 TRU alkaline or organic plume	All relevant aspects are addressed.		
K 6.07 Mineralogy	All relevant aspects are addressed.		
K 6.08 Groundwater chemistry	All relevant aspects are addressed.		
K 6.20 TRU alkaline or organ-ics plume	All relevant aspects are addressed.		
K 7.08 Groundwater chemistry	All relevant aspects are addressed.		
M 2.1.11 Chemical effects: oxidation of the host rock (1)		FEP not relevant for SR-PSU FEP Ge13, as it concerns Boom clay.	
S 001 Alteration/weathering of flow paths	All relevant aspects are addressed.		
S 002 Anion-exclusion	All relevant aspects are addressed.		
S 048 Groundwater chemistry	All relevant aspects are addressed.		
S 074 Redox front	All relevant aspects are addressed.		
W 1.038 Effects of dissolution	All relevant aspects are addressed.		
W 2.065 Reduction–oxidation fronts	All relevant aspects are addressed.		
W 3.035 Borehole-induced mineralization	All relevant aspects are addressed.		
W 3.036 Borehole-induced geochemical changes	All relevant aspects are addressed.		

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Table A12-13. SR-PSU FEP Ge14 Dissolution/precipitation of fracture-filling minerals.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.11 Chemical kinetics	All relevant aspects are addressed.		
A 2.29 Geochemical interactions	All relevant aspects are addressed.		
A 2.35 Hydraulic properties - evolution	All relevant aspects are addressed.		
A 2.49 Precipitation and dissolution	All relevant aspects are addressed.		
A 2.53 Recharge groundwater	All relevant aspects are addressed.		
E GEN-01 Alteration and weathering along flow paths	All relevant aspects are addressed.		
E GEN-22 Far-field groundwater chemistry	All relevant aspects are addressed.		
E GEN-37 Surface water chemistry	All relevant aspects are addressed.		
E SFL-38 Redox fronts	All relevant aspects are addressed.		
H 2.2.2 Rock property changes	All relevant aspects are addressed.		
H 2.3.6 Far-field transport: Changes in sorptive surfaces	All relevant aspects are addressed.	Dissolution/precipitation in soil is not addressed here as it would be of higher importance for the so-called "surface system" (reported elsewhere).	
H 2.3.7 Far-field transport: Changes in groundwater chemistry and flow direction	All relevant aspects are addressed.		
I 040 Farfield chemical interactions	All relevant aspects are addressed.	Dissolution/precipitation in soil is not addressed here as it would be of higher importance for the so-called "surface system" (reported elsewhere).	
J 6.06 Weathering of flow paths	All relevant aspects are addressed.		
K 4.05 Geochemical alteration	All relevant aspects are addressed.		
K 4.06 Groundwater chemistry	All relevant aspects are addressed.		
K 5.07 Mineralogy	All relevant aspects are addressed.		
K 5.08 Groundwater chemistry	All relevant aspects are addressed.		
K 5.20 TRU alkaline or organic plume	All relevant aspects are addressed.		
K 6.07 Mineralogy	All relevant aspects are addressed.		
K 6.08 Groundwater chemistry	All relevant aspects are addressed.		
K 6.20 TRU alkaline or organics plume	All relevant aspects are addressed.		
K 7.08 Groundwater chemistry	All relevant aspects are addressed.		
M 1.6.11 Fracture mineralisation and weathering		FEP not relevant for SR-PSU FEP Ge13, as it concerns Boom clay.	
M 2.1.11 Chemical effects: oxidation of the host rock (1)	All relevant aspects are addressed.		
S 001 Alteration/weathering of flow paths	All relevant aspects are addressed.		
S 048 Groundwater chemistry	All relevant aspects are addressed.		
S 074 Redox front	All relevant aspects are addressed.		
W 1.009 Changes in fracture properties	All relevant aspects are addressed.		
W 1.022 Fracture infills	All relevant aspects are addressed.		
W 1.038 Effects of dissolution	All relevant aspects are addressed.		
W 2.059 Precipitation	All relevant aspects are addressed.		
W 2.060 Kinetics of precipitation and dissolution	All relevant aspects are addressed.		
W 2.065 Reduction–oxidation fronts	All relevant aspects are addressed.		
W 3.035 Borehole-induced mineralization	All relevant aspects are addressed.		
W 3.036 Borehole-induced geochemical changes	All relevant aspects are addressed.		

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Table A12-14. SR-PSU FEP Ge15 Microbial processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.03 Biological activity		Biological activity in the vault is not addressed here, but in the SR-PSU FEPs WM17, Pa11, BMABa14, BTFBa13, SiBa20, BRTBa13 and BLABa12.	
A 1.53 Methylation		The formation of methylated species in the vaults is not addressed here but in SR-PSU FEPs WM17, Pa11, BMABa14, BTFBa13, SiBa20, BRTBa13 and BLABa12.	
A 2.45 Microbes	Impact of microbes on transport of contaminants is addressed in the process description.		
A 2.49 Precipitation and dissolution	All relevant aspects are addressed.		
E GEN-04 Colloid behaviour in the host rock	All relevant aspects are addressed.		
E GEN-18 Gas flow in the far-field	All relevant aspects are addressed.		
E GEN-19 Gas generation in the far-field	All relevant aspects are addressed.		
E GEN-20 Gas generation in the near-field rock	All relevant aspects are addressed.		
E GEN-22 Far-field groundwater chemistry	All relevant aspects are addressed.		
E SFL-32 Microbial activity	The influence of microbes on groundwater chemistry is addressed.	The transport of radionuclides attached to microbial cells is not addressed here, but in SR-PSU FEP Ge23.	
H 2.3.9 Far-field transport: Transport of radionuclides bound to microbes	The viability of microbes is addressed as well as their potential interaction with radionuclides.	The transport of radionuclides attached to microbial cells is not addressed here, but in SR-PSU FEP Ge23.	
H 2.3.13 Far-field transport: Biogeochemical changes	All relevant aspects are addressed.		
I 012 Biological activity (bacteria & microbes)	The viability of microbes and their influence on geosphere variables such as mineralogy and groundwater chemistry is addressed.	Microbially mediated changes in the physical and chemical environment in the vaults are not addressed here, but in SR-PSU FEPs WM17, Pa11, BMABa14, BTFBa13, SiBa20, BRTBa13 and BLABa12.	
I 015 Gas generation (CH_4, CO_2, H_2)	Gas generation resulting from biological degradation of organic material is addressed.	Corrosion of metal containers is not addressed here, but in SR-PSU FEP WM18.	
J 2.1.10 Microbes	All relevant aspects are addressed.		
K 3.17 Microbial activity	Microbial activity in the geosphere is addressed in the process description.	Microbial activity in the engineered barriers is not addressed here, but in SR-PSU FEPs BMABa14, BTFBa13, SiBa20, BRTBa13 and BLABa12.	
K 5.22 Microbial activity	All relevant aspects are addressed.		
K 6.22 Microbial activity	All relevant aspects are addressed.		
M 3.2.07 Microbiological effects		Microbially mediated corrosion and degradation of glass, metals, concrete and bitumen is not addressed here, but in SR-PSU FEPs WM17, Pa11, BMABa14, BTFBa13, SiBa20, BRTBa13 and BLABa12.	

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
S 043 Gas generation and gas sources, far-field	All relevant aspects are addressed.		
S 046 Gas generation, near-field rock	All relevant aspects are addressed.		
S 048 Groundwater chemistry	All relevant aspects are addressed.		
S 057 Microbial activity	Microbial activity in the geosphere is addressed in the process description.	The transport of radionuclides attached to microbial cells is not addressed here, but in SR-PSU FEP Ge23.	
W 2.044 Degradation of organic material	All relevant aspects are addressed.		
W 2.045 Effect of temperature on microbial gas generation	All relevant aspects are addressed.		
W 2.046 Effect of pressure on microbial gas generation	All relevant aspects are addressed.		
W 2.048 Effect of biofilms on microbial gas generation	Formation of biofilms on fracture surfaces in the geosphere is addressed.	Development of biofilms in the vaults of the repository is not addressed here, but in SR-PSU FEPs WM17 and Pa11.	
W 2.087 Microbial transport		The transport of radionuclides attached to microbial cells is not addressed here, but in SR-PSU FEP Ge23.	
W 2.088 Biofilms	Development of biofilms on fracture surfaces in the geosphere is addressed in the process description, but radionuclide retention due to the formation of biofilms is pessimistically neglected in the safety assessment.		

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Table A12-15. SR-PSU FEP Ge16 Degradation of grout.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.60 Shaft seal failure	Aspects relevant for degradation of injection grout and grout used to secure rock bolts are addressed. Flow limiting properties of the injection grout are addressed but pessimistically neglected in the safety assessment, at all times.	Flow limiting seals in the rock vaults and plugs are not addressed here, but in SR-PSU FEP Pg04.	
E GEN-01 Alteration and weathering along flow paths	Reactions involved in alteration and degradation of injection grout are addressed. Their contribution to changes in the groundwater chemistry is negligible compared to the degradation of other cementitious sources in the repository barriers and waste packages. The flow limiting properties of grout is pessimistically neglected in the safely assessment, at all times.	Other aspects considered in the FEP are not relevant for the degradation of injection grout but are addressed in SR-PSU FEPs Ge13 and Ge14.	This NEA FEP mainly concerns chemical water-rock reactions and not for injection grout.
E GEN-08 Degradation of the rock reinforcement and grout	Degradation of injection grout is addressed. Its contribution to changes in the groundwater chemistry is negligible compared to the contribution from other sources in the barriers and waste packages. The flow limiting properties of grout is pessimistically neglected in the safely assessment, at all times.	Degradation of rock bolts and shotcrete in the repository vaults is not addressed here, but in SR-PSU FEP Pg18.	
H 1.1.2 Physico-chemical degradation of concrete	Physico-chemical degradation of injection grout is addressed.	Other types of concrete structures and backfill are not addressed here, but in SR-PSU FEPs BMABa12, BTFBa11, SiBa13, BRTBa11 and BLABa13.	
I 061 Concrete (influence on vault chemistry)	Addressed but neglected. The contribution of injection grout degradation in maintaining an alkaline environment in the rock vaults is negligible compared to other cementitious sources in the SFR barriers and waste packages.		
J 3.1.07 Reactions with cement pore water	All relevant aspects are addressed.		
J 4.1.08 Change of groundwater chemistry in nearby rock		No beneficial effects of grout degradation are accounted for, i.e. formation of clay minerals which may act as a sink for cations. The contribution to changes in the groundwater chemistry of grout degradation is negligible compared to the contribution from degradation of other cementitious sources in the repository barriers and waste packages.	
M 3.2.02 Interactions of host materials and ground water with repository materials	All relevant aspects are addressed.		
S 021 Degradation of rock reinforcement and grout	All relevant aspects are addressed.		
W 2.037 Mechanical degradation of seals		Mechanical degradation of injection grout is not addressed as its flow limiting properties are not accounted for in the safety assessment.	

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Checked and revised by: Kristina Skagius	**Date:** 2014-09-01
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Table A12-16. SR-PSU FEP Ge17 Colloidal processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.63 Psuedo-colloids	All relevant aspects are addressed.		
A 2.08 Colloid formation	All relevant aspects are addressed.		
A 2.45 Microbes	All relevant aspects are addressed.	Microbial cells are addressed separately in SR-PSU FEP Ge15.	
A 2.50 Pseudo-colloids	All relevant aspects are addressed.		
E GEN-04 Colloid behaviour in the host rock	All relevant aspects are addressed.		
E GEN-22 Far-field groundwater chemistry	Aspects relevant for colloid formation and transport are addressed.		
H 2.3.8 Far-field transport: Colloid transport	All relevant aspects are addressed.		
I 058 Colloid formation (natural and vault generated)	All relevant aspects are addressed.		
J 3.1.06 Sedimentation of bentonite	All relevant aspects are addressed.		
J 5.45 Colloid generation and transport	All relevant aspects are addressed.		
K 4.12 Colloids	All relevant aspects are addressed.		
K 5.15 Natural colloids	All relevant aspects are addressed.		
K 6.15 Natural colloids	All relevant aspects are addressed.		
S 008 Colloid generation and transport	All relevant aspects are addressed.		
S 018 Deep saline water intrusion	Addressed in the process description, although highly saline waters such as brine is unlikely at the relatively shallow localization of SFR.		
S 074 Redox front		Establishment of oxidizing conditions due to radiolysis in the close vicinity of the waste that affect colloid stability is not addressed. The radionuclide activity within SFR is low and the effect of water radiolysis on water composition is therefore negligible.	
W 1.034 Saline intrusion	Addressed in the process description, although highly saline waters such as brine is unlikely at the relatively shallow localization of SFR.		
W 1.035 Freshwater intrusion	Freshwater intrusion under glacial conditions and its influence on colloid formation and transport is addressed.		
W 1.036 Changes in groundwater Eh	All relevant aspects are addressed.		
W 1.037 Changes in groundwater pH	All relevant aspects are addressed.		
W 2.078 Colloid transport	Colloid-facilitated radionuclide transport is addressed but has not been modelled within the safety assessment. Instead, low consequence on safety is argued for, based on stability criteria and residual scenario analyses.		
W 2.079 Colloid formation and stability	Colloid stability considerations are addressed.		
W 2.080 Colloid filtration	Colloid-facilitated radionuclide transport and filtering is addressed but has not been modelled within the safety assessment. Instead, low consequence on safety is argued for, based on stability criteria and residual scenario analyses.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
W 2.081 Colloid sorption	Colloid-facilitated radionuclide transport and filtering is addressed but has not been modelled within the safety assessment. Instead, low consequence on safety is argued for, based on stability criteria and residual scenario analyses.		
W 2.087 Microbial transport		Microbially mediated radionuclide transport is addressed in SR-PSU FEP Ge15, but has not been modelled within the safety assessment.	
Recorded by: Magnus Sidborn, Miranda Keith-Roach			**Date:** 2014-07-10
Checked and revised by: Kristina Skagius			**Date:** 2014-09-01
Revisions approved by: Teresita Morales			**Date:** 2014-09-04

Table A12-17. SR-PSU FEP Ge19 Methane hydrate formation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
H 2.1.9 Effects of natural gases	All relevant aspects are addressed.		
J 5.22 Accumulation of gases under permafrost	All relevant aspects are addressed.		
J 5.43 Methane intrusion	All relevant aspects are addressed.		
Recorded by: Martin Löfgren			**Date:** 2012-03-02
Checked and revised by: Kristina Skagius			**Date:** February 2014
Revisions approved by: Not applicable			**Date:**

Table A12-18. SR-PSU FEP Ge20 Salt exclusion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
S 059 Permafrost	All relevant aspects are addressed.		
Recorded by: Martin Löfgren			**Date:** 2012-03-02
Checked and revised by: Kristina Skagius			**Date:** February 2014
Revisions approved by: Not applicable			**Date:**

Table A12-19. SR-PSU FEP Ge21 Earth currents.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.36 Galvanic coupling	All relevant aspects are addressed.		
E GEN-13 Electro-chemical effects	All relevant aspects are addressed.		The statement "Since most rocks are poor electrical conductors, telluric currents flow mainly through water conducting features such as fractures…" is disagreed upon. Most currents will flow in the microporous system of the rock matrix.
J 2.1.06.2 Natural telluric electrochemical reactions	All relevant aspects are addressed.	Evolution of natural earth currents not addressed, as they are overshadowed by anthropogenic currents.	The statement "At repository and since crystalline rocks are mostly resistors, the flow of the electric currents will take place in the water conducting fractures" is disagreed upon. Most currents will flow in the microporous system of the rock matrix.
S 029 Electrochemical effects/gradients	All relevant aspects are addressed.	Evolution of natural earth currents not addressed, as they are overshadowed by anthropogenic currents.	The statement "At repository and since crystalline rocks are mostly resistors, the flow of the electric currents will take place in the water conducting fractures" is disagreed upon. Most currents will flow in the microporous system of the rock matrix.
S 098 Transport and release of nuclides, near-field rock	All relevant aspects are addressed.		
W 2.094 Electro-chemical effects	All relevant aspects are addressed.		
W 2.096 Electrophoresis	All relevant aspects are addressed.		
Recorded by: Martin Löfgren			**Date:** 2012-05-21
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Table A12-20. SR-PSU FEP Ge22 Speciation of radionuclides.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.14 Complexation by organics		Not specifically addressed here, but in SR-PSU FEPs Ge12 and Ge23.	See also NEA FEP I 044 Chealting agents.
A 1.37 Geochemical pump		Not addressed. Deemed not relevant for geosphere transport processes.	
A 1.77 Speciation	All relevant aspects are addressed.		
A 2.09 Complexation by organics		Not specifically addressed here, but in SR-PSU FEPs Ge12 and Ge23.	
A 2.26 Fulvic acid		Not specifically addressed here, but in SR-PSU FEPs Ge12 and Ge23.	
A 2.34 Humic acid		Not specifically addressed here, but in SR-PSU FEPs Ge12 and Ge23.	
A 2.64 Speciation	All relevant aspects are addressed.		
E GEN-27 Radionuclide precipitation and dissolution	Mentioned briefly, although addressed in more detail in SR-PSU FEP Ge23.		Not considered to be primary retardation mechanism in geosphere for migrating radionuclides. More relevant for near field source term.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
E GEN-31 Radionuclide reconcentration	Implicit in assignment of differing K_d values for alkaline affected and non-affected zone (i.e. as a spatially dynamic process).	Reconcentration/remobilsation of radionuclides as a temporally dynamic process is specifically excluded in SR-PSU.	
H 2.3.4 Far-field transport: Solubility constraints	Mentioned briefly, although addressed in more detail in SR-PSU FEP Ge23.		Not considered to be primary retardation mechanism in geosphere for migrating radionuclides. More relevant for near field source term.
H 2.3.12 Far-field transport: Thermal effects on hydrochemistry	All relevant aspects are addressed.		
I 044 Chealting agents	Discussed as a subset of the impact of "complexing ligands".	Specific agents such as EDTA not included in general overview.	ISA is included in discussion in SR-PSU FEP Ge12.
J 4.1.09 Complexing agents	See NEA FEP I 044.	See NEA FEP I 044.	See NEA FEP I 044.
J 5.44 Solubility and precipitation	All relevant aspects are addressed.		
K 4.10 Elemental solubility		Not relevant for geosphere transport processes (FEP relates specifically to near-field source term).	
K 5.16 Solubility limits/ colloid formation	All relevant aspects are addressed.		
K 5.21 Organics	See NEA FEP I 044.	See NEA FEP I 044.	See NEA FEP I 044.
K 6.16 Solubility limits/ colloid formation	All relevant aspects are addressed.		
K 6.21 Organics	See NEA FEP I 044.	See NEA FEP I 044.	See NEA FEP I 044.
S 060 Precipitation/ dissolution	Mentioned briefly.		Not considered to be primary retardation mechanism in geosphere for migrating radionuclides. More relevant for near field source term.
S 073 Reconcentration	Implicit in assignment of differing K_d values for alkaline affected and non-affected zone (i.e. as a spatially dynamic process).	Reconcentration/ remobilsation of radionuclides as a temporally dynamic process is specifically excluded in SR-PSU.	
W 2.056 Speciation	All relevant aspects are addressed.		
W 2.057 Kinetics of speciation		Not relevant for geosphere transport processes.	
W 2.068 Organic complexation	See NEA FEP I 044.	See NEA FEP I 044.	See NEA FEP I 044.
W 2.071 Kinetics of organic complexation		Not relevant for geosphere transport processes.	

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Table A12-21. SR-PSU FEP Ge23 Transport of radionuclides in the water phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.37 Geochemical pump		Not addressed. Deemed not relevant for geosphere transport processes.	
A 1.65 Radioactive decay	All relevant aspects are addressed.		
A 2.45 Microbes	All relevant aspects are addressed.		
A 2.51 Radioactive decay	All relevant aspects are addressed.		
E GEN-04 Colloid behaviour in the host rock	All relevant aspects are addressed.		
E GEN-10 Radionuclide dispersion	All relevant aspects are addressed.		
E GEN-11 Distribution and release of radionuclides from the far-field	Only briefly mentioned. By definition Ge23 only includes transport as far as the geosphere–biosphere interface zone. Transport and dissemination in the biosphere is handled elsewhere.		
E GEN-13 Electrochemical effects	Mentioned briefly with regard to pH and redox buffering of groundwater.	Electrochemical effects directly influencing transport are handled elsewhere ("Earth currents", SR-PSU FEP Ge21).	
E GEN-25 Matrix diffusion	All relevant aspects are addressed.		
E GEN-26 Permafrost	All relevant aspects are addressed.		
E GEN-28 Radioactive decay	All relevant aspects are addressed.	Radiolysis effects in FEP not discussed since not deemed relevant for far-field geosphere.	See also SR-PSU FEP Ge04.
E GEN-31 Radionuclide reconcentration	Implicit in assignment of differing K_d values for alkaline affected and non-affected zone (i.e. as a spatially dynamic process).	Reconcentration/remobilsation of radionuclides as a temporally dynamic process is specifically excluded in SR-PSU.	
E GEN-35 Fast transport pathways	All relevant aspects are addressed.		
H 2.3.1 Far-field transport: Advection	All relevant aspects are addressed.		
H 2.3.3 Far-field transport: Hydrodynamic dispersion	All relevant aspects are addressed.		
H 2.3.4 Far-field transport: Solubility constraints	All relevant aspects are addressed.		
H 2.3.5 Far-field transport: Sorption including ion-exchange	All relevant aspects are addressed.		
H 2.3.6 Far-field transport: Changes in sorptive surfaces		Not addressed here, but in SR-PSU FEPs Ge12 and Ge13.	
H 2.3.8 Far-field transport: Colloid transport	All relevant aspects are addressed.		
H 2.3.9 Far-field transport: Transport of radionuclides bound to microbes		Transport by microbe cells not addressed here, but discussed in more detail in SR-PSU FEPs Ge15 and Ge17.	
H 2.3.12 Far-field transport: Thermal effects on hydrochemistry	All relevant aspects are addressed.		
I 044 Chealting agents		Not addressed here, but in SR-PSU FEP Ge22.	

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 2.1.06.2 Natural telluric electrochemical reactions		Not addressed here, but in SR-PSU FEP Ge21.	
J 4.1.06 Reconcentration	Implicit in assignment of differing K_d values for alkaline affected and non-affected zone (i.e. as a spatially dynamic process).	Reconcentration/remobilsation of radionuclides as a temporally dynamic process is specifically excluded in SR-PSU.	
J 4.1.09 Complexing agents	All relevant aspects are addressed.		
J 4.2.03 Extreme channel flow of oxidants and nuclides	All relevant aspects are addressed.		
J 7.05 Isotopic dilution	Not specifically discussed as "isotopic dilution", although isotope effects mentioned briefly. Also implicit in selection of K_d values.		Handled in more detail in SR-PSU FEP Ge14.
K 4.01 Excavation-disturbed zone (EDZ)		Not relevant for far-field geosphere transport processes. Addressed in SR-PSU FEP Ge07.	
K 4.08 Radionuclide migration		Not relevant for far-field geosphere transport processes. Specific migration aspects in this FEP (near field processes) handled elsewhere.	
K 4.09 Radionuclide retardation		Not relevant for far-field geosphere transport processes. Specific retardation aspects in this FEP (near field processes) handled elsewhere.	
K 4.10 Elemental solubility		Not relevant for far-field geosphere transport processes. Specific retardation aspects in this FEP (near field processes) handled elsewhere.	
K 5.15 Natural colloids	Discussed briefly.		More detailed account in SR-PSU FEPs Ge11, Ge12, and Ge17.
K 5.16 Solubility limits/colloid formation	All relevant aspects are addressed.		
K 5.21 Organics		Not addressed here, but discussed as a subset of the impact of "complexing ligands" in SR-PSU FEP Ge12.	
K 5.22 Microbial activity		Not addressed here, but discussed in SR-PSU FEP Ge15.	
K 6.05 Radionuclide transport through MWCF	Assumed to be a subset of far-field transport flowpaths and therefore implicit in transport descriptions.		Not handled by name MWCF (Major Water Conducting Fault).
K 6.15 Natural colloids	Discussed briefly.		More detailed account in SR-PSU FEPs Ge11, Ge12, and Ge17.
K 6.16 Solubility limits/colloid formation	All relevant aspects are addressed.		
K 6.21 Organics		Not addressed here, but discussed as a subset of the impact of "complexing ligands" in SR-PSU FEP Ge12.	
K 6.22 Microbial activity		Not addressed here, but discussed in SR-PSU FEP Ge15.	
M 1.6.01 Advection and dispersion	All relevant aspects are addressed.		
M 3.2.03 Interactions of waste and repository materials with host materials	All relevant aspects are addressed.		See also SR-PSU FEPs Ge16 and Ge22.
S 070 Radioactive decay of mobile nuclides	All relevant aspects are addressed.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
S 073 Reconcentration	Implicit in assignment of differing K_d values for alkaline affected and non-affected zone (i.e. as a spatially dynamic process).	Reconcentration/remobilsation of radionuclides as a temporally dynamic process is specifically excluded in SR-PSU.	
S 098 Transport and release of nuclides, near-field rock		Not relevant for far-field geosphere. Handled elsewhere.	
W 1.034 Saline intrusion		Implicit in groundwater chemistry defined for different climate domains. Handled elsewhere.	
W 1.035 Freshwater intrusion		Implicit in groundwater chemistry defined for different climate domains. Handled elsewhere.	
W 1.036 Changes in groundwater Eh	Implicit in assignment of differing K_d values for alkaline affected and non-affected zone (i.e. as a spatially dynamic process).	Implicit in groundwater chemistry defined for different climate domains. Handled elsewhere.	
W 1.037 Changes in groundwater pH	Implicit in assignment of differing K_d values for alkaline affected and non-affected zone (i.e. as a spatially dynamic process).	Implicit in groundwater chemistry defined for different climate domains. Handled elsewhere.	
W 2.078 Colloid transport	All relevant aspects are addressed.		See also SR-PSU FEP Ge17.
W 2.080 Colloid filtration	Addressed in the process description, but not included in processes modelled in SR-PSU.		See also SR-PSU FEP Ge17.
W 2.081 Colloid sorption	Addressed in the process description, but not included in processes modelled in SR-PSU.		See also SR-PSU FEP Ge17.
W 2.087 Microbial transport	Addressed in the process description, but not included in processes modelled in SR-PSU.		See also SR-PSU FEP Ge17.
W 2.099 Alpha recoil		Not deemed relevant for migration processes of anthropogenic radionuclides and therefore not discussed.	

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Table A12-22. SR-PSU FEP Ge24 Transport of radionuclides in the gas phase.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.65 Radioactive decay		NEA FEP not relevant for SR-PSU FEP Ge24, as it concerns waste and vaults.	
A 2.27 Gases and gas transport	All relevant aspects are addressed.		
A 2.51 Radioactive decay	All relevant aspects are addressed.		
E GEN-11 Distribution and release of radionu-clides from the far-field	All relevant aspects are addressed.		
E GEN-18 Gas flow in the far-field	All relevant aspects are addressed.		
E GEN-19 Gas genera-tion in the far-field	All relevant aspects are addressed.	Radiolytic processes in the far-field, affecting the gas flow, are not discussed due to the low activity of SFR.	
E GEN-20 Gas gen-eration in the near-field rock	All relevant aspects are addressed.	Radiolytic processes in the far-field, affecting the gas flow, are not discussed due to the low activity of SFR.	
E GEN-28 Radioactive decay	All relevant aspects are addressed.		
H 2.3.10 Far-field transport: Transport of radioactive gases	All relevant aspects are addressed.	Attenuation processes in the far-field are not recommended to be modelled, but instead pessimistically neglected.	
H 2.3.11 Far-field transport: Gas induced groundwater transport	All relevant aspects are addressed.		
H 4.1.3 Gas discharge	All relevant aspects are addressed.		
K 0.3 Gaseous and volatile isotopes	All relevant aspects are addressed.	Volatile organic compounds binding to radionuclides such as Se and I are not discussed, as such are unlikely.	
K 5.24 Geogas	All relevant aspects are addressed.		
K 6.24 Geogas	All relevant aspects are addressed.		
M 1.6.04 Gas mediated transport		NEA FEP not relevant for SR-PSU FEP Ge24, as it concerns clay.	
S 098 Transport and release of nuclides, near-field rock	All relevant aspects are addressed.		
W 2.055 Radioactive gases	All relevant aspects are addressed.		
W 2.089 Transport of radioactive gases	All relevant aspects are addressed.		

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Appendix 13

Handling of NEA Project FEPs sorted to SR-PSU External factors

Table A13-1. SR-PSU FEP Cli02 Climate forcing.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.07 Climate change	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration. Natural climate variability and the impact on climate of an enhanced greenhouse effect are considered within this range.	Reversal of magnetic poles and destruction of the ozone layer are not covered. They are considered to be of minor importance for the climate system.	The atmosphere's importance for the radiation balance and climate are covered.
A 2.31 Greenhouse effect	The increased greenhouse effect could lead to changes in e.g. temperature and precipitation.		Changes in temperature and precipitation rates associated with an increased greenhouse effect are described and analysed in three climate cases representing prolonged interglacial conditions. . See also NEA FEP A 2.07.
A 2.40 Magnetic poles (reversal)		Changes in the Earth's ionization layer due to reversal of magnetic poles are not considered since they are considered insignificant for the radiation balance.	
A 2.48 Ozone layer		Changes in the Earth's radiation balance due to destruction of the stratospheric ozone layer are not considered since they are considered insignificant for Swedish climate. Changes in groundwater flow patterns are not considered. Groundwater flow is a geosphere process.	See also SKB FEP Ge03.
A 3.051 Flipping of earth's magnetic poles		Temporary changes in the Earth's ionization layer and increased solar radiation are not considered since they are considered insignificant for the radiation balance.	See NEA FEP A 2.40.
A 3.059 Greenhouse effect	The radiative effect of atmospheric carbon dioxide and other greenhouse gases.	Changes in the Earth's radiation balance due to destruction of the stratospheric ozone layer are not considered since they are considered insignificant for Swedish climate.	See NEA FEP A 2.07.
A 3.078 Ozone layer failure		Changes in the Earth's radiation balance due to destruction of the stratospheric ozone layer are not considered since they are considered insignificant for Swedish climate. UV radiation can induce skin cancer. Only cancers that are caused by the repository is included in the safety assessment.	See NEA FEP A 2.07
E GEN-21 Glaciation	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration. Glacial conditions associated with future ice sheet coverage at the repository site, and associated changes in permafrost distribution, hydrostatic pressure, groundwater flow and chemistry, hydraulic jacking, glacial erosion, shoreline displacement, are considered within this range.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 5.20 Changes of the magnetic field		Reversal of magnetic poles is not covered. It is considered to be of minor importance for the climate system.	
J 5.42 Glaciation	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration. Glaciation is considered within this range.		
M 1.1.02 Solar insolation	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration. .		
M 1.2.02 Changes in Earth's magnetic field		Reversal of magnetic poles is not covered. It is considered to be of minor importance for the climate system.	
M 1.3.04 Sea-level change	Sea-level changes caused by human-induced global warming and glaciations, and its effect on e.g. landscape development and ground water flow are considered with the included climate cases.		
M 1.3.05 Periglacial effects and glaciation	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration. Glaciation and permafrost, and associated erosion and changes in groundwater flow and chemistry, are considered within this range.		
S 047 Glaciation	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration. Glaciation is considered within this range.		
W 1.061 Climate change	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration. Future climate change and related effects on hydrology are considered within this range.	Alteration of the groundwater table and groundwater flow in the vicinity of the WIPP repository (Carlsbad, New Mexico, USA).	
W 3.049 Damage to the ozone layer	Natural climate variability and the impact on climate of an enhanced greenhouse effect.	Destruction of the ozone layer is not covered. It is considered to be of minor importance for the climate system. Alteration of the climate in the vicinity of the WIPP repository (Carlsbad, New Mexico, USA).	

Recorded by: Jenny Brandefelt, Jens-Ove Näslund **Date:** 2014-02-25
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Revisions approved by: Not applicable **Date:**

Table A13-2. SR-PSU FEP Cli03 Climate evolution.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.12 Climate change	Changes to the current climate that may affect the performance of the repository. Increased or decreased rates of meteoric precipitation.	Volume and rate of groundwater flow past the disposal vault is a geosphere process (Ge03).	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration. The possible impacts of future changes in climate-related issues on the repository are covered. The hydrological cycle, formation of groundwater and its dependence on climate conditions are covered.
A 2.07 Climate change	Natural climate variability and the impact on climate of an enhanced greenhouse effect, Changes of the current climate to wetter, drier, warmer, cooler and/or permafrost conditions, affecting flow properties of the geosphere (including recharge volumes). Glaciation.	Reversal of magnetic poles and destruction of the ozone layer are not covered. They are considered to be of minor importance for the climate system.	Coverage - see comment to NEA FEP A 1.12.
A 2.19 Drought	The current levels of meteoric precipitation could change leading to reduced flow of water through the geosphere.	Changes to the biosphere are biosphere processes.	Coverage - see comment to NEA FEP A 1.12.
A 2.25 Flood	The current levels of meteoric precipitation could change leading to greater flows of water through the geosphere.	Changes to the biosphere are biosphere processes.	Coverage - see comment to NEA FEP A 1.12.
A 2.31 Greenhouse effect	Increased concentrations of carbon dioxide and other greenhouse gases in the atmosphere.		
A 3.024 Climate change	Climate changes due to anthropogenic and natural causes. Occurrence of continental glaciations.		Coverage - see comment to NEA FEP A 1.12.
A 3.043 Dust storms and desertification		Deforestation, disappearance of grassland, transport of contaminants in soil, dispersion of contaminants due to wind erosion, no human habitats and formation of alkali flats are biosphere processes. Erosion due to wind erosion and dust storms is a biosphere process (SR-PSU FEP Bio38).	Coverage - see comment to NEA FEP A 1.12.
A 3.059 Greenhouse effect	The impact on climate of an enhanced greenhouse effect due to the human-induced increase in atmospheric greenhouse gas concentrations. The duration of the human-induced greenhouse effect on the climate and the rate of disappearance of the greenhouse gases from the atmosphere.	Conditions in North America are not covered since the repository site is located in Sweden.	Effects on the global and Scandinavian climate conditions are handled.
E GEN-21 Glaciation	Glacial conditions associated with future ice sheet coverage at the repository site. Associated changes in permafrost distribution, hydrostatic pressure, groundwater flow and chemistry, hydraulic jacking, glacial erosion, shore line displacement.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
H 3.1.1 Climate change: Human induced	Changes to the climate and climate system due to human activities e.g. release of greenhouse gases to the atmosphere. Impact of the increased greenhouse effect on the timing of the next glacial inception.	Ecological consequences of a warmer climate are biosphere processes.	Coverage - see comment to NEA FEP A 1.12.
H 3.1.2 Climate change: Natural	Glacial/interglacial cycles. Changes in temperature, sea-level, precipitation, evaporation, groundwater recharge and ecosystems.		
H 3.1.3 Exit from glacial/interglacial cycling	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration.	At present groundwater storage is basically at its maximum, the additional water during deglaciation would not alter groundwater flow significantly.	
H 3.1.4 Intensification of natural climate change	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration.		
I 049 Climate change	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration. Changes of the current climate to wetter, drier, warmer, cooler and/or permafrost conditions and/or glacial conditions are considered within this range. Possible subsurface impact are also considered.	The influence of temperature on heating fuel needs and radionuclide concentrations in indoor air. Climate changes in the vicinity of the IRUS repository (Canada) and their possible impact on the IRUS repository. Alteration of groundwater flow is a geosphere process. The impact of climate changes on the biosphere is included among the biosphere processes. Deforestation, disappearance of grassland, transport of contaminants in soil, dispersion of contaminants due to wind erosion, no human habitats and formation of alkali flats are biosphere processes. Erosion due to wind erosion and dust storms is a biosphere process (SR-PSU FEP Bio38).	Coverage - see comment to NEA FEP A 1.12. See also SKB PSU FEPs Cli10 and Ge03 as well as the biosphere FEPs.
J 5.32 Desert and unsaturation	Drilling of wells to repository depth is considered as future human actions.	Dry climate and lowering of the groundwater surface is not considered. It is considered very unlikely. Unsaturated flow and the effects of unsaturated conditions on technical and geological barriers are not external processes.	Coverage - see comment to NEA FEP A 1.12.
J 5.42 Glaciation	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration. Glaciation is considered within this range.		
J 6.10 No ice age	Temperate climate conditions during the next 100 ka are considered within the range of future climate developments (climate cases).		It is unclear what the authors of the FEP mean by no ice age, it is said to be "a variation of ice age". It is assumed that the FEP refers to interglacial periods and warm phases (interstadials) of glacial periods.
K 10.03 Seasonality of climate		The effect on biosphere conditions by alterations of the length of temperate periods are biosphere processes.	Coverage - see comment to NEA FEP A 1.12. See also SKB's Biosphere FEPs.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
K 10.04 Future climatic conditions	Conceivable variations of climate related conditions during the assessment period.		Coverage - see comment to NEA FEP A 1.12.
K 10.05 Tundra climate	Tundra climate, general conditions and possible subsurface impact.		
K 10.06 Glacial climate	Glacial climate, general conditions and possible subsurface impact.		Coverage - see comment to NEA FEP A 1.12. Glacial erosion and weathering is discussed in SKB FEP Cli10.
K 10.07 Warmer climate - arid		A warmer arid climate is not considered. It is considered very unlikely. Ecological consequences of a warmer arid climate are biosphere processes.	
K 10.08 Warmer climate - seasonal humid	Warm humid climate conditions all year around.	A warmer climate with marked seasonality between warm, humid rainy seasons and cold, dry seasons (monsoon-like) is not considered. It is considered very unlikely.	
K 10.09 Warmer climate - equable humid	Climate with high temperatures, precipitation and moderate evapotranspiration with minor seasonality.		
K 10.10 Greenhouse effect	Global climate changes due to emissions of greenhouse gases.		
K 11.09 Human-induced climate change	The impact of anthropogenic greenhouse gases (e.g. CO_2, CH_4 etc.) on the climate.		Coverage - see comment to NEA FEP A 1.12.
M 1.3.05 Periglacial effects and glaciation	Permafrost development under various climate assumptions, and associated changes in groundwater flow and chemistry. Glaciation is considered.		Fluvial and glacial erosion are considered under FEP Cli10.
M 2.4.09 Anthropogenic climate changes (greenhouse effect)	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration.		
W 1.056 Changes in groundwater recharge and discharge	Groundwater recharge and discharge given different climate conditions.	Alteration of the groundwater table and groundwater flow in the vicinity of the WIPP repository (Carlsbad, New Mexico, USA).	See also SKB FEP Ge03.
W 1.061 Climate change	A range of future climate developments (climate cases) is defined based on current scientific knowledge, including known future variations in the orbital parameters, obliquity, the eccentricity of the Earth's orbit, and the precession of the equinoxes, and projected future variations in the atmospheric CO_2 concentration. Future climate change and related effects on hydrology are considered within this range.	Alteration of the groundwater table and groundwater flow in the vicinity of the WIPP repository (Carlsbad, New Mexico, USA).	
W 1.062 Glaciation	Glaciation is considered within the range of future climate developments (climate cases).	Glaciations in the vicinity of the WIPP repository (Carlsbad, New Mexico, USA) are unrealistic.	
W 1.063 Permafrost	Permafrost is considered within the range of future climate developments (climate cases).	Permafrost in the vicinity of the WIPP repository (Carlsbad, New Mexico, USA) is unrealistic.	
W 3.047 Greenhouse gas effects	The impact on climate of an enhanced greenhouse effect is considered within the range of future climate developments (climate cases).	Alteration of the climate in the vicinity of the WIPP repository (Carlsbad, New Mexico, USA).	

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Table A13-3. SR-PSU FEP Cli05 Permafrost development.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.30 Glaciation	Permafrost could affect rock and groundwater flow characteristics. Aggradation and degradation of permafrost and its potential impact on the repository are covered.		
E GEN-21 Glaciation	Glacial conditions associated with future ice sheet coverage at the repository site. Associated changes in permafrost distribution, groundwater flow and chemistry, glacial erosion, shoreline displacement.		
E GEN-26 Permafrost	Development of permafrost and frozen ground. Potential timing of first future period of permafrost at repository site. Associated effects on groundwater flow. Effects of freezing on the repository.		
H 3.1.2 Climate change: Natural	Seasonally and permanently frozen ground.		
J 5.17 Permafrost	Permafrost in Sweden in a glacial time scale. Current occurrence of permafrost. Potential timing of first future period of permafrost at repository site. Relationship between mean annual air temperature and permafrost depth. Effect of surface conditions on development of permafrost. Effect of geothermal heat flow on development of permafrost. Potential subsurface effects of permafrost. Temperature gradients. Groundwater flow in areas of permafrost.	Accumulation of gas and radionuclides below the lower surface of the permafrost. Groundwater flow, accumulation of gas and radionuclides are not external processes.	See also PSU FEPs related to freezing, e.g. Ge02.
K 10.13 Permafrost	Development of permafrost and its dependence on surface temperature and conditions and geological conditions. Current occurrence of permafrost. Possible permafrost depths given defined surface and subsurface conditions. Groundwater recharge/discharge in unfrozen zones, "taliks".		
M 1.3.05 Periglacial effects and glaciation	Permafrost development under various climate assumptions, and associated changes in ground water flow and chemistry. Potential timing of first future periods of permafrost at repository site. Glaciation is considered.		
S 059 Permafrost	Permafrost in Sweden in a glacial time scale. Current occurrence of permafrost. Relationship between mean annual air temperature and permafrost depth. Effect of surface conditions on development of permafrost. Groundwater flow in areas of permafrost. Effect of geothermal heat flow on development of permafrost. Freeze-out of salt during permafrost development. Potential subsurface effects of permafrost. Temperature gradients.	Accumulation of gas and radionuclides below the lower surface of the permafrost. Groundwater flow, accumulation of gas and radionuclides are not external processes.	See also PSU FEPs Ge02, Ge03,Ge04 and Ge20.

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Table A13-4. SR-PSU FEP Cli06 Ice-sheet dynamics and hydrology.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.38 Glaciation	Possible timing of first future period of glaciation.		All detailed potential effects of glacial conditions are not explicitly analysed. Instead, the full potential effects of glacial conditions on repository safety are treated by a simplistic pessimistic safety assessment scenario assuming fully degraded repository barriers after ice sheet deglaciation.
A 2.30 Glaciation	Possible timing of first future period of glaciation.		Coverage – see comment to NEA FEP A 1.38.
A 3.057 Glaciation	Glaciation may influence the repository system.	Massive disruptions in the biosphere since they are biosphere processes.	Coverage - see comment to NEA FEP A 1.38.
E GEN-21 Glaciation	Possible timing of first future period of glaciation. Glacial conditions associated with future ice sheet coverage at the repository site.		Coverage – see comment to NEA FEP A 1.38.
H 3.1.2 Climate change: Natural	Natural climate change, including periods of glaciation, is included in the range of climate scenarios (climate cases) used in the assessment.		
J 5.42 Glaciation	Possible timing of first future period of glaciation.		Coverage – see comment to NEA FEP A 1.38.
K 10.16 Ice sheet effects (loading, melt water recharge)	Occurrence of permafrost during periods of colder climate conditions. Possible timing of first future period of glaciation.		Coverage – see comment to NEA FEP A 1.38.
M 1.3.05 Periglacial effects and glaciation	Permafrost development under various climate assumptions, and associated changes in groundwater flow. Glaciation and glacial erosion are considered.		Coverage – see comment to NEA FEP A 1.38.
S 047 Glaciation	Possible timing of first future period of glaciation. Shore-line displacement associated with glaciations.	Hydrofracturing of the bedrock and alteration of fracture aperture due to freezing of subglacial meltwater are not external processes.	Glacial erosion is mainly covered by the process denudation (Cli10). Coverage – see comment to NEA FEP A 1.38. The FEP says "The ice will constitute a shielding barrier layer which will bind most of the precipitation, thus limiting recharge and flow through the (most probably permafrosted) bedrock." It is assumed that this refers to a cold based ice where there is no liquid water available. See also geosphere processes Ge03, Ge06 and Ge07.

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Table A13-5. SR-PSU FEP Cli08 Glacial isostatic adjustment.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.30 Glaciation	Glaciations cause isostatic depression. These effects may significantly change rock stresses and groundwater flow characteristics. During interglacial periods isostatic rebound affects rock and flow characteristics. Isostatic adjustment due to the redistribution of water masses from the oceans to land based ice sheets and vice versa and its potential impact on the repository are covered.		
A 2.38 Isostatic rebound	The presence of ice sheets will depress the crust followed later by rebound effects when the load is removed.		Associated changes in relative sea-level are covered.
E GEN-39 Uplift and subsidence	Possible timing of next glacial inception, and associated timing of glacial isostatic changes. Isostatic changes due to loading and unloading from continental glaciation. Associated changes in sea-level and shoreline displacement. Glacial erosion.	Tectonic uplift and crustal movements are not considered except for description of current uplift rates which include both isostatic and tectonic components.	Coverage – see comment to NEA FEP A 1.38 in SR-PSU FEP Cli06.
H 2.1.1 Regional tectonic activity	Glacial isostatic adjustment.		
J 5.16 Uplift and subsidence	Possible timing of next glacial inception, and associated timing of glacial isostatic changes. Ongoing isostatic uplift in Sweden. Current rate of uplift. Largest isostatic uplift in connection to retreat of the ice sheet. Total isostatic uplift since LGM. Remaining isostatic uplift.	Tectonic uplift and crustal movements are not considered except for description of current uplift rates which include both isostatic and tectonic components.	Coverage - see comment to NEA FEP A 2.30. Coverage – see comment to NEA FEP A 1.38 in SR-PSU FEP Cli06.
J 5.31 Change in sealevel	Redistribution of water masses during a glacial cycle. The effect shore-line displacement (sum of sea-level change and isostatic changes) on groundwater flow.	It is said that exposed sea bottoms suffers extensive erosion close to the ice rim during interglacial periods, but during interglacial periods there are only ice sheets on Greenland and in Antarctica and sea levels are high. Consequently this aspect has not been considered.	It is unclear whether the NEA FEP refers to the eustatic or isostatic process or their combined effect on shore-line migration.
J 5.42 Glaciation	The weight of the ice sheet will cause an isostatic depression of the Earth's crust.		Coverage – see comment to NEA FEP A 1.38 in SR-PSU FEP Cli06.
M 1.2.06 Uplift and subsidence	Denudation over a time-scale of 100 ka.	Tectonic uplift and crustal movements are not considered except for description of current uplift rates which include both isostatic and tectonic components.	
S 047 Glaciation	Glacial isostatic depression of the Earth's crust.		
W 1.005 Regional uplift and subsidence	Isostatic uplift in Sweden (see handling of NEA FEP J 5.16).		

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Table A13-6. SR-PSU FEP Cli09 Shore-level changes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.59 Sea level change	Changes in sea-level and shore line elevation caused by climate change and different stages of glacial cycles.		
E GEN-33 Sea level changes	Sea level changes due to natural and anthropogenic causes (the latter through an increased greenhouse effect). Changes from terrestrial to marine conditions. Effects on hydrological and chemical conditions. Shore line migration, and associated changes in landscape development and biosphere.		
H 2.2.1 Changes in geometry and driving forces of the flow system	Changes caused by permafrost development and sea level change.		See also PSU FEP Ge03.
H 3.1.3 Exit from glacial/interglacial cycling	Alteration of sea level when glaciers and icesheets melt.		
I 266 Sea level (rising)	The combined effect of isostatic and eustatic processes on the shoreline.	The effect on groundwater flow and contaminant transport of shore-line migration are geosphere processes. Shore-line migration in the vicinity of the IRUS repository (Canada).	See also PSU FEP Ge03.
J 5.31 Change in sealevel	Resulting shore-level migration from isostatic and eustatic processes. Resulting effect on groundwater flow and biosphere recipients.	Shore-level migration due to erosion/sedimentation is not covered. Along the Swedish Baltic coasts this process is considered to be of minor importance in the studied time perspective and in relation to shore-line migration due to glaciations. Changes in groundwater flow and salinity due to shore-line migration are not external processes.	See also Glacial isostatic adjustment (Cli08) and Denudation (Cli10).
J 5.42 Glaciation	Impact of the glacial isostatic process on shore-level migration.		See also geosphere processes; Ge03, Ge06, Ge07.
M 1.3.04 Sea-level change	Estimates of possible future sea-level rise on short (until 2100 AD) and long (several thousands of years) time-scales according to present scientific literature. Sea level changes caused by glaciations and by human induced global warming, and its effect on e.g. landscape development and ground water flow.		
M 1.3.05 Periglacial effects and glaciation	The effects of glaciations on shore-level are considered.		
S 047 Glaciation	The combined effect of glacial isostatic and eustatic processes on the shore-level.		See also geosphere processes; Ge03, Ge06, Ge07.
S 081 Sea level changes	Estimates of possible future sea-level rise on short (until 2100 AD) and long (several thousands of years) time-scales according to present scientific literature. Resulting shore-level migration from isostatic and eustatic processes and their coupling to climate and ice sheet extent. The impact of temperature on sea level.	Changes in groundwater flow and salinity due to shore-line migration are not external processes. Alteration of biosphere conditions due to shore line migration is a biosphere process. Exposed sea bottoms suffers extensive erosion close to the ice rim during interglacial periods, but during interglacial periods there are only ice sheets on Greenland and in Antarctica and sea levels are high. Consequently this aspect has not been considered.	See also biosphere FEP Bio49.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
W 1.068 Sea level changes	Sea level change due to build up of ice sheets. Sea level change if the climate gets warmer for instance due an increased greenhouse effect.	Short-term changes in sea level, brought about by events such as meteorite impact, tsunamis, seiches, and hurricanes as their impact on sea levels in the Baltic are neglectable for the safety of the repository. Shore-level migration will not impact the WIPP repository (Carlsbad, New Mexico, USA).	

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Table A13-7. SR-PSU FEP Cli10 Denudation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.22 Erosion	Erosion during temperate, periglacial and glacial conditions.		
E GEN-21 Glaciation	Erosion during glacial conditions.		
E GEN-29 Erosion and weathering	Surface denudation (erosion (fluvial, glacial eolian etc) and weathering) are considered in a 100 ka time perspective. Glacial erosion in relation to topography.		
H 2.1.8 Major incision	Potential glacial erosion at the repository site and surrounding region.		
H 2.2.1 Changes in geometry and driving forces of the flow system		In Sweden erosion is of minor significance in this context in relation to glaciation and related isostatic and eustatic processes.	See also PSU FEP Ge03.
H 2.4.1 Generalised denudation	Denudation during temperate, periglacial and glacial conditions.		
H 2.4.2 Localised denudation	Denudation during temperate, periglacial and glacial conditions.	Coastal erosion is not included since the repository site does not constitute an erosional coast.	
H 4.1.2 Solid discharge via erosional processes		Erosion and redistribution of contaminated sediments.	See PSU FEP Bio38.
I 049 Climate change		Erosion of exposed soil, through desertification, are not treated since desertification has been ruled out.	See also Climate FEP Cli03.
I 112b Denuding of the site		Denudation of the IRUS site.	
J 5.26 Erosion on surface/ sediments	Erosion during temperate, periglacial and glacial conditions.		
K 5.18 Hydraulic gradient changes (magnitude, direction)		In Sweden erosion is of minor significance in this context in relation to glaciation and related isostatic and eustatic processes.	See also PSU FEP Ge03.
K 6.18 Hydraulic gradient changes (magnitude, direction)	See NEA FEP H 2.2.1		
K 7.11 Erosion	See NEA FEP A 2.22		
K 8.22 Erosion/ deposition	See NEA FEP A 2.22		
K 9.07 Erosion/ denudation	See NEA FEPs A 2.22, J 5.26, H 2.4.1 and H 2.4.2		
K 10.06 Glacial climate	Glacial erosion and weathering are discussed.		See also Climate FEP Cli03.
K 10.12 Surface denudation	See NEA FEPs A 2.22, J 5.26, H 2.4.1 and H 2.4.2		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
K 10.14 Glacial erosion/sedimentation	Erosion under glacial conditions.		
K 10.15 Glacial–fluvial erosion/sedimentation	Erosion under glacial conditions.		
M 1.3.05 Periglacial effects and glaciation	Glaciation, including glacial erosion, is considered.		
M 1.4.02 Denudation	Surface denudation (erosion (fluvial, glacial eolian etc) and weathering) are considered in a 100 ka time perspective.		
S 047 Glaciation	Glacial erosion is considered.		
W 1.009 Changes in fracture properties		There is no direct impact of surface erosion on fracture properties. However, erosion of the bedrock and erosion/redistribution of sediments will alter the stress field and cause compression/dilatation of fractures. This process is considered insignificant in the studied time frame.	Erosion/sedimentation in fractures described separately, see PSU FEP Ge09.
W 1.041 Mechanical weathering	Weathering, including mechanical weathering, is considered in a 100 ka time perspective.		
W 1.042 Chemical weathering	Weathering, including chemical weathering. hydration, hydrolysis, reduction and oxidation, is considered in a 100 ka time perspective.		

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Table A13-8. SR-PSU FEP LSGe01 Mechanical evolution of the Shield.

NEA FEP	Aspects of the FEP not addressed in the SR-PSU Geosphere process report because:	Comments
E GEN-05 Creeping of the rock mass	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Occurrence of threshold strength is addressed in SR-Site, SKB TR-10-48, Section 4.1.2.
E GEN-36 Stress field	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Thermal and glacial impact on stress field is addressed in SR-Site, SKB TR-10-48, Section 4.1.2.
E GEN-39 Uplift and subsidence	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Plate tectonics and glacial isostatic adjustment are addressed in SR-Site, SKB TR-10-48, Section 4.1.2. See also SR-PSU FEP Cli08.
H 2.1.1 Regional tectonic activity	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Regional tectonic activity is addressed in SR-Site, SKB TR-10-48, Section 4.1.2.
J 4.2.06 Faulting	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Large-scale changes in tectonic conditions are addressed in SR-Site, SKB TR-10-48, Section 4.1.2.
J 5.16 Uplift and subsidence	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Plate tectonics and glacial isostatic adjustment are addressed in SR-Site, SKB TR-10-48, Section 4.1.2. See also SR-PSU FEP Cli08.
M 1.2.01 Plate movement tectonic change	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Estimates of Baltic Shield tectonic strain rates are addressed in SR-Site, SKB TR-10-48, Section 4.1.2.
M 1.2.06 Uplift and subsidence	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Plate tectonics and glacial isostatic adjustment are addressed in SR-Site, SKB TR-10-48, Section 4.1.2. See also SR-PSU FEP Cli08.
M 1.2.10 Fault generation	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Regional tectonics and changes in the stress in the Baltic Shield are addressed in SR-Site, SKB TR-10-48, Section 4.1.2.
W 1.003 Changes in regional stress	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Regional tectonics and changes in the stress in the Baltic Shield are addressed in SR-Site, SKB TR-10-48, Section 4.1.2.
W 1.004 Regional tectonics	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Regional tectonics and changes in the stress in the Baltic Shield are addressed in SR-Site, SKB TR-10-48, Section 4.1.2.
W 1.005 Regional uplift and subsidence	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Regional tectonics and changes in the stress in the Baltic Shield are addressed in SR-Site, SKB TR-10-48, Section 4.1.2.
W 1.010 Formation of new faults	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Site-specific FEP that mainly address fault movement covered by NEA FEP W1.011.
W 1.011 Fault movement	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Regional tectonics (Baltic Shield) including fault movement is addressed in SR-Site, SKB TR-10-48, Section 4.1.2.

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Table A13-9. SR-PSU FEP LSGe02 Earthquakes.

NEA FEP	Aspects of the FEP not addressed in the process report because:	Comments
A 1.29 Earthquakes	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
A 2.21 Earthquakes	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
A 3.045 Earthquakes	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
H 2.1.6 Seismicity	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
I 100 Seismic events	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
J 4.2.01 Mechanical failure of repository	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
J 4.2.06 Faulting	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
J 5.15 Earthquakes	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
J 5.42 Glaciation	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Post-glacial faulting is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
K 9.05 Seismic activity	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
K 9.06 Stress changes - hydrogeological effects	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
M 1.2.08 Seicmicity	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
M 1.2.10 Fault generation	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
S 036 Faulting	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
W 1.011 Fault movement	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
W 1.012 Seismic activity	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
W 1.031 Hydrological response to earthquakes	Large-scale geological processes are not specifically addressed in SR-PSU because the SR-Site descriptions are applicable for the Forsmark site, including SFR.	Seismic activity in Scandinavia is addressed in SR-Site, SKB TR-10-48, Section 4.1.3.
Recorded by: Kristina Skagius		**Date:** 2014-08-26
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Revisions approved by:		**Date:**

Table A13-10. SR-PSU FEP FHA01 State of knowledge.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.071 Intrusion (inadvertent)	Intent and responsibilities.		
I 169 Intrusion (human/inadvertent)	Intent and responsibilities.		
I 189 Loss of markers (misinterpretation)	Knowledge of the repository.		
I 190 Loss of records	Conservation of information, countermeasures against unintentional intrusion.		
I 253 Retrievability	Intent and responsibilities.		Only intent and responsibility is discussed. The question of whether it should be possible to retrieve waste is not discussed for the low and intermediate level waste repository.
J 5.33 Waste retrieval, mining	Intent and responsibilities.		Only intent and responsibility is discussed. The question of whether it should be possible to retrieve waste is not discussed for the low and intermediate level waste repository.
J 7.09 Loss of records	Knowledge of the repository.		
K 11.10 Repository records, markers	Conservation of information, countermeasures against unintentional intrusion.		
K 11.11 Planning restrictions	Countermeasures against unintentional intrusion.		
M 2.4.01 Loss of records	Knowledge of the repository.		
W 3.057 Loss of records	Knowledge of the repository.		
Recorded by: Eva Andersson			**Date:** 2014-03-06
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Revisions approved by: Not applicable			**Date:**

Table A13-11. SR-PSU FEP FHA02 Societal development.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 223 Political (loss of institutional control)	Capacity of society's information system, legitimacy of government and degree of governability may affect loss of memory of the repository.		
J 5.37 Archeological intrusion	Possible purposes of unintentional intrusion.		
J 7.09 Loss of records	Knowledge of the repository.		
M 2.4.01 Loss of records	Knowledge of the repository.		
M 2.4.08 Demographic change, urban development	Human settlements and demographic pattern affect the societal development which in turn may affect loss of memory of the repository.		
W 3.056 Demographic change and urban development	Human settlements and demographic pattern which in turn may affect loss of memory of the repository.		
W 3.057 Loss of records	Knowledge of the repository.		
Recorded by: Eva Andersson			**Date:** 2014-03-06
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Table A13-12. SR-PSU FEP FHA03 Technical development.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.61 Solution mining		Solution mining is not addressed since this is used for extracting soluble ores such as potash and salt. These kinds of minerals are not available at the repository site.	
W 3.056 Demographic change and urban development	Societal changes may affect loss of memory of the repository	Technological changes at the site since current technology is assumed in the assessment.	
Recorded by: Eva Andersson			**Date:** 2014-03-06
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Table A13-13. SR-PSU FEP FHA04 Heat storage.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.061 Heat storage in lakes or under-ground	Build heat store.		A heat storage system may include blasting and excavation of rock caverns but would start with drilling at which case the repository should be discovered, i.e. included in the drilling scenario FHA CC1.
Recorded by: Eva Andersson			**Date:** 2014-03-06
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Table A13-14. SR-PSU FEP FHA05 Heat pump system.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.061 Heat storage in lakes or under-ground	Build heat store.		A heat storage system would start with drilling at which case the repository should be discovered, i.e. included in the drilling scenario FHA CC1.
Recorded by: Eva Andersson			**Date:** 2014-03-06
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Table A13-15. SR-PSU FEP FHA06 Geothermal energy.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 5.34 Geothermal energy production	Extraction of geothermal energy.		Considered in SKB FEP FHA05 (Heat pump system). This would start with exploratory drilling and are thus covered by FHA scenarios drilling FHA CC1.
K 11.03 Geothermal exploitation	Extraction of geothermal energy.		Considered in SKB FEP FHA05 (Heat pump system). This would start with exploratory drilling and are thus covered by FHA scenarios drilling FHA CC1.
M 2.3.05 Geothermal energy production	Extraction of geothermal energy.		Considered in SKB FEP FHA05 (Heat pump system). This would start with exploratory drilling and are thus covered by FHA scenarios drilling FHA CC1.
W 3.007 Geothermal	Extraction of geothermal energy, exploratory drilling.		Unlikely to occur, but if it does, it would start with exploratory drilling and are thus covered by FHA scenarios drilling FHA CC1.
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SR-PSU FEP FHA07 Heating/cooling plant

No NEA Project FEPs associated with this SR-PSU FEP.

Table A13-16. SR-PSU FEP FHA08 Drilled well.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.03 Borehole - well	Construct well.		FHA CC4 to use a borehole as a well is included in the main calculation cases and are not described in detail in the FHA report but in the SR-PSU Main report (SKB TR-14-01) and in the Radionuclide transport report (SKB TR-14-09).
A 3.068 Industrial water use	Construct well, irrigation, drainage or infiltration system.	Building a dam is not considered since for SFR, this is assumed to have insignificant effect on water flows at repository depth and thereby does not affect the safety functions of the repository. Change the course or extent of surface water bodies (streams, lakes, sea) and their connections with other surface water bodies since this is assumed to have minor effect on the water flows at the repository depth and thereby have minor effects on the safety functions of the repository.	FHA CC4 to use a borehole as a well is included in the main calculation cases and are not described in detail in the FHA report but in the SR-PSU Main report (SKB TR-14-01) and in the Radionuclide transport report (SKB TR-14-09).
J 5.27 Human induced actions on groundwater recharge	Construct well.	Changed conditions for ground-water recharge by changes in land use are considered in the main calculation cases for the change of wetland to agricultural land.	FHA CC4 to use a borehole as a well is included in the main calculation cases and are not described in detail in the FHA report but in the SR-PSU Main report (SKB TR-14-01) and in the Radionuclide transport report (SKB TR-14-09).
J 5.36 Reuse of boreholes	Construct well.		FHA CC4 to use a borehole as a well is included in the main calculation cases and are not described in detail in the FHA report but in the SR-PSU Main report (SKB TR-14-01) and in the Radionuclide transport report (SKB TR-14-09).
K 11.05 Deep ground-water abstraction	Construct well.		FHA CC4 to use a borehole as a well is included in the main calculation cases and are not described in detail in the FHA report but in the SR-PSU Main report (SKB TR-14-01) and in the Radionuclide transport report (SKB TR-14-09).
W 3.005 Groundwater exploitation	Construct well.		FHA CC4 to use a borehole as a well is included in the main calculation cases and are not described in detail in the FHA report but in the SR-PSU Main report (SKB TR-14-01) and in the Radionuclide transport report (SKB TR-14-09).
W 3.026 Groundwater extraction	Construct well.		FHA CC4 to use a borehole as a well is included in the main calculation cases and are not described in detail in the FHA report but in the SR-PSU Main report (SKB TR-14-01) and in the Radionuclide transport report (SKB TR-14-09).

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Table A13-17. SR-PSU FEP FHA09 Water management.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.14 Dams	Water management.	Building a dam is not considered since for SFR, this is assumed to have insignificant effect on water flows at repository depth and thereby does not affect the safety functions of the repository.	
A 3.068 Industrial water use	Water management, construct well, drainage or infiltration system, change the course or extent of surface water bodies (streams, lakes, sea) and their connections with other surface water bodies.		FHA CC4 to use a borehole as a well is included in the main calculation cases and are not described in detail in the FHA report but in the SR-PSU Main report (SKB TR-14-01) and in the Radionuclide transport report (SKB TR-14-09).
A 3.115 Water management projects	Build dam, hydropower or irrigation system.		
J 5.27 Human induced actions on groundwater recharge	Changed conditions for groundwater recharge by changes in land use, construct well.	Changed conditions for groundwater recharge by changes in land use are considered in the main calculation cases for the biosphere but not specifically addressed in the FHA scenarios. Building a dam is not considered since for SFR, this is assumed to have insignificant effect on water flows at repository depth and thereby does not affect the safety functions of the repository.	FHA CC4 to use a borehole as a well is included in the main calculation cases and are not described in detail in the FHA report but in the SR-PSU Main report (SKB TR-14-01) and in the Radionuclide transport report (SKB TR-14-09).
J 7.07 Human induced changes in surface hydrology	Construct well, irrigation, drainage or infiltration system, change the course or extent of surface water bodies (streams, lakes, sea) and their connections with other surface water bodies.	Changed conditions for groundwater recharge by changes in land use are considered in the main calculation cases for the biosphere but not specifically addressed in the FHA scenarios. Building a dam is not considered since for SFR, this is assumed to have insignificant effect on water flows at repository depth and thereby does not affect the safety functions of the repository.	FHA CC4 to use a borehole as a well is included in the main calculation cases and are not described in detail in the FHA report but in the SR-PSU Main report (SKB TR-14-01) and in the Radionuclide transport report (SKB TR-14-09).
K 8.37 Earthworks (human actions, dredging, etc.)	Water management.		
K 11.06 Water management schemes	Construct well, irrigation, drainage or infiltration system, change the course or extent of surface water bodies (streams, lakes, sea) and their connections with other surface water bodies.	Building a dam is not considered since for SFR, this is assumed to have insignificant effect on water flows at repository depth and thereby does not affect the safety functions of the repository.	FHA CC4 to use a borehole as a well is included in the main calculation cases and are not described in detail in the FHA report but in the SR-PSU Main report (SKB TR-14-01) and in the Radionuclide transport report (SKB TR-14-09).
M 2.4.02 Dams and reservoirs, built/drained		Building a dam is not considered since for SFR, this is assumed to have insignificant effect on water flows at repository depth and thereby does not affect the safety functions of the repository.	

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Table A13-18. SR-PSU FEP FHA10 Altered land use.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.20 Earthmoving	Construct quarry or landfill, earthmoving.		FHA13 and FHA14 (quarry and landfill) are deemed to have insignificant effect on SFR but earthmoving in the form of removing the pier to SFR is considered (FHA CC2).
A 3.044 Earthmoving projects	Construct quarry or landfill, earthmoving		FHA13 and FHA14 (quarry and landfill) are deemed to have insignificant effect on SFR but earthmoving in the form of removing the pier to SFR is considered (FHA CC2)
I 099 Earth moving projects (civil)	Construct quarry or landfill, earthmoving		FHA13 and FHA14 (quarry and landfill) are deemed to have insignificant effect on SFR but earthmoving in the form of removing the pier to SFR is considered (FHA CC2)
J 5.27 Human induced actions on groundwater recharge	Changed conditions for groundwater recharge by constructing well.	Changed conditions for groundwater recharge by changes in land use are considered in the main calculation cases for the biosphere (going from wetland to agricultural land) but not specifically addressed in the FHA scenarios. Building a dam is not considered since for SFR, this is assumed to have insignificant effect on water flows at repository depth and thereby does not affect the safety functions of the repository.	FHA CC4 to use a borehole as a well is included in the main calculation cases and are not described in detail in the FHA report but in the SR-PSU Main report (SKB TR-14-01) and in the Radionuclide transport report (SKB TR-14-09).
J 7.07 Human induced changes in surface hydrology	Construct well, irrigation, drainage or infiltration system, change the course or extent of surface water bodies (streams, lakes, sea) and their connections with other surface water bodies.	Changed conditions for groundwater recharge by changes in land use are considered in the main calculation cases for the biosphere (going from wetland to agricultural land) but not specifically addressed in the FHA scenarios. Building a dam is not considered since for SFR, this is assumed to have insignificant effect on water flows at repository depth and thereby does not affect the safety functions of the repository.	FHA CC4 to use a borehole as a well is included in the main calculation cases and are not described in detail in the FHA report but in the SR-PSU Main report (SKB TR-14-01) and in the Radionuclide transport report (SKB TR-14-09).
J 7.11 City on the site	Build rock cavern, tunnel, shaft, etc.		
K 8.37 Earthworks (human actions, dredging, etc.)	Earthmoving.		FHA13 and FHA14 (quarry and landfill) are deemed to have insignificant effect on SFR but earthmoving in the form of removing the pier to SFR is considered (FHA CC2).
W 3.041 Surface disruptions	Construct quarry or landfill, water management.		FHA13 and FHA14 (quarry and landfill) are deemed to have insignificant effect on SFR but earthmoving in the form of removing the pier to SFR is considered (FHA CC2).

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Table A13-19. SR-PSU FEP FHA11 Drilling.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.49 Intrusion (human)	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
A 2.05 Boreholes - exploration	Drill in the rock.		
A 3.071 Intrusion (inadvertent)	Explorations.		
H 5.2.4 Accidental intrusion	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
I 200 Minerals (exploration, exploitation)	Possible purposes of unintentional intrusion.		
K 11.01 Exploratory drilling	Drill in the rock.		
M 2.3.03 Exploratory drilling	Drill in the rock.		
M 2.3.04 Explotation drilling	Drill in the rock.		
M 2.3.09 Archaeological investigation	Drill in the rock.		
W 2.084 Cuttings	Drill in the rock.		The amount of cuttings and doses from cuttings are analysed in the SR-PSU FHA report.
W 2.085 Cavings	Drill in the rock.		The amount of cavings and doses from cavings are analysed in the SR-PSU FHA report.
W 2.086 Spallings	Drill in the rock	The particulate material introduced into drilling mud by the movement of gas from the waste into the borehole annulus is not considered but focus has been on the uptake of cuttings and caving.	
W 3.001 Oil and gas exploration	Drill in the rock.		
W 3.002 Potash exploration	Drill in the rock.		
W 3.003 Water resources exploration	Drill in the rock.		
W 3.006 Archeological investigations	Drill in the rock.	Archeological investigations at the surface. Activities at the surface do not impact the repository.	
W 3.008 Other resources	Drill in the rock.		
W 3.011 Hydrocarbon storage	Drill in the rock, build rock cavern, tunnel, shaft, etc.		Primarily an activity related to oil and gas exploitation and thus not relevant for the Swedish case but still covered by drilling scenario FHA CC1.
W 3.014 Other resources	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
W 3.017 Archeological excavations	Drill in the rock, build rock cavern, tunnel, shaft, etc.	Archeological excavations close to the surface. Activities at the surface do not impact the repository.	
W 3.021 Drilling fluid flow	The transport of radionuclides with the bore fluid (water) during drilling.	Loss of bore fluid to an under pressurized subsurface unit. Outflow of brine from isolated over pressurized volumes. These kinds of features do not exist at the candidate sites.	
W 3.022 Drilling fluid loss		Borehole fluid lost to (thief) fracture zones, The escape of borehole fluid is not deemed to affect the hydraulic conditions unless there is large amounts of fluid lost which is considered unlikely considering the relatively short time drilling is performed.	

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
W 3.023 Blowouts		During drilling, fluid could flow from pressurized zones through the borehole to the land surface (blowout). If isolated pressurized zones exist in crystalline rock the amount of water in them is limited and the effect on groundwater flow can be neglected.	
W 3.024 Drilling-induced geochemical changes	Fluid flow during drilling that pollutes the bedrock (is covered by one of the main calculation, i.e. no sorption in near field, see **SR-PSU Main report** and the **Radionuclide transport report**).	Flow through abandoned boreholes. The alteration of groundwater composition due to the presence of abandoned boreholes is deemed to be negligible in crystalline rock.	
W 3.029 Hydro-carbon storage	Store waste in the rock.		Primarily an activity related to oil and gas exploitation and thus not relevant for the Swedish case.
W 3.030 Fluid injection-induced geochemical changes		Injection of fluids through a leaking borehole. The escape of borehole fluid in boreholes is omitted since the duration of drilling is short; the affected area deemed to be limited in space and the fluid generally consists of water.	

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Table A13-20. SR-PSU FEP FHA12 Underground constructions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.49 Intrusion (human)	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
A 2.37 Intrusion (mines)	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
A 2.46 Mines	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
H 5.2.4 Accidental intrusion	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
I 200 Minerals (exploration, exploitation)	Possible purposes of unintentional intrusion.		
J 5.28 Under-ground dwellings	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
J 7.11 City on the site	Build rock cavern, tunnel, shaft, etc.		
K 11.02 Mining activities	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
M 2.3.07 Tun-neling	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
M 2.3.08 Underground construction	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
W 3.011 Hydro-carbon storage	Drill in the rock, build rock cavern, tunnel, shaft, etc.		Primarily an activity related to oil and gas exploitation and thus not relevant for the Swedish case.
W 3.014 Other resources	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
W 3.015 Tun-neling	Build rock cavern, tunnel, shaft, etc.		
W 3.016 Con-struction of under-ground facilities (for example storage, disposal, accomodation)	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
W 3.029 Hydro-carbon storage	Store waste in the rock.		Primarily an activity related to oil and gas exploitation and thus not relevant for the Swedish case.
W 3.037 Changes in groundwater flow due to mining	Build rock cavern, tunnel, shaft, etc.		
W 3.038 Changes in geochemistry due to mining	Hydrological disturbances altering groundwater composition.		The drainage of a mine may cause enhanced groundwater flow during a limited period. However, the worst case sce-nario, no sorption in the near field is covered by one of the main calculation cases and thus covered in the assess-ment (see SR-PSU Main report, SKB TR-14-01,and the Radionuclide transport report, SKB TR-14-09).

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Table A13-21. SR-PSU FEP FHA13 Quarry.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.49 Intrusion (human)	Drill in the rock, build rock cavern, tunnel, shaft, etc.		
A 2.20 Earthmoving	Construct quarry or landfill.		
A 3.044 Earthmoving projects	Construct quarry or landfill.		
I 099 Earth moving projects (civil)	Construct quarry or landfill.		
J 5.35 Other future uses of crystalline rock	Mining of granite in the vicinity of the repository.	Mining of granite in the foot print of the repository is not included. Although granite may become a useful raw material in the future, mining it at the repository depth and location are considered highly unlikely and thus not considered.	Effects of mining of granite in the vicinity of the repository can be assumed to be covered by scenarios of tunnel or rock cavern in the vicinity of the repository.
W 3.041 Surface disruptions	Construct quarry or landfill.		
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Table A13-22. SR-PSU FEP FHA14 Landfill.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.20 Earthmoving	Construct quarry or landfill.		
A 3.044 Earthmoving projects	Construct quarry or landfill.		
I 046a Waste management sites adjacent (additive effects of contaminants)	Store waste in the rock, construct sanitary landfill.	Effects (doses) of contaminants from other facilities. It is unclear whether “effects” refer to doses from adjacent facilities or the possible impact of contaminants on the analysed repository. Only impact on the analysed repository is considered in the SKB FEP. Doses from other facilities are considered in the dose acceptance criteria.	
I 046b Waste management sites adjacent (effects on vault)	Store waste in the rock, construct sanitary landfill.		
I 099 Earth moving projects (civil)	Construct quarry or landfill.		
J 5.12 Near storage of other waste	Store waste in the rock, construct sanitary landfill.		
W 3.041 Surface disruptions	Construct quarry or landfill.		
Recorded by: Eva Andersson			**Date:** 2014-03-07
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Table A13-23. SR-PSU FEP FHA15 Bombing or blasting, explosions and crashes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.32 Explosions	Subsurface and surface explosions (bomb or blast).		
A 2.02 Bomb blast	Surface explosions (bomb or blast).		
A 2.56 Sabotage	Intent and responsibilities.		
A 3.025 Collisions, explosions and impacts	Subsurface and surface explosions (bomb or blast).	Collision by aircraft has no impact on repository safety. Meteorite impact is not a human action.	See also SR-PSU FEP Oth01 Meteorite impact.
I 022 Explosions/ bombs/blasting/collision/ impacts/vibration	Surface explosions (bomb or blast).	Collision by aircraft has no impact on repository safety.	
J 5.30 Underground test of nuclear devices	Subsurface bomb or blast.		
J 6.07 Nuclear war	Surface explosions (bomb or blast).		
M 2.3.12 Underground nuclear testing	Subsurface explosions (bomb or blast).		
W 3.019 Explosions for resource recovery	Subsurface explosions (bomb or blast).		
W 3.020 Underground nuclear device testing	Subsurface explosions (bomb or blast).		
W 3.039 Changes in groundwater flow due to explosions		Direct effect on groundwater flow due to an explosion. The direct effect on groundwater flow due to an explosion is of very short duration and can be neglected.	

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Table A13-24. SR-PSU FEP FHA16 Hazardous waste facility.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 046a Waste management sites adjacent (additive effects of contaminants)	Store waste in the rock, construct sanitary landfill.	Effects (doses) of contaminants from other facilities. It is unclear whether “effects” refer to doses from adjacent facilities or the possible impact of contaminants on the analysed repository. Only impact on the analysed repository is considered in the SKB FEP. Doses from other facilities are considered in the dose acceptance criteria.	
I 046b Waste management sites adjacent (effects on vault)	Store waste in the rock, construct sanitary landfill.		
J 5.12 Near storage of other waste	Store waste in the rock, construct sanitary landfill.		
K 11.04 Liquid waste injection	Store waste in the rock.		
M 2.3.10 Injection of liquid wastes	Store waste in the rock.		
W 3.010 Liquid waste disposal	Store waste in the rock.		
W 3.027 Liquid waste disposal	Store waste in the rock.		

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Table A13-25. SR-PSU FEP FHA17 Contamination with chemical substances.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.001 Acid rain	Acidify air, soil and bedrock.		No sorption in the near field is covered by one of the main calculation cases and thus covered in the assessment (see SR-PSU Main report, SKB TR-14-01, and the Radionuclide transport report, SKB TR-14-09).
I 001 Acid rain	Acidify or in other way pollute air, water, soil and/or bedrock.		No sorption in the near field is covered by one of the main calculation cases and thus covered in the assessment (see SR-PSU Main report, SKB TR-14-01, and the Radionuclide transport report, SKB TR-14-09).
J 7.08 Altered surface water chemistry by humans	Acidify air, soil and/or bedrock or cause accident resulting in chemical contamination.		No sorption in the near field is covered by one of the main calculation cases and thus covered in the assessment (see SR-PSU Main report, SKB TR-14-01, and the Radionuclide transport report, SKB TR-14-09).
K 11.07 Groundwater pollution	Acidify or in other way pollute air, water, soil and/or bedrock, cause accident resulting in chemical contamination.		No sorption in the near field is covered by one of the main calculation cases and thus covered in the assessment (see SR-PSU Main report, SKB TR-14-01, and the Radionuclide transport report, SKB TR-14-09).
K 11.08 Surface pollution (soils, rivers)	Acidify or in other way pollute air, water, soil and/or bedrock, cause accident resulting in chemical contamination.		No sorption in the near field is covered by one of the main calculation cases and thus covered in the assessment (see SR-PSU Main report, SKB TR-14-01, and the Radionuclide transport report, SKB TR-14-09).
W 3.046 Altered soil or water surface chemistry by human activities	Acidify or in other way pollute air, water, soil and/or bedrock.	Surface activities associated with potash mining. Potash is not available at the candidate sites.	No sorption in the near field is covered by one of the main calculation cases and thus covered in the assessment (see SR-PSU Main report, SKB TR-14-01, and the Radionuclide transport report, SKB TR-14-09).
W 3.048 Acid rain	Acidify or in other way pollute air, water, soil and/or bedrock.		No sorption in the nearfield is covered by one of the main calculation cases and thus covered in the assessment (see SR-PSU Main report, SKB TR-14-01, and the Radionuclide transport report, SKB TR-14-09).

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Appendix 14

Handling of NEA Project FEPs sorted to SR-PSU Biosphere process FEPs

Table A14-1. SR-PSU FEP Bio01 Bioturbation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.014 Bioturbation of soil and sediment	Bioturbation is considered in the radionuclide model (SKB R-13-46). In the radionuclide model, the depth of the bio-turbated layer is identified for agricultural land, wetlands, marine basins, lakes and streams (SKB R-13-18).		
A 3.042 Dispersion	Dispersion refers to the movement of radionuclides away from its source and includes advection, diffusion, water and air transport. These processes are considered in the radionuclide model (SKB R-13-46).		
H 4.2.3 Sediment transport including bioturbation	Transport of elements including bioturba-tion is considered in the radionuclide model where processes such as resus-pension and deposition are parameterised (SKB R-13-18).		The other aspects of this FEP are treated in the processes relocation (Bio38) and resuspen-sion (Bio39).
I 021 Bioturbation (soil & sediment)	Same as NEA FEP A 3.014.		
K 8.35 Bioturbation	Same as NEA FEP A 3.014.		
M 1.7.04 Soil and sediment bioturbation	Same as NEA FEP A 3.014.		
Recorded by: Eva Andersson			**Date:** 2014-04-11
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Table A14-2. SR-PSU FEP Bio02 Consumption (see also Bio06 Food supply).

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.003 Animal diets	Domestic and wild animals have different diets which may affect the radionuclide concentrations in the animals. Animal diets are included in the radionuclide model (SKB R-13-46).		
A 3.005 Animal soil ingestion	Soil may be used as a food source for some organisms. This is considered in the radionuclide model and in the assessment of dose to biota (SKB R-13-46).		
A 3.009 Bioconcentration	Bioconcentration is considered by the use of concentration ratios (SKB R-13-01) used in the radionuclide model (SKB R-13-46).		
A 3.012 Biomagnification	Biomagnification is considered by the use of concentration ratios (SKB R-13-01) used in the radionuclide model (SKB R-13-46).		
A 3.016 Burrowing animals	Burrowing animals may consume soils (or have soil adhered to their surface). The burrowing animals may be consumed by other animals and humans, thus posing a pathway for radionuclides in the soils to humans. This is considered in calculating dose to non-human biota by the use of concentration ratios for different animals (SKB R-13-01), i.e. taking into account where they spend their life (burrowing or on the surface) (SKB R-13-46).		
A 3.050 Fish farming	Fish farming is considered in the biosphere interaction matrix but is not included in the radionuclide model (SKB R-13-46). This is a cautious assumption since fish farming demand input of food (e.g. pellets) for the aquaculture and import of food from an area outside the contaminated model area would lead to a dilution of radionuclides (SKB R-13-46).		
A 3.054 Food preparation	Food preparation is considered in the biosphere interaction matrix. However, it is likely unimportant in determining the total dose to humans and is thus not included in the radionuclide model (SKB R-13-46).		
A 3.065 Human diet	Human diet is considered in the radionuclide model (SKB R-13-46). In the model, typical dietary fraction of food items is calculated from land use and productivity characteristics in the biosphere objects, Thus the production represents the food supply that may be utilized. The diet changes over time as the proportion of sea/lakes/mires/and agricultural lands changes over time due to landscape development processes and thereby different diets are included in the radionuclide model (SKB R-13-46).		
A 3.066 Human soil ingestion	Humans may consume soil unintentionally when consuming e.g. carrots and potatoes. This is considered in the biosphere interaction matrix and in a separate calculation case (SKB R-13-46).		
A 3.069 Intake of drugs		Drugs may be locally produced and may then be contaminated with radionuclides. This is assumed to be covered by the ingestion of other food sources that are not considered to be drugs and the aspect of drugs is not further considered.	

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.089 Scavengers and predators	Scavengers and predators may have larger radionuclide concentrations since radionuclides tend to accumulate at higher trophic levels. This is accounted for by the concentration ratios (SKB R-13-01) used in the radionuclide model (SKB R-13-46).		
A 3.110 Tree sap	All potential food sources are considered in the biosphere interaction matrix. Tree sap is not extracted from trees in Forsmark at present conditions. Even if utilized at a later stage, it will most likely contribute only minor to dose and is thus not considered in the radionuclide model (SKB R-13-46).		
H 4.3.1 Land and surface water use: Terrestrial	The land use is considered in the radionuclide model (SKB R-13-46).		
I 003 Animal diets (domestic and wild)	Same as NEA FEP A 3.003.		
I 007 Animals (external contamination)	External contamination of animals may become internal if the contaminants are taken up. This is considered in the concentration ratios and transfer coefficients (SKB R-13-01) used to calculate radionuclide concentration in animals.		
I 014 Bioaccumulation/ bioconcentration/ biomagnification	Same as NEA FEPs A 3.009 and A 3.012.		
I 113 Food chain (dose pathway)	Same as NEA FEP A 3.065.		
I 163 Insect pathways	Insects may be consumed by other animals and this pathway is considered in the biosphere interaction matrix. It is unlikely that insects will be consumed by humans since the effort to handle (catch) insects are large and thus insects are not included as a pathway for dose to humans in the radionuclide model (SKB R-13-46).		
K 8.44 Consumption of uncontaminated products	Consumption of all available sources is considered in the biosphere interaction matrix. The food supply in the radionuclide model is cautiously considered to be derived exclusively from the model area, i.e. being contaminated with radionuclides.		

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Table A14-3. SR-PSU FEP Bio03 Death.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.079 Peat and leaf litter harvesting	Human utilization of the environment for other purposes than feeding and water use is considered in the radionuclide model (SKB R-13-46). External exposure is included in the radionuclide model, but has limited importance for a few and non-dominating radionuclides. The external dose is considered by all sources.		
H 4.2.5 Bioaccumulation and translocation	Translocation of radionuclides concentrated in organisms to e.g. sediments is considered in the radionuclide model (SKB R-13-46). In the latter, organisms that are not consumed by other organisms may upon death contribute to soil or sediments.		
I 102 Ecological successions	Succession is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46). Marine basins are developed to lakes and thereafter to mires. The latter can after draining be used as agricultural land.		
M 1.6.12 Accumulation in soils and organic debris	Deposited material may accumulate in soils and organic debris. This is considered in the landscape development model (SKB R-13-27) and in the radionuclide model (SKB R-13-46).		
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Table A14-4. SR-PSU FEP Bio04 Decomposition.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.007 Bacteria and microbes in soil	Decomposers are considered in the ecosystem models (SKB TR-10-01, TR-10-02 and TR-10-03) and the radionuclide model (SKB R-13-46). Bacteria decompose organic matter, which remobilize incorporated radionuclides. The release of radionuclides incorporated into organic material is considered in the radionuclide model (SKB R-13-46).		
A 3.018 Carcasses	The release of substances to the environment due to decomposition is considered in the biosphere interaction matrix, but the release from organic material coming from consumers in terrestrial ecosystems is assumed to be insignificant in the radionuclide model (SKB R-13-46).		
H 4.2.5 Bioaccumulation and translocation	Translocation of radionuclides concentrated in organisms to e.g. sediments is considered in the radionuclide model (SKB R-13-46). In the latter, organisms that are not consumed by other organisms may upon death contribute to sediments.		
H 4.2.6 Biogeochemical processes	Biogeochemical processes are included in the radionuclide model (SKB R-13-46).		
I 102 Ecological successions	Succession is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46). Marine basins are developed to lakes and thereafter to mires. The latter can thereafter be used as agricultural land.		
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Table A14-5. SR-PSU FEP Bio05 Excretion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.009 Bioconcentration	Elements may become concentrated in higher organisms. The bioconcentration is dependent on uptake and excretion of elements. Bioconcentration is considered by the use of concentration ratios in the radionuclide model (SKB R-13-01).		
A 3.018 Carcasses	Elements may be excreted when animals are decomposed, and thereby the elements may be recycled. The excess of production in the radionuclide model is assumed to be available to recycling in the radionuclide model (SKB R-13-46).		
H 4.2.5 Bioaccumulation and translocation	Translocation of radionuclides concentrated in organisms to e.g. sediments is considered in the radionuclide model (SKB R-13-46). In the latter, organisms that are not consumed by other organisms may upon death contribute to soil or sediments.		
H 4.2.6 Biogeochemical processes	Biogeochemical processes are included in the radionuclide model (SKB R-13-46).		
I 010 Recycling process (biomass)	Ashes and sewage sludge may increase crop yield due to an extra supply of essential elements. In the safety assessment, values of crop production from fertilized land are used to calculate production of food and thereby this process is considered.		
I 014 Bioaccumulation /bioconcentration/ biomagnification	See NEA FEP A 3.009.		

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Table A14-6. SR-PSU FEP Bio06 Food supply (see also Bio02 Consumption).

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.003 Animal diets	Domestic and wild animals have different diets which may affect the radionuclide concentrations in the animals. Animal diets are included in the radionuclide model (SKB R-13-46).		
A 3.004 Animal grooming and fighting	Animal fighting and grooming may lead to exposure if the animals take up radionuclides that have been attached to their fur/skin during fighting. This is indirectly considered as concentration ratios of animals are estimated based on measurements on wild animals (SKB R-13-01). These animals have due to a natural life style experienced grooming and fighting.		
A 3.050 Fish farming	Fish farming is considered in the biosphere interaction matrix but is not included in the radionuclide model (SKB R-13-46). This is a cautious assumption since fish farming demand input of food (e.g. pellets) for the aquaculture and import of food from an area outside the contaminated model area would lead to a dilution of radionuclides.		
A 3.065 Human diet	Human diet is considered in the radionuclide model (SKB R-13-46). In the model, typical dietary fraction of food items is calculated from land use and productivity characteristics in the biosphere objects. Thus the production represents the food supply that may be utilized. The diet changes over time as the proportion of sea/lakes/mires/and agricultural lands changes over time due to landscape development processes and thereby different diets are included in the radionuclide model (SKB R-13-46).		
A 3.067 Hydroponics		The raising of certain crops without soil on water and on medium consisting of nutrients and microelements are not considered since it is not a common way of agriculture and it is not assumed to pose any increased radionuclide concentrations compared to conventional agricultural production.	
A 3.096 Soil	Soil is considered in the radionuclide model (SKB R-13-46). In the radionuclide model, stratification, characteristics and composition of regolith (e.g. porosity, density, and carbon content) are included (SKB R-13-18). Soil function as a habitat and a food supply for soil organisms. This is considered in the calculations of biomass production and decomposition.		
H 4.3.3 Land and surface water use: Coastal waters	Use of coastal water is considered in the biosphere interaction matrix. Swimming is assumed to give insignificant dose compared to internal doses from ingestion and inhalation and is thus not included in the radionuclide model (SKB R-13-46). Food production is included in the radionuclide model (treated as FEPs Bio02 and Bio06).		
I 003 Animal diets (domestic and wild)	Domestic and wild animals have different diets which may affect the radionuclide concentrations in the animals. Animal diets are included in the radionuclide model (SKB R-13-46).		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 113 Food chain (dose pathway)	Same as NEA FEP A 3.065.		
I 157 Hydroponics (dose pathway)		See NEA FEP A 3.067.	
I 163 Insect pathways	Insects may be consumed by other animals and this pathway is considered in the biosphere interaction matrix. It is unlikely that insects will be consumed by humans since the effort to handle (catch) insects are large and thus insects are not included as a pathway for dose to humans in the radionuclide model (SKB R-13-46).		
K 8.40 Natural and semi-natural environments	Food supply is dependent on which types of ecosystems that are present in the model area. Natural environments with wild crops and game give rise to another amount of food (food supply) than agriculture area. This is considered in the radionuclide model (SKB R-13-46) as both natural and agricultural land are considered. As the object develop with time, the amount of agricultural and natural land changes over time and both types of land (and subsequent food supply) are considered.		
K 8.41 Hunter/gathering lifestyle	Gathering life style is considered in the biosphere interaction matrix. In the radionuclide model (SKB R-13-46), gathering of food is only considered within biosphere objects and neither humans nor food are exported out from the model area. This is a cautious assumption since gathering life style would most likely dilute dose to humans due to humans gathering food from a larger area than the contaminated biosphere objects.		

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SR-PSU FEP Bio07 Growth

No NEA FEP associated with this SR-PSU FEP.

Table A14-7. SR-PSU FEP Bio08 Habitat supply.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.096 Soil	Soil is considered in the radionuclide model (SKB R-13-46). In the radionuclide model, stratification, characteristics and composition of regolith (e.g. porosity, density, and carbon content) are included (SKB R-13-18). Soil function as a habitat for soil organisms thereby supplying a living habitat for these. This is considered in the calculations of biomass and production.		
A 3.112 Urbanization on the discharge site	Whether humans are urbanized or rural influence the exposure. In the safety assessment, as a cautious assumption, human populations are assumed to be rural and to only feed on products produced within the biosphere objects, i.e. the contaminated area (SKB R-13-46, SKB R-14-02).		
H 4.3.1 Land and surface water use: Terrestrial	The land use is considered in the radionuclide model (SKB R-13-46).		
H 4.3.3 Land and surface water use: Coastal waters	Use of coastal water is considered in the biosphere interaction matrix. Swimming is assumed to give insignificant dose compared to internal doses from ingestion and inhalation and is thus not included in the radionuclide model (SKB R-13-46). Food production is included in the radionuclide model (treated as FEPs Bio02 and Bio06).		
H 4.3.4 Land and surface water use: Seas	Use of seas is considered in the biosphere interaction matrix. Shipping and sailing are assumed not to give any significant dose and are thus not considered in the radionuclide model (SKB R-13-46). Food supply from seas is included (treated as FEPs Bio20 and Bio21).		
I 227 Urbanization (demographics)	See NEA FEP A 3.112.		
K 8.25 Soil	See NEA FEP A 3.096.		
M 2.4.03 River rechannelling	River erosion and channel erosion are considered in the biosphere interaction matrix, but not acknowledged in the radionuclide model (SKB R-13-46). At the site, the regolith consists of till and streams are small, which gives a low potential for any substantial stream erosion. In the radionuclide model, no long-term accumulation is assumed to occur in streams and thereby the annual sedimentated material is assumed to be resuspended (eroded) and transported downstream to the next biosphere object, i.e. the sizes of the streams are assumed to remain throughout the modelled time period.		

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Table A14-8. SR-PSU FEP Bio09 Intrusion.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 1.48 Intrusion (animal)		Intrusion by animals to the repository is not considered since it is highly unlikely that animals will intrude to the repository depth of SFR. Human intrusion is considered.	

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Table A14-9. SR-PSU FEP Bio10 Material supply.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.006 Ashes and sewage sludge fertilizers	Ashes in building material may contribute to external exposure. External exposure is included in the radionuclide model (SKB R-13-46), but has limited importance for a few and non-dominating radionuclides. The external dose is considered by all sources.		
A 3.010 Biogas production	Heating needs may be met with biogas from biological reactors fuelled by plant materials, faeces and refuse, or from trapping natural methane from garbage disposal sites, bogs and sediments. These fuels may be contaminated with radionuclides leading to external exposure. External exposure is considered in the biosphere interaction matrix and included in the radionuclide model (SKB R-13-46), but has limited importance for a few and non-dominating radionuclides. The external dose is considered by all sources.		
A 3.015 Building materials	Wood etc used as building material may expose humans to external exposure. External exposure is considered in the biosphere interaction matrix and included in the radionuclide model (SKB R-13-46), but has limited importance for a few and non-dominating radionuclides. The external dose is considered by all sources.		
A 3.095 Smoking		Tobacco is not cultivated at Forsmark at present and this FEP is not considered in the radionuclide model (SKB R-13-46). However, any contribution to dose from smoking is likely to be minor compared to the amounts ingested through food and water.	
A 3.102 Space heating	Space heating when burning contaminated materials such as trees may contribute to external exposure. External exposure is considered in the biosphere interaction matrix and included in the radionuclide model (SKB R-13-46), but has limited importance for a few and non-dominating radionuclides. The external dose is considered by all sources.		
H 4.3.3 Land and surface water use: Coastal waters	Use of coastal water is considered in the biosphere interaction matrix. Swimming is assumed to give insignificant dose compared to internal doses from ingestion and inhalation and is thus not included in the radionuclide model (SKB R-13-46). Food production is included in the radionuclide model (treated as FEPs Bio02 and Bio06).		
I 276 Smoking (dose pathway)		See NEA FEP A 3.095.	
K 8.13 Exposure pathways	Exposure pathways are considered in the radionuclide model (SKB R-13-46, SKB R-14-02). Ingestion of various food sources, water, inhalation of dust and external exposure are considered.		
K 8.42 Contaminated products (non-food)	External exposure is considered in the biosphere interaction matrix and included in the radionuclide model (SKB R-13-46), but has limited importance for a few and non-dominating radionuclides. The external dose is considered by all sources.		
W 3.040 Land use changes	Land use is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and in the radionuclide model (SKB R-13-46). Forsmark is situated in an area where there is shore-line displacement, i.e. new land is uplifted and new areas may be used for agriculture. Water extraction is considered in the model as the use of a well for irrigation. Mining and drilling are considered in supporting calculations.		

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Table A14-10. SR-PSU FEP Bio11 Movement.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
H 4.3.3 Land and surface water use: Coastal waters		Not addressed since the influence on surface water movement by the presence and movement of organisms in surface waters is assessed as not important to consider for a repository located in the Forsmark area.	
W 3.045 Lake usage		Not addressed since the influence on surface water movement by the presence and movement of organisms in surface waters is assessed as not important to consider for a repository located in the Forsmark area.	
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Table A14-11. SR-PSU FEP Bio12 Particle release/trapping.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.026 Colloids	Colloids in water, i.e. particulate matter, are considered in the biosphere interaction matrix and are included in the ecosystems-specific parameters (SKB R-13-18) and in the radionuclide model (SKB R-13-46) as these influence sorption/desorption and thereby transport and accumulation of radionuclides.		
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Table A14-12. SR-PSU FEP Bio13 Primary production.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.090 Seasons	Seasons are considered in the biosphere interaction matrix. In the radionuclide model, annual mean values are used for parameterisation (SKB R-13-18). These values are based on site specific measurements considering seasonal variations.		
I 292 Surface water bodies (physical/ chemical changes)	Physical and chemical changes of water bodies are considered in the radionuclide model (SKB R-13-46). For example, in the radionuclide model, changes in chemistry are considered by the use of different parameter sets for marine and limnic stages of the aquatic objects and physical changes are considered by the use of time specific values of the geometry of the objects (SKB R-13-18).		
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Table A14-13. SR-PSU FEP Bio14 Stimulation/inhibition.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.006 Ashes and sewage sludge fertilizers	Ashes and sewage sludge are considered in the radionuclide model (SKB R-13-46). Ashes and sewage sludge may increase crop yield. In the radionuclide model, values of crop production from conventional agriculture including both fertilizers and pesticides are used to calculate production of food (SKB R-13-18). This is cautious due to the fact that a larger crop yield allows for more people to live in the contaminated area.		
A 3.036 Crop fertilizers and soil conditioners	See NEA FEP A 3.006.		
A 3.055 Game ranching	During game ranching, animals could become contaminated through the intake of contaminated food, water, soil or air. These sources of contamination are similar to those for domestic animals, as are other considerations. Thus game ranching is just another type of animal husbandry that is included in the radionuclide model (SKB R-13-46).		
A 3.058 Greenhouse food production	Greenhouse production demands addition of nutrients, most often received from outside the model area. In addition, soil and soil conditioners may be derived from areas outside the model area. One aspect that may concentrate radionuclides in primary producers due to greenhouse farming is irrigation. Irrigation is used for agricultural land and thereby this effect of greenhouse farming is included in the radionuclide model (SKB R-13-46), whereas other aspects (such as import of uncontaminated nutrients, soils and soil conditioners), as a cautious assumption, are not included.		
A 3.062 Herbicides, pesticides and fungicides	See NEA FEP A 3.006.		
3.079 Peat and leaf litter harvesting	Peat is used in agriculture in the radionuclide model (SKB R-13-46) as agriculture is allowed on drained wetlands. As a conservative estimate, radionuclides are not removed from the soil with harvesting but radionuclides are available also for the next human utilising the peat land.		
I 010 Recycling process (biomass)	See NEA FEP A 3.006.		
I 148 Herbicides, pesticides & fungicides (dose pathway)	See NEA FEP A 3.006.		
K 8.39 Agricultural practices	Humans may be exposed to radionuclides through various sources e.g. agricultural products. Different products may expose humans with different doses. This is considered in the radionuclide model (SKB R-13-46).		
W 3.054 Ranching	Ranching is considered in the radionuclide model (SKB R-13-46).		
W 3.055 Fish farming	Fish farming is considered in the biosphere interaction matrix but is not included in the radionuclide model (SKB R-13-46). This is a cautious assumption since fish farming demand input of food (e.g. pellets) for the aquaculture and import of food from an area outside the contaminated model area would lead to a dilution of radionuclides.		

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Table A14-14. SR-PSU FEP Bio15 Uptake.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.006 Ashes and sewage sludge fertilizers	Ashes and sewage sludge may increase crop yield, In the radionuclide model, values of crop production from fertilized land are used to describe production of food and thereby this process is indirectly included. Ashes of burned peat may concentrate radionuclides in the soil. In the radionuclide model (SKB R-13-46), each object is assumed to receive the entire radionuclide release and thus radionuclides are already present within the object and ashes will not introduce an extra source of contaminants.		
A 3.008 Bioaccumu-lation	Radionuclides may accumulate in different organism groups. This is considered by the different concentration ratios used for different organism groups (SKB R-13-01) in the radionuclide model and assessment of dose to biota (SKB R-13-46).		
A 3.009 Bioconcen-tration	Radionuclides may accumulate in different organism groups. This is considered by the different concentration ratios used for different organism groups (SKB R-13-01) in the radionuclide model and assessment of dose to biota (SKB R-13-46).		
A 3.012 Biomagnifi-cation	See NEA FEP A 3.009.		
A 3.016 Burrowing animals	Burrowing animals may consume soils (or have soil adhered to their surface). The burrowing animals may be consumed by other animals and humans, thus posing a pathway for radionuclides in the soils to humans. This is considered in the bio-sphere interaction matrix and in calculating dose to non-human biota by the use of concentration ratios (SKB R-13-01) for different animals, i.e. taking into account where they spend their life (burrowing or on the surface) (SKB R-13-46).		
A 3.029 Critical group - agricultural labour	Inhalation of dust by farmers is considered in the safety assessment by including inhalation of dust in the radionuclide model (SKB R-13-46).		
A 3.036 Crop fertilizers and soil conditioners	Fertilizers and soil conditioners increase the yield from agricultural land. In the safety assessment, values of crop produc-tion from fertilized land describe production of food and thereby this process is considered.		
A 3.037 Crop storage		When crop is stored radionuclide concentration may increase if seepage or flooding wet the crop. Decay of radionuclides in the stored crop may also decrease the exposure. If crop is wetted it is most likely discarded as food and decay of radionuclides is only important for short-lived isotopes considering the length of storage of crops. For radionuclides entering from a repository this is thus irrelevant.	
A 3.040 Dermal sorp-tion (except tritium)	Dermal sorption in general is likely of minor importance for humans, compared to the direct ingestion and inhalation of radionuclides. Cautious assumptions built into these major pathways in the radionuclide model could readily include dermal sorption, and therefore, no explicit quantitative treatment of dermal sorption is required.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.041 Dermal sorption (tritium)	Dermal sorption in general is likely of minor importance for humans, compared to the direct ingestion and inhalation of radionuclides. Cautious assumptions built into these major pathways in the radionuclide model could readily include dermal sorption, and therefore, no explicit quantitative treatment of dermal sorption is required.		
A 3.050 Fish farming	Fish farming is considered in the biosphere interaction matrix but is not included in the radionuclide model (SKB R-13-46). This is a cautious assumption since fish farming demand input of food (e.g. pellets) for the aquaculture and import of food from an area outside the contaminated model area would lead to a dilution of radionuclides.		
A 3.058 Greenhouse food production	Greenhouse production demands addition of nutrients, most often received from outside the model area. In addition, soil and soil conditioners may be derived from areas outside the model area. One aspect that may concentrate radionuclides in primary producers due to greenhouse farming is irrigation with water. Irrigation is used for agricultural land and thereby this effect of greenhouse farming is included in the radionuclide model (SKB R-13-46), whereas other aspects (such as import of uncontaminated nutrients, soils and soil conditioners), as cautious assumption, are not included.		
A 3.062 Herbicides, pesticides and fungicides	Herbicides, pesticides and fungicides may stimulate crop production and increase the yield from agricultural land. This is considered in the radionuclide model as values of crop production are from conventional agricultural land where herbicides, pesticides and fungicides are used. In FEP A 3.062 it is suggested that agricultural chemicals can become contaminated and pass contaminants onto plants and into various food chains. However, in the radionuclide model (SKB R-13-46), objects are assumed to receive the entire radionuclide release and thus, no extra import of radionuclides is assumed to occur via addition of pesticides, fungicides and herbicides.		
A 3.067 Hydroponics		The raising of certain crops without soil on water and on medium consisting of nutrients and microelements are not considered since it is not a common way of agriculture and it is not assumed to pose any increased radionuclide concentrations compared to conventional agricultural production.	
A 3.069 Intake of drugs		Drugs may be locally produced and may then be contaminated with radionuclides. This is assumed to be covered by the ingestion of other food sources that are not considered to be drugs and the aspect of drugs is not further considered.	
A 3.073 Irrigation	Irrigation may increase radionuclide concentrations in crops and therefore irrigation has been included in the radionuclide model in the safety assessment (SKB R-13-46).		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.080 Plant roots	The uptake by plants is considered by the use of concentration ratios (SKB R-13-01). The uptake by plants is assumed not to be limited by element supply but is assumed to be dependent on the rate of primary production. The uptake into tuber (e.g. potatoes, carrots etc.) can then be directly utilised by humans.		
A 3.094 Showers and humidifiers	Showers and humidifiers may release radionuclides indoors. However, the dose from this source is assumed to be very small in comparison to the radionuclide source from ingestions and this pathway is not included in the radionuclide model (SKB R-13-46).		
A 3.095 Smoking		Tobacco is not cultivated at Forsmark at present and this FEP is not considered in the radionuclide model (SKB R-13-46). However, any contribution to dose from smoking is likely to be minor compared to the amounts ingested through food and water.	
A 3.110 Tree sap	Tree sap is not extracted from trees in Forsmark at present conditions. Even if utilized at a later stage it will most likely contribute only minor to dose and is thus not considered in the radionuclide model (SKB R-13-46).		
H 4.2.5 Bioaccumulation and translocation	Translocation of radionuclides concentrated in organisms to e.g. sediments is considered in the radionuclide model (SKB R-13-46). In the latter, organisms that are not consumed by other organisms may upon death contribute to soil or sediments.		
H 4.2.6 Biogeochemical processes	Biogeochemical processes are included in the radionuclide model (SKB R-13-46).		
H 4.4.2 Human exposure: Ingestion	Human exposure due to drinking and feeding is included in the radionuclide model (SKB R-13-46).		
H 4.4.3 Human exposure: Inhalation	Human exposure due to inhalation is considered in the radionuclide model as inhalation of dust (SKB R-13-46).		
I 003 Animal diets (domestic and wild)	Domestic and wild animals have different diets which may affect the radionuclide concentrations in the animals. Animal diets are included in the radionuclide model (SKB R-13-46).		
I 007 Animals (external contamination)	External contamination of animals may become internal if the contaminants are taken up. This is considered in the concentration ratios used to calculate radionuclide concentration in animals (SKB R-13-01).		
I 010 Recycling process (biomass)	Ashes and sewage sludge may increase crop yield due to an extra supply of essential elements. In the safety assessment, values of crop production from fertilized land are used to calculate production of food and thereby this process is considered.		
I 014 Bioaccumulation/ bioconcentration/ biomagnification	See NEA FEP A 3.009.		
I 082 Crop storage		See NEA FEP A 3.037.	
I 090 Dermal sorption (tritium and others)	See NEA FEPs A 3.040 and A 3.041.		
I 148 Herbicides, pesticides & fungicides (dose pathway)	See NEA FEP A 3.062.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 157 Hydroponics (dose pathway)		See NEA FEP A 3.067.	
I 175 Irrigation (dose pathway)	See NEA FEP A 3.073.		
I 272 Showers and humidifiers (atmospheric dose pathway)	See NEA FEP A 3.094.		
I 276 Smoking (dose pathway)		See NEA FEP A 3.095.	
K 8.08 Filtration	Filtration is considered in the radionuclide model (SKB R-13-46). As a cautious assumption, particles are not filtrated out of water before it is used by humans. This is cautious since filtration decrease the exposure of humans since many radionuclides are associated with particles.		
K 8.09 Uptake by crops	Uptake by crops of radionuclides is included in the radionuclide model by the use of concentration ratios.		
K 8.10 Uptake by livestock	Uptake by live stock is considered in the radionuclide model (SKB R-13-46). Radionuclides may be taken up as a result of ingestion of water, food or inhalation. This is considered by the use of transfer coefficients presented in (SKB R-13-01) in the radionuclide model (SKB R-13-46).		
K 8.11 Uptake in fish	Radionuclides may be taken up by fish as a result of ingestion of water, gases, or food. This is included in the radionuclide model (R-13-46) and in the assessment of dose to biota as concentration ratios presented in SKB R-13-01.		
K 8.13 Exposure pathways	Exposure pathways are considered in the radionuclide model (SKB R-13-46). Ingestion of various food sources, water inhalation of dust and external exposure are considered.		
M 1.7.01 Plant uptake	Uptake of radionuclides by plants is considered in the radionuclide model by using concentration ratios presented in SKB R-13-01. It is also considered in the assessment of dose to non-human biota.		
M 1.7.02 Animal uptake	Animal uptake of radionuclides is considered in the radionuclide model by using concentration ratios presented in SKB R-13-01.		
M 1.7.03 Uptake by deep rooting species	Uptake by deep rooting species is considered in the radionuclide model by using concentration ratios presented in SKB R-13-01. Deep rooted species are not separated from other primary producer. However, in the radionuclide model, the upper regolith is assumed to be mixed so it is irrelevant if the roots are long or short for the uptake of radionuclides.		
W 2.101 Plant uptake	See NEA FEP M 1.7.01.		
W 2.102 Animal uptake	See NEA FEP M 1.7.02.		

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Table A14-15. SR-PSU FEP Bio16 Anthropogenic release.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.006 Ashes and sewage sludge fertilizers	Ashes and sewage sludge may increase crop yield, In the radionuclide model, values of crop production from fertilized land are used to calculate production of food and thereby this process is indirectly included. Ashes of burned peat may concentrate radionuclides in the soil. In the safety assessment, each object is assumed to receive the entire radionuclide release and thus radionuclides are already present within the object and ashes will not introduce an extra source of contaminants.		
A 3.020 Charcoal production	The dose from charcoal production is considered to become insignificant in comparison to ingestion of contaminated food. This process is not included in the radionuclide model (SKB R-13-46).		
A 3.036 Crop fertilizers and soil conditioners	Fertilizers and soil conditioners increase the yield from agricultural land but may also dilute the concentration of radionuclides in the crop if radionuclides that are essential elements are diluted with uncontaminated elements in the fertilizers. In the safety assessment, values of crop production from fertilized land are used to calculate production of food and thereby this process is considered. As a cautious assumption, fertilizers are not considered when estimating concentration of radionuclides in the crop but then all elements are assumed to be taken up from the soil.		
A 3.102 Space heating	Space heating when burning contaminated materials such as trees may contribute to external exposure. External exposure is considered in the radionuclide model, but has limited importance for a few and non-dominating radionuclides. The external dose is considered by all sources.		
I 261 Salt (road salt, CaCl2, etc.)	Road salts may influence the ion strength of water. As water composition used in the radionuclide model is based on in situ measurements, the effects of road salts are indirectly included (SKB R-13-18).		
S 087 Surface water chemistry	Surface water chemistry is considered in the radionuclide model where site-specific water chemistry parameters are considered (SKB R-13-18). Human actions may influence the water composition by e.g. release of substances. Release of toxins are not considered as a cautious assumptions as this would most likely decrease human utilization of surface waters for drinking and feeding.		
W 3.053 Arable farming	Human affecting the environment through farming is considered in the radionuclide model (SKB R-13-46).		

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Table A14-16. SR-PSU FEP Bio17 Material use.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.010 Biogas production	Heating needs may be met with biogas from biological reactors fuelled by plant materials, faeces and refuse, or from trapping natural methane from garbage disposal sites, bogs and sediments. These fuels may be contaminated with radionuclides leading to external exposure. External exposure is considered in the biosphere interaction matrix and included in the radionuclide model (SKB R-13-46), but has limited importance for a few and non-dominating radionuclides. The external dose is considered by all sources.		
A 3.020 Charcoal production	Charcoal production is considered in the biosphere interaction matrix. However, as the dose from charcoal production is considered to become insignificant in comparison to ingestion of contaminated food this process is not included in the radionuclide model (SKB R-13-46).		
A 3.034 Critical group - leisure pursuits	Activities such as hockey, curling on contaminated ice or swimming in contaminated water may expose humans to external exposure. In the radionuclide model, the concern is mainly long-lived radionuclides and these give the highest external dose from ground (SKB R-13-46), and time spent in lakes swimming or on ice skating has not to be considered. Instead, as a cautious assumption, humans are assumed to spend their entire time (100%) outdoors receiving external exposure from the ground.		
A 3.054 Food preparation	Food preparation is considered in the biosphere interaction matrix. However, it is likely unimportant in determining the total dose to humans and is thus not included in the radionuclide model (SKB R-13-46).		
A 3.064 House-plants	External exposure is included in the radionuclide model (SKB R-13-46), but has limited importance for a few and non-dominating radionuclides. The external dose is considered by all sources although contribution from household plants is assumed to be small.		
A 3.079 Peat and leaf litter harvesting	Human utilization of the environment for other purposes than feeding and water use are considered in the biosphere interaction matrix. External exposure is included in the radionuclide model (SKB R-13-46), but has limited importance for a few and non-dominating radionuclides. The external dose is considered by all sources.		
A 3.117 Wetlands	Wetlands may be used in several ways; they may be used for collecting wild berries and game, they may be drained and used for agricultural sources, and peat from wetlands may be utilized for fuel and as building material. Wetlands are considered in the biosphere interaction matrix and are included in the radionuclide model (SKB R-13-46), where occurrence, sizes, and peat depths of wetlands in the model area is included.		
H 4.3.1 Land and surface water use: Terrestrial	The land use is considered in the radionuclide model (SKB R-13-46).		
H 4.3.4 Land and surface water use: Seas	Use of seas is considered in the biosphere interaction matrix. Shipping and sailing are assumed not to give any significant dose and is thus not considered in the radionuclide model (SKB R-13-46). Food supply from seas is included (treated as FEP Bio20 and Bio21).		
I 010 Recycling process (biomass)	Ashes and sewage sludge may increase crop yield due to an extra supply of essential elements. In the safety assessment, values of crop production from fertilized land are used to calculate production of food and thereby this process is considered (SKB R-13-18).		
I 150 Household plants (dose pathway)	See NEA FEP A 3.064.		
M 2.4.10 Qurries, near surface extraction	Extraction of Quarries may give rise to external exposure. External exposure is considered in the radionuclide model (SKB R-13-46). The external dose is considered by all sources.		

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SR-PSU FEP Bio18 Species introduction/extermination

No NEA Project FEP is associated with this SR-PSU FEP.

Table A14-17. SR-PSU FEP Bio19 Water use (see also Bio28 Water supply).

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.03 Borehole - well	The borehole may be used as a well. This is considered in the safety assessment.		
A 2.14 Dams	Dam constructions may influence hydraulic heads and may affect surface water flows. Dams are made by artificial thresholdings.	Artificial thresholdings are not considered in SR-PSU. Such thresholdings would enlarge present lakes and the flat landscape of Forsmark would not encourage larger dam constructions.	
A 2.73 Wells	Wells are assumed to be utilized for drinking. The amount of water (water supply) is not assumed to limit the utilization of water from the well but the amount used is based on the human demand (SKB R-13-46).		
A 2.74 Wells (high-demand)	See NEA FEP A 2.73.		
A 3.042 Dispersion	Dispersion refers to the movement of radionuclides away from its source and includes advection, diffusion, water and air transport. These processes are considered in the hydrological model (SKB R-13-19) and radionuclide model (SKB R-13-46).		
A 3.073 Irrigation	Irrigation may increase radionuclide concentrations in crops and therefore irrigation has been included in the radionuclide model (SKB R-13-46).		
A 3.075 Lake mixing (artificial)	Artificial lake mixing (such as aeration and wave maker may affect contaminant concentrations in lakes by accelerating mixing of the water column or stirring up sediment particles) is considered in the biosphere interaction matrix. In the radionuclide model, dose is calculated on an annual basis and although the water column may be stratified in winter and/or summer it is completely mixed at least at two occasions each year, i.e. spring and autumn. Thus, artificial mixing is not specifically addressed in the radionuclide model since the water is already assumed to be completely mixed (SKB R-13-46).		
A 3.077 Outdoor spraying of water	Water and dust intake are handled in the radionuclide model (SKB R-13-46).		
A 3.094 Showers and humidifiers	Showers and humidifiers may release radionuclides indoors. However, the dose from this source is assumed to be very small in comparison to the radionuclide source from ingestions and this pathway is not included in the radionuclide model (SKB R-13-46).		
I 085a Dams (filling, draining)	See NEA FEP A 2.14.		
I 175 Irrigation (dose pathway)	Same as NEA FEP A 3.073.		
I 211 Outdoor spraying of water (atmospheric dose pathway)	Same as NEA FEP A 3.077.		
I 272 Showers and humidifiers (atmospheric dose pathway)	Same as NEA FEP A 3.094.		
J 5.27 Human induced actions on groundwater recharge	Human induced changes in land use that affect recharge are not considered in the hydrological modelling. Contamination through irrigation is considered in the radionuclide model (SKB R-13-46), but not as recharge in the flow modelling (SKB R-13-19).		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 5.36 Reuse of boreholes	Same as NEA FEP A 2.03.		
J 5.41 Water producing well	Wells are assumed to be utilized for drinking in the radionuclide model (SKB R-13-46). The amount of water (water supply) is not assumed to limit the utilization of water from the well but the amount used is based on the human demand (SKB R-13-46).		
J 7.07 Human induced changes in surface hydrology	Human induced changes in surface hydrology are addressed in the landscape modelling, to some extent. Irrigation is considered in the dose calculations in the radionuclide model (SKB R-13-46).		
K 8.07 Water resource exploitation	Water resource exploitation is considered in the biosphere interaction matrix and radionuclide model (SKB R-13-46). The source of water for human utilisation (lake, rivers well) may have an influence on the exposure as different sources may have different concentrations of radionuclides.		
K 8.33 Irrigation	See NEA FEP A 3.073.		
K 11.05 Deep groundwater abstraction	See NEA FEP A 2.03 and A 2.73.		
M 2.4.02 Dams and reservoirs, built/drained	See NEA FEP A 2.14.		
M 2.4.04 Irrigation	See NEA FEP A 3.073.		
W 3.005 Groundwater exploitation	See NEA FEP A 2.03 and A 2.73.		
W 3.026 Groundwater extraction	See NEA FEP A 2.03 and A 2.73.		
W 3.042 Damming of streams or rivers	See NEA FEP A 2.14.		
W 3.043 Reservoirs	See NEA FEP A 2.14.		
W 3.044 Irrigation	See NEA FEP A 3.073.		
W 3.045 Lake usage	Water use is the use of water for other purpose than drinking and is considered in the radionuclide model (SKB R-13-46) In the radionuclide model, irrigation is included whereas recreational purposes and industrial use are assumed to be insignificant compared to internal exposure due to ingestion, and also smaller than external exposure from terrestrial ground and therefore this is not further considered.		
W 3.050 Coastal water use	Water use is the use of water for other purpose than drinking and is considered in the biosphere interaction matrix. Coastal waters are available for recreational utilization, and industrial uses. Although this may pose exposure to humans it is assumed to be insignificant compared to internal exposure due to ingestion, and also smaller than external exposure from terrestrial ground and therefore this is not further considered in the radionuclide model (SKB R-13-46).		
W 3.051 Sea water use	Water use is the use of water for other purpose than drinking and is considered in the biosphere interaction matrix. Sea waters are available for recreational utilization, shipping etc. Although this may pose exposure to humans it is assumed to be insignificant compared to internal exposure due to ingestion, and also smaller than external exposure from terrestrial ground and therefore this is not further considered in the radionuclide model (SKB R-13-46).		

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SR-PSU FEP Bio20 Change of pressure

No NEA Project FEP associated with this SR-PSU FEP.

Table A14-18. SR-PSU FEP Bio21 Consolidation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
H 2.1.4 Diagenesis	Consolidation and diagenesis are addressed in the biosphere interaction matrix and considered not of importance due to that the bedrock consists of archean crystalline rock and the regular scoring by ice will prevent accumulation of looser rock during these conditions.		
J 7.10 Diagenesis	Consolidation and diagenesis are addressed in the biosphere interaction matrix and considered not of importance due to that the bedrock consists of archean crystalline rock and the regular scoring by ice will prevent accumulation of looser rock during these conditions.		
M 1.2.05 Diagenesis	Consolidation and diagenesis are addressed in the biosphere interaction matrix and considered not of importance due to that the bedrock consists of archean crystalline rock and the regular scoring by ice will prevent accumulation of looser rock during these conditions.		
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Table A14-19. SR-PSU FEP SR-PSU FEP Bio22 Element supply (see also Bio15 Uptake).

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.006 Ashes and sewage sludge fertilizers	Ashes and sewage sludge may increase crop yield, In the radionuclide model (SKB R-13-46), values of crop production from fertilized land are used to calculate production of food and thereby this process is indirectly included. Ashes of burned peat may concentrate radionuclides in the soil. In the safety assessment this case is investigated by separate calculations (SKB TR-14-06).		
A 3.036 Crop fertilizers and soil conditioners	Fertilizers and soil conditioners increase the yield from agricultural land but may also dilute the concentration of radionuclides in the crop if radionuclides that are essential elements are diluted with uncontaminated elements in the fertilizers. In the radionuclide model, values of crop production from fertilized land are included to calculate production of food and thereby this process is considered (SKB R-13-18).		
A 3.080 Plant roots	Plants can take up radionuclides from the soil via their roots. The uptake is dependent on the supply in the regolith. The uptake is considered in the safety assessment as production and also by CR-factors used to determine the concentration of radionuclides in plants (SKB R-13-01).		
K 8.13 Exposure pathways	Exposure pathways are considered in the biosphere interaction matrix and are described in (SKB R-14-02). Ingestion of various food sources, water, inhalation of dust and external exposure are considered in the radionuclide model (SKB TR-14-06).		
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SR-PSU FEP Bio23 Loading

No NEA Project FEP associated with this SR-PSU FEP.

Table A14-20. SR-PSU FEP Bio24 Phase transitions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.021 Chemical precipitation	Chemical precipitation influences the phase of elements and thereby transport of radionuclides. This is considered in the radionuclide model by applying sorption coefficients (K_d) (SKB R-13-01).		
A 3.090 Seasons	Seasons are considered in the radionuclide model, annual mean values are used for parameterisation (SKB R-13-18).		
A 3.094 Showers and humidifiers	Showers and humidifiers may release radionuclides indoors. However, the dose from this source is assumed to be very small in comparison to the radionuclide source from ingestions and this pathway is not included in the radionuclide model (SKB R-13-46).		
A 3.098 Soil leaching	Soil leaching is considered for agricultural land in the radionuclide model (SKB R-13-46) by applying parameters presented in (SKB R-13-18).		
A 3.105 Suspension in air	One pathway for radionuclides from soil and water to become part of the air is by degassing. This is included in the radionuclide model (SKB R-13-46).		
H 4.2.1 Soil moisture and evaporation	This process is considered in the hydrological modelling (SKB R-13-19) that calculates input parameters to the radionuclide model (SKB R-13-46).		
H 4.2.4 Sediment/water/gas interaction with the atmosphere	Exchange over the air–water interface is considered, and the exchange of 14-C is included in the radionuclide model (SKB R-13-46).		
H 4.2.6 Biogeochemical processes	Biogeochemical processes are included in the radionuclide model (SKB R-13-46).		
I 112a Fire (atmospheric dose pathway)	Fires are considered in the biosphere interaction matrix.		
I 115 Flooding (localized, short-term surface flooding)	Flooding of terrestrial areas may lead to transport of radionuclides from the water to terrestrial areas. This is included in the radionuclide model (SKB R-13-46) by the use of a specific flooding coefficient (SKB R-13-18).		
I 272 Showers and humidifiers (atmospheric dose pathway)	See NEA FEP A 3.094.		
K 8.12 Radionuclide volatilisation/aerosol/dust production	Volatilisation/aerosol/dust is considered in the radionuclide model (SKB R-13-46). Inhalation of contaminated soil dust is an exposure pathway and thus volatilisation/aerosol/dust is considered in the radionuclide model (SKB R-13-46).		
K 8.28 Interface effects	Interactions between the geosphere and biosphere are considered in the radionuclide model (SKB R-13-46).		
K 8.30 Evapotranspiration	Evapotranspiration is included in the hydrological modelling (SKB R-13-19). Water balance results from the hydrological modelling are used to parameterise the radionuclide model (SKB R-13-18).		
W 2.103 Accumulation in soil	Deposited material may accumulate in soils and organic debris. This is considered in the radionuclide model both as deposition and permanent accumulation (SKB R-13-46).		

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Table A14-21. SR-PSU FEP Bio25 Physical properties change.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.090 Seasons	In the radionuclide model, annual mean values are used for parameterisation. These values are based on site-specific measurements considering seasonal variations (SKB R-13-18).		
K 8.28 Interface effects	Interactions between the geosphere and biosphere are considered in the radionuclide model (SKB R-13-46).		

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Table A14-22. SR-PSU FEP Bio26 Reactions.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.007 Bacteria and microbes in soil	Decomposers are considered in the ecosystem models (SKB TR-10-01, TR-10-02 and TR-10-03), and the radionuclide model (SKB R-13-46). Bacteria decompose organic matter and thereby liberate radionuclides, which may then become available and recycled. The breakdown of primary incorporated radionuclides is considered in the radionuclide model (SKB R-13-46).		
A 3.010 Biogas production	Heating needs may be met with biogas from biological reactors fuelled by plant materials, faeces and refuse, or from trapping natural methane from garbage disposal sites, bogs and sediments. These fuels may be contaminated with radionuclides leading to external exposure. External exposure is included in the radionuclide model, but has limited importance for a few and non-dominating radionuclides (SKB R-13-46). The external dose is considered by all sources.		
A 3.020 Charcoal production	As the dose from charcoal production is considered to become insignificant in comparison to ingestion of contaminated food, this process is not included in the radionuclide model (SKB R-13-46).		
A 3.021 Chemical precipitation	Chemical precipitation influences the phase of elements and thereby transport of radionuclides. This is considered in the radionuclide model (SKB R-13-46).		
A 3.048 Fires (agricultural)	Fires are considered in the biosphere matrix, but not included in the radionuclide model (SKB R-13-46). Although fires may give rise to high concentration in the atmosphere on a short time scale the contribution to dose on a 50 year perspective is assumed to be small.		
A 3.049 Fires (forest and grass)	Fires are considered in the biosphere interaction matrix, but not included in the radionuclide model (SKB R-13-46). Although fires may give rise to high concentration in the atmosphere on a short time scale the contribution to dose on a 50 year perspective is assumed to be small.		
A 3.102 Space heating	Space heating when burning contaminated materials such as trees may contribute to external exposure. External exposure is included in the radionuclide model, but has limited importance for a few and non-dominating radionuclides (SKB R-13-46). The external dose is considered by all sources.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.104 Surface water pH	The surface water pH affects reactions, sorption of radionuclides etc. and may change over time due to landscape development processes. The effects of changing pH on transport of radionuclides are considered in the radionuclide model by the use of element-specific K_d values for different soils. These K_d values are based on site measurements and thereby take into account different pH values as well as other important characteristics of regolith types that affect K_d. Surface water pH also affects other parameters such as biomass of biota and degassing, which is also accounted for by site-specific measurements (SKB R-13-18).		
E GEN-31 Radionuclide reconcentration	Remobilization of radionuclides due to changed conditions, due to shore-level displacement, bioturbation, ploughing is considered in the radionuclide model (SKB R-13-18).		
I 112a Fire (atmospheric dose pathway)	See NEA FEP A 3.049.		
I 112b Denuding of the site	Denuding of the site may remove the upper regolith and thereby affect the dispersion of radionuclides. This is considered in the landscape model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46) since we consider a glacial cycle and thereby conditions when the ice has removed the upper regolith layers. In addition, by modelling many objects, many different depths of regolith are considered.		
I 292 Surface water bodies (physical/chemical changes)	Physical and chemical changes of water bodies are considered in the radionuclide model (SKB R-13-46). For example, in the radionuclide model changes in chemistry are considered by the use of different parameter sets for marine and limnic stages of the aquatic objects and physical changes are considered by the use of time-specific values of the geometry of the objects (SKB R-13-18).		
K 8.28 Interface effects	Interactions between the geosphere and biosphere are identified in the biosphere interaction matrix but considered non-significant.		
W 1.042 Chemical weathering	Chemical weathering has little effect on the overall erosion, Nevertheless, any effects of weathering on chemical composition of water and soil is assumed to be included in the ecosystem-specific parameters (SKB R-13-18) since measurements are performed in situ and thereby including effects of weathering. Weathering is assumed not to change over time and thus this process does not have to be further explored in the models.		
W 2.071 Kinetics of organic complexation	Kinetics of organic complexation are included in the radionuclide model, where K_d and CR-values used are based on site-specific measurements thereby including the effect of organic complexation that occur in situ (SKB R-13-01).		

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Table A14-23. SR-PSU FEP Bio27 Sorption/desorption.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.026 Colloids	Particles suspended in water are included in the radionuclide model as these influence sorption/desorption and thereby transport and accumulation of radionuclides (SKB R-13-46).		
A 3.072 Ion exchange in soil	Ion exchange in soils is considered by the use of site-specific properties of the regolith and K_d values (SKB R-13-01) in the radionuclide modelling.		
A 3.092 Sedimentation in water bodies	Sedimentation of radionuclides is dependent on the sorption/desorption of radionuclide to particles. This is included in the radionuclide model (SKB R-13-46) as modelled sedimentation and K_d values (SKB R-13-01).		
A 3.098 Soil leaching	Soil leaching is considered for agricultural land in the radionuclide model (SKB R-13-46).		
A 3.099 Soil pore water pH	The pH affects reactions, sorption of radionuclides etc. The effects of changing pH on transport of radionuclides are considered in the radionuclide model by the use of specific K_d values for different soil types (SKB R-13-01). These K_d values are based on site measurements and thereby take into account different pH values as well as other important characteristics of regolith types that affect transport of radionuclides in regolith.		
A 3.100 Soil sorption	Soil sorption is considered in the radionuclide model (SKB R-13-46). Sorption to soils and sediments are estimated by the use of K_d values presented in SKB R-13-01.		
E GEN-31 Radionuclide reconcentration	Remobilization of radionuclides due to changed conditions, due to shore-level displacement, bioturbation, ploughing is considered in the radionuclide model (SKB R-13-46).		
H 4.2.6 Biogeochemical processes	Biogeochemical processes are included in the radionuclide model (SKB R-13-46).		
I 009 Sediments (in water bodies)	The sorption/desorption of radionuclides to particles is considered in the radionuclide model by element-specific K_d values. In additions, the transport of particles between the water column and the sediment is dependent on sedimentation/ resuspension processes which are also included in the radionuclide model (SKB R-13-46).		
I 174 Ion exchanges in soil	See NEA FEP A 3.072.		
K 8.05 Radionuclide accumulation in sediments	Radionuclide accumulation in sediments is considered in the radionuclide model (SKB R-13-46). Deposited material may accumulate in soils and organic debris. This is considered in the radionuclide model both as deposition and permanent accumulation.		
K 8.06 Radionuclide accumulation in soils	Radionuclide accumulation in soils is considered in the radionuclide model (SKB R-13-46).		
K 8.17 Radionuclide sorption	The sorption/desorption of radionuclides to particles and sediment is included in the radionuclide model by element-specific K_d values presented in (SKB R-13-01).		
K 8.36 Suspended sediment transport	See NEA FEP A 3.026.		
M 1.6.07 Sorption	See NEA FEP K 8.17.		
W 2.071 Kinetics of organic complexation	Kinetics of organic complexation are considered in the radionuclide model, where K_d and CR-values used are based on site-specific measurements thereby including the effect of organic complexation that occur in situ.		

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Table A14-24. SR-PSU FEP Bio28 Water supply (see also Bio19 Water use).

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.03 Borehole - well	The borehole may be used as a well. This is considered in the radionuclide model (SKB R-13-46).		
A 2.73 Wells	Wells are assumed to be utilized for drinking. The amount of water (water supply) is assumed not to limit the utilization of water from the well, but the amount used is based on the human demand (SKB R-13-46 and R-13-18).		
A 2.74 Wells (high-demand)	See NEA FEP A 2.73.		
A 3.073 Irrigation	Irrigation may increase radionuclide concentrations in crops and therefore irrigation has been included in the radionuclide model (SKB R-13-46).		
A 3.116 Water source	The source of water (lake, rivers well) for human utilisation (uptake by drinking and other water use) may have an influence on the exposure as different sources may have different concentrations of radionuclides. The utilisation of different sources (e.g. surface water or water extracted from wells) has been considered in the radionuclide model (SKB R-13-46).		
H 4.3.1 Land and water use: Terrestrial	Water supply is the supply of water for drinking and other purposes. Use of water in the terrestrial ecosystem for drinking and other purposes are considered in the radionuclide model (SKB R-13-46).		
H 4.3.3 Land and surface water use: Coastal waters	Use of coastal water is considered in the biosphere interaction matrix. Swimming is assumed to give insignificant dose compared to internal doses from ingestion and inhalation and is thus not included in the radionuclide model (SKB R-13-46). Food production is included in the radionuclide model (treated as FEPs Bio02 and Bio06).		
H 4.3.4 Land and surface water use: Seas	Water supply is the supply of water for drinking and other purposes. Food supply from seas is considered in the radionuclide model (SKB R-13-46), as fish production (treated as FEP Bio02 Consumption). Drinking of sea water is not possible and other uses, such as shipping and sailing are assumed not to give any significant dose. Thus this is not considered in the radionuclide model (SKB R-13-46).		
I 003 Animal diets (domestic and wild)	Animals drink water and are dependent on water supply, i.e. if no water is available there will be no animals. Animals are assumed to utilize surface water for drinking in the radionuclide model.		
I 175 Irrigation (dose pathway)	Same as NEA FEP A 3.073.		
J 5.36 Reuse of boreholes	Same as NEA FEP A 2.03.		
J 5.41 Water producing well	Same as NEA FEP A 2.73.		
K 8.33 Irrigation	Same as NEA FEP A 3.073.		
K 11.05 Deep groundwater abstraction	Same as NEA FEP A 2.03.		
M 2.4.04 Irrigation	Same as NEA FEP A 3.073.		
W 3.005 Groundwater exploitation	Same as NEA FEP A 2.03.		
W 3.040 Land use changes	Land use is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and in the radionuclide model (SKB R-13-46). Forsmark is situated in an area where there is shore-line development, i.e. new land is uplifted and new areas may be used for agriculture (see landscape development model (SKB R-13-27, SKB TR-14-06). Water extraction is considered in the model as the use of a well for irrigation.		
W 3.044 Irrigation	Same as NEA FEP A 3.073.		

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Table A14-25. SR-PSU FEP Bio29 Weathering.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.046 Erosion - lateral transport	Erosion is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46). Erosion leads to transport of sediments and soils. The extent of erosion has formed the present topography and will form the future landscape.		
A 3.047 Erosion (wind)	Erosion is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46). Erosion leads to transport of sediments and soils. The extent of erosion has formed the present topography and will form the future landscape.		
E GEN-29 Erosion and weathering	See NEA FEP A 3.047.		
I 305 Topography (changes)	Changes in topography and landscape development (e.g. transformation from lake to wetland) are considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46).		
J 5.26 Erosion on surface/sediments	Erosion leads to transport of sediments and soils. In addition, erosion may affect depths of the regolith layer which influence recharge and discharge. The extent of erosion has formed the present topography which is included in the radionuclide model (SKB R-13-46). For future landscape, erosion is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46).		
K 8.22 Erosion/ deposition	See NEA FEP K 10.11.		
K 8.24 Soil formation	Soil formation is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46).		
K 9.07 Erosion/ denudation	See NEA FEPs A 3.046 and K 10.12.		
K 10.11 Fluvial erosion/ sedimentation	Erosion and sedimentation are considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and in the radionuclide model (SKB R-13-46).		
K 10.12 Surface denudation	Denuding of the site may remove the upper regolith and thereby affecting the dispersion of radionuclides. This is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46) since we considered a glacial cycle and thereby conditions when the ice has removed the upper regolith layers. In addition, by modelling many objects, many different depths of regolith are considered.		
K 10.14 Glacial erosion/sedimentation	See NEA FEP K 10.11.		
K 10.15 Glacial–fluvial erosion/sedimentation	Erosion and sedimentation are considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46).		
M 1.4.02 Denudation	See NEA FEP K 10.12.		
M 1.4.08 Frost weathering and chemical denudation	Denuding of the site may remove the upper regolith and thereby affecting the dispersion of radionuclides. This is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46) since we considered a glacial cycle and thereby conditions when the ice has removed the upper regolith layers. In addition, by modelling many objects, many different depths of regolith are considered.		
W 1.041 Mechanical weathering	Erosion is considered in the biosphere interaction matrix.		

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SR-PSU FEP Bio30 Wind stress

No NEA Project FEP is associated with this SR-PSU FEP.

Table A14-26. SR-PSU FEP Bio31 Acceleration.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.023 Climate	Climate may have a large impact on transport of radionuclides, e.g. by altered precipitation and runoff patterns. This has been considered in climate cases calculations for the radionuclide model (SKB R-13-46).		
A 3.027 Convection, turbulence and diffusion (atmospheric)	Air-borne radionuclides may be directed, diluted and dispersed by convection, turbulence and diffusion. This is considered in the radionuclide model (SKB R-13-46) by dilution in atmosphere and by export from the local atmosphere above the ecosystems to global atmosphere (SKB R-13-46).		
A 3.075 Lake mixing (artificial)	In the radionuclide model, dose is calculated on an annual basis and although the water column may be stratified in winter and/or summer it is completely mixed at least at two occasions each year, i.e. spring and autumn. Thus, artificial mixing is not specifically addressed in the radionuclide model since the water is already assumed to be completely mixed (SKB R-13-46).		
W 3.042 Damming of streams or rivers	Dam constructions may influence hydraulic heads and may affect surface water flows. Dams are made by artificial thresholdings.	Artificial thresholdings are not considered in SR-PSU. Such thresholdings would enlarge present lakes and the flat landscape of Forsmark would not encourage larger dam constructions.	
W 3.043 Reservoirs	Dam constructions may influence hydraulic heads and may affect surface water flows. Dams are made by artificial thresholdings.	Artificial thresholdings are not considered in SR-PSU. Such thresholdings would enlarge present lakes and the flat landscape of Forsmark would not encourage larger dam constructions.	
W 3.045 Lake usage	Water use is the use of water for other purpose than drinking and is considered in the radionuclide model (SKB R-13-46). In the radionuclide model, irrigation is included, whereas recreational purposes and industrial use are assumed to be insignificant compared to internal exposure due to ingestion, and also smaller than external exposure from terrestrial ground and therefore this is not further considered (SKB R-13-46).		

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Table A14-27. SR-PSU FEP Bio32 Convection.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.17 Discharge zones	Discharge zones of groundwater and thereby discharge zones of radionuclides from a repository in Forsmark are thoroughly considered and included in the hydrological model (SKB R-13-19) and radionuclide model (SKB R-13-46).		
A 3.017 Capillary rise in soil	The modelling of surface hydrology (SKB R-13-19) handles variably saturated flow, which means that the unsaturated zone and capillary rise are modelled. The sensitivity to plant uptake of solutes is also studied.		
A 3.023 Climate	Climate may have a large impact on transport of radionuclides, e.g. by altered precipitation and runoff patterns. This has been considered in supporting calculations for the radionuclide model (SKB R-13-46) where altered conditions have been applied (SKB R-13-46).		
A 3.026 Colloids	Colloids in water, i.e. particulate matter, are considered in the radionuclide model as these influence sorption/desorption and thereby transport and accumulation of radionuclides (SKB R-13-46).		
A 3.027 Convection, turbulence and diffusion (atmospheric)	Air-borne radionuclides may be directed, diluted and dispersed by convection, turbulence and diffusion. This is considered in the radionuclide model by dilution in the atmosphere and by export from the local atmosphere above the ecosystems to global atmosphere (SKB R-13-46).		
A 3.042 Dispersion	Dispersion refers to the movement of radionuclides away from its source and includes advection, diffusion, water and air transport. These processes are considered in the radionuclide model (SKB R-13-46).		
A 3.052 Flooding	Flooding of terrestrial areas may lead to a transport of radionuclides from the water to terrestrial areas. This is considered in the radionuclide model (SKB R-13-46) by the use of a specific flooding coefficient (SKB R-13-18).		
A 3.053 Flushing of water bodies	The retention time of water in aquatic water bodies is important for the accumulation and transport of radionuclides and is consequently included in the radionuclide model (SKB R-13-46).		
A 3.056 Gas leakage into basements	Gas leakage into buildings is considered in the biosphere interaction matrix, but was screened out (see SKB R-14-02).	Exposure from the biosphere object all year around is regarded to be higher than exposure inside a house.	
A 3.075 Lake mixing (artificial)	Artificial lake mixing (such as aeration and wave maker may affect contaminant concentrations in lakes by accelerating mixing of the water column or stirring up sediment particles). In the radionuclide model, dose is calculated on an annual basis and although the water column may be stratified in winter and/or summer it is completely mixed at least at two occasions each year, i.e. spring and autumn. Thus, artificial mixing is not specifically addressed in the radionuclide model since the water is already assumed to be completely mixed.		
A 3.084 Radon emission	Radon emission is considered in the biosphere interaction matrix but not included in the radionuclide model (SKB R-13-46).		
A 3.087 Runoff	Runoff is important for the convection of radionuclides and water balances. Runoff is included in the hydrological model (SKB R-13-19) and water balances that are used for the radionuclide model in SKB R-13-18.		
A 3.090 Seasons	In the radionuclide model, annual mean values are used for parameterisation. These values are based on site-specific measurements considering seasonal variations.		
A 3.097 Soil depth	Soil depth is important for the retention and transport of radionuclides in the regolith. The depth of different regolith layers, including the upper soils is modelled in the regolith model (SKB R-13-22) and included in the radionuclide model (SKB R-13-46).		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.098 Soil leaching	Soil leaching is considered for agricultural land in the radionuclide model (SKB R-13-46).		
A 3.101 Soil type	Soil type, e.g. porosity and pH have a large influence on the mobility of radionuclides in the soil. Properties (density, porosity) of different regolith layers are presented in SKB R-13-18 and included in the radionuclide model (SKB R-13-46).		
A 3.105 Suspension in air	Water and soils may be suspended in air and thereby become suspended or gaseous particles in the air. Processes involved are degassing, erosion, ploughing and irrigation. These processes are included in the radionuclide model (SKB R-13-46).		
A 3.108 Terrestrial surface	The type of terrestrial area, forest, outcrops, grasslands are important for the transport and accumulation of radionuclides. The landscape development model (SKB R-13-27, SKB TR-14-06) is used to predict the type of future landscape at Forsmark and the occurrence of wetlands and forest are mapped over time for the entire model area which is included in the radionuclide model (SKB R-13-46).		
A 3.117 Wetlands	Wetlands may be used in several ways; they may be used for wild berries and game, they may be drained and used for agricultural sources, and peat from wetlands may be utilized for fuel and as building material. Wetlands are included in the radionuclide model (SKB R-13-46) where occurrence, sizes, and peat depths of wetlands (SKB R-13-18) in the model area is included.		
A 3.118 Wind	Wind affects the transport of radionuclides by affecting soil erosion, degassing and dilution and transport of radionuclide by wind. Accordingly, wind speed is considered in the radionuclide model (SKB R-13-46) and parameterisation (SKB R-13-18).		
E GEN-33 Sea level changes	Sea level changes are considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and in the radionuclide model (SKB R-13-46). At the start of the modelling of the Forsmark landscape, the entire area is situated below sea level and at the end of the modelling period, the entire area is situated above sea level.		
H 2.2.1 Changes in geometry and driving forces of the flow system	Changes in geometry changes the flow pattern. This is considered in the radionuclide model where shoreline displacement is included and flow to different objects is calculated for each time step in the radionuclide model (SKB R-13-46).		
H 4.1.1 Groundwater discharge to soils and surface waters	The location of discharge of radionuclides is central in the safety assessment and is considered in hydrological model (SKB R-13-19), landscape model (SKB R-13-27, SKB TR-14-06), and radionuclide model (SKB R-13-46).		
H 4.2.2 Surface water mixing	Surface mixing is considered in the radionuclide model. Water is assumed to be mixed since the water column will be mixed at least twice (during spring an autumn) on the time scale of the model (i.e. 1 year) (SKB R-13-46).		
I 069 Atmospheric pathways (dispersion)	Atmospheric pathways include direction of radionuclides, dilution, dispersion and contamination of vegetation, soil and water. All these are considered in the radionuclide model (SKB R-13-46); radionuclides entering the atmosphere are diluted in the atmospheric layer above and some is exported due to wind. Gas uptake by water and primary producers is also considered.		
I 116 Flushing of water bodies	See NEA FEP A 3.053.		
I 128 Gas leakage into basements	See NEA FEP A 3.056.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 143 Groundwater (redirection of)	Effects on hydrology of changes in topography and regolith stratigraphy are addressed in the hydrological modelling (SKB R-13-19). Redirection of flow under permafrost and glacial conditions are considered in the hydrogeological modelling (SKB R-13-25). Redirection of flow due to pumping in wells is handled separately in the radionuclide assessment based on conservative assumptions. The reduced contaminant input to the biosphere objects that result from pumping in wells is not taken into account (also conservative).		
I 180 Surface water bodies (non-uniform mixing of)	Stratification, i.e. the opposite of mixing, may occur in summer and winter. This is reflected in site investigations where samples are taken from multiple depths. In the radionuclide model, the long term-average concentrations are assumed to be better represented by assuming a mixed water column (SKB R-13-46).		
I 258 Surface runoff	See NEA FEP A 3.087.		
J 5.26 Erosion on surface/sediments	Erosion leads to transport of sediments and soils. In addition, erosion may affect depths of the regolith layer which influence recharge and discharge. The extent of erosion has formed the present topography which is included in the radionuclide model (SKB R-13-46). For the future landscape, erosion is considered in the landscape development model (SKB R-13-27, SKB TR-14-06), and radionuclide models (SKB R-13-46).		
J 5.27 Human induced actions on groundwater recharge	Human induced changes in land use that affect recharge are not considered in the hydrological modelling (SKB R-13-19). Contamination through irrigation is considered in the radionuclide model (SKB R-13-46), but not as recharge in the flow modelling.		
J 5.41 Water producing well	Wells are assumed to be utilised for drinking in the radionuclide model (SKB R-13-46). The amount of water (water supply) is not assumed to limit the utilisation of water from the well but the amount used is based on the human demand (SKB R-13-18).		
J 7.05 Isotopic dilution	Dilution of radionuclides with stable elements is considered in the radionuclide model e.g. it is considered in the uptake of plants where C-14 is diluted with naturally occurring C-12.		
K 8.03 Exfiltration to a local aquifer	The whole system is modelled in the hydrological modelling of the biosphere, including surface water and shallow and deep aquifers and this FEP is considered in the hydrological model (SKB R-13-19) and in the radionuclide model (SKB R-13-46).		
K 8.04 Exfiltration to surface waters	Exfiltration is considered in supporting calculations to the radionuclide model (SKB R-13-46). These calculations were done in order to understand the effect of the regolith as a barrier for the repository. In these calculations, the regolith has been excluded (i.e. exfiltration) and thus this process is considered, although it is highly unlikely to occur in Forsmark.		
K 8.21 Dilution of radionuclides in surface water (aquifer, river, lake etc.)	The dilution of radionuclides in water bodies is considered in the radionuclide model where the radionuclide release is assumed to become completely mixed within the receiving water bodies (SKB R-13-46).		
K 8.27 Atmosphere	The atmosphere is considered in the radionuclide model (SKB R-13-46).		
K 8.29 Precipitation	Precipitation is considered in the hydrological model (SKB R-13-19) and water balances that are used to derive input parameters to the radionuclide model in SKB TR-13-18.		
K 8.30 Evapotranspiration	Evapotranspiration is included in the hydrological modelling (SKB R-13-19). Water balance results from the hydrological modelling are used in the radionuclide model (SKB R-13-46).		
K 8.31 Capillary rise	See NEA FEP A 3.017.		
K 8.32 Percolation	The downward flux of water and elements in soils are considered in the radionuclide model by applying parameters presented in SKB TR-13-18.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
K 8.34 Surface run-off	Surface water runoff is considered in the hydrological model (SKB R-13-19) and radionuclide model (SKB R-13-46).		
K 8.36 Suspended sediment transport	Particles suspended in water are included in the radionuclide model (SKB R-13-46) as these influence sorption/desorption and thereby transport and accumulation of radionuclides (SKB R-13-46).		
K 10.02 Effective moisture (recharge)	In the surface hydrology modelling, meteorological input is used and evapotranspiration processes are quantified explicitly by the model (SKB R-13-19).		
M 1.3.02 Extremes of precipitation, snow melt, and associated	Flooding which is caused by extremes in snowmelt or precipitation is considered in the hydrological model (SKB R-13-19) and in the radionuclide model (SKB R-13-46).		
M 1.3.03 Coastal surge, storms and hurricanes		Coastal storms and hurricanes are assumed not to have any large effect on the transport or accumulation of radionuclides. In the marine stage, radionuclides are mainly diluted due to short retention time of water.	
M 1.4.05 Fresh-water sediment transport and deposition	Sediment transport and deposition are included in the radionuclide model (SKB R-13-46). Sediment and resuspension parameters are presented in SKB R-13-18.		
M 1.4.06 Coastal erosion and estuarine development	Erosion in marine basins is considered in the landscape development modelling (SKB R-13-27, SKB TR-14-06), e.g. distribution of accumulation and erosion bottoms is described.		
M 1.5.01 River flow and lake level changes	Changes in river flows and lake levels are included in the radionuclide model as future object have different sizes of catchment areas (thereby different amounts of water passing). Moreover, terrestrialisation affects lake depths and lake levels. Changes in lake levels and sea levels are also considered in the transition from marine basins to lakes in the radionuclide model (SKB R-13-46).		
M 1.5.02 Site flooding	Flooding of terrestrial areas may lead to transport of radionuclides from the water to terrestrial areas. This is considered in the radionuclide model by the use of a specific flooding coefficient presented in SKB R-13-18.		
M 1.5.03 Recharge to ground water	Recharge is included in the hydrological modelling (SKB R-13-19) and radionuclide model (SKB R-13-46).		
M 1.5.04 Ground water discharge	Discharge is included in the hydrological modelling (SKB R-13-19) and radionuclide model (SKB R-13-46).		
M 1.6.02 Diffusion	Diffusion is considered in advection–dispersion simulations of the surface/near-surface system (SKB R-13-19).		
M 2.4.03 River rechannelling	The regolith at the site consists of till and rivers are small, which gives a low potential for any substantial river erosion of the river banks. In the radionuclide model, no long-term accumulation is assumed to occur in streams and thereby the annual sedimentated material is assumed to be resupended (eroded) and transported downstream, i.e. the sizes of the rivers are assumed to remain throughout the modelled time period (SKB R-13-46).		
M 2.4.10 Qurries, near surface extraction	Extraction from Quarries may give rise to external exposure. External exposure is considered in the radionuclide model (SKB R-13-46). The external dose is considered by all sources.		
S 087 Surface water chemistry	Surface water chemistry is considered in the radionuclide model where site specific water chemistry characteristics are considered (SKB R-13-18).		
W 1.051 Stream and river flow	Flows in streams and rivers are included in the radionuclide model (SKB R-13-46).		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
W 1.057 Lake formation	Lake formation under present and future conditions is considered in the hydrological modelling (SKB R-13-19), landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46).		
W 1.058 River flooding	See NEA FEP M 1.5.02.		
W 1.059 Precipitation (for example, rainfall)	See NEA FEP K 8.29.		
W 1.060 Temperature	Temperature affects convection by e.g. influencing the amount and form of precipitation. Temperature is included in calculation of parameters from several disciplines affecting radionuclide transport (SKB R-13-18).		
W 1.067 Marine sediment transport and deposition	Sediment transport and deposition in marine basins are included in the radionuclide model (SKB R-13-46) and in the landscape development model (SKB R-13-27, SKB TR-14-06).		
W 3.044 Irrigation	Irrigation may increase radionuclide concentrations in crops and therefore irrigation is included in the radionuclide model (SKB R-13-46).		
W 3.045 Lake usage	Water use is the use of water for other purpose than drinking and is considered in the radionuclide model (SKB R-13-46). In the radionuclide model, irrigation is included whereas recreational purposes and industrial use are assumed to be insignificant compared to internal exposure due to ingestion, and also smaller than external exposure from terrestrial ground and therefore this is not further considered (SKB R-13-46).		
W 3.050 Coastal water use	Coastal waters are available for recreational utilisation, and industrial uses. Although this may pose exposure to humans it is assumed to be insignificant compared to internal exposure due to ingestion, and also smaller than external exposure from terrestrial ground and therefore this is not further considered in the radionuclide model (SKB R-13-46).		
W 3.051 Sea water use	Water use is the use of water for other purpose than drinking. . Sea waters are available for recreational utilisation, shipping etc. Although this may pose exposure to humans it is assumed to be insignificant compared to internal exposure due to ingestion, and also smaller than external exposure from terrestrial ground and therefore this is not further considered in the radionuclide model (SKB R-13-46).		
W 3.053 Arable farming	Human affecting the environment through farming is considered in the radionuclide model (SKB R-13-46).		

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Table A14-28. SR-PSU FEP Bio33 Covering.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
W 3.045 Lake usage	Water use is the use of water for other purpose than drinking and is considered in the radionuclide model (SKB R-13-46). In the radionuclide model, irrigation is included whereas recreational purposes and industrial use are assumed to be insignificant compared to internal exposure due to ingestion, and also smaller than external exposure from terrestrial ground and therefore this is not further considered.		
W 3.050 Coastal water use	Water use is the use of water for other purpose than drinking. Coastal waters are available for recreational utilisation, and industrial uses. Although this may pose exposure to humans it is assumed to be insignificant compared to internal exposure due to ingestion, and also smaller than external exposure from terrestrial ground and therefore this is not further considered in the radionuclide model (SKB R-13-46).		
W 3.051 Sea water use	Water use is the use of water for other purpose than drinking. Sea waters are available for recreational utilisation, shipping etc. Although this may pose exposure to humans it is assumed to be insignificant compared to internal exposure due to ingestion, and also smaller than external exposure from terrestrial ground and therefore this is not further considered in the radionuclide model (SKB R-13-46).		
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Table A14-29. SR-PSU FEP Bio34 Deposition.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.023 Climate	Climate may have a large impact on transport of radionuclides, e.g. by altered precipitation and runoff patterns. This has been considered in climate cases in the radionuclide model (SKB R-13-46) where altered conditions have been applied.		
A 3.026 Colloids	Colloids in water, i.e. particulate matter is included in the radionuclide model (SKB R-13-46) as these influence sorption/desorption and thereby transport and accumulation of radionuclides.		
A 3.039 Deposition (wet and dry)	Deposition is included in the hydrological water balances (SKB R-13-19) that are used in the radionuclide model (SKB R-13-46).		
A 3.063 Household dust and fumes	Inhalation of contaminated soil dust is included as an exposure pathway and thus volatilisation/aerosol/dust is included in the radionuclide model (SKB R-13-46).		
A 3.074 Lake infilling	Lake infilling is considered in the, landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46) where lakes are gradually infilled due to succession.		
A 3.081 Precipitation (meteoric)	See NEA FEP A 3.039.		
A 3.086 River-course meander	River meandering may result in agriculture on former stream beds. River meandering is not considered, but the result would be similar to agricultural use of former lake beds (which is included in the radionuclide model) and thus the effect of this process is considered (SKB R-13-46).		
A 3.088 Saltation	Saltation is considered in the radionuclide model (SKB R-13-46) where dust particles are included.		
A 3.091 Sediment resuspension in water bodies	Resuspension is included in the radionuclide model (SKB R-13-46).		
A 3.092 Sedimentation in water bodies	Sedimentation of radionuclides is dependent on the sorption/desorption of radionuclides to particles. This is included in the radionuclide model (SKB R-13-46) as modelled sedimentation (in dry weight per area and year) and K_d values.		
A 3.104 Surface water pH	The surface water pH affects reactions, sorption of radionuclides etc. and may change over time due to landscape development processes. This is thoroughly discussed in site descriptions. The effects of changing pH on transport of radionuclides are considered in the radionuclide model by the use of specific K_d values in different regolith types (SKB R-13-01). These K_d values are based on site measurements and thereby take into account different pH values as well as other important characteristics of regolith types that affect K_d. Surface water pH also affects other parameters such as biomass of biota and degassing, which is also accounted for by site-specific measurements (SKB R-13-18).		
A 3.105 Suspension in air	One pathway for radionuclides from soil and water to become part of the air is by degassing. This is included in the radionuclide model (SKB R-13-46).		
H 4.2.4 Sediment/water/gas interaction with the atmosphere	Exchange of C-14 over the air–water interface is included in the radionuclide model (SKB R-13-46).		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 009 Sediments (in water bodies)	The sorption/desorption of radionuclides to particles is considered in the radionuclide model by K_d values for different radionuclides (SKB R-13-01). In addition, the transport of particles between the water column and the sediment is dependent on sedimentation/resuspension processes which are also included in the radionuclide model (SKB R-13-46).		
I 069 Atmospheric pathways (dispersion)	Atmospheric pathways include direction of radionuclides, dilution, dispersion and contamination of vegetation, soil and water. All these are considered in the radionuclide model; radionuclides entering the atmosphere are diluted in the atmospheric layer above and some is exported due to wind, Gas uptake by water and primary producers is also considered (SKB R-13-46).		
I 112b Denuding of the site	Denuding of the site may remove the upper regolith and thereby affecting the dispersion of radionuclides. This is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46) since we considered a glacial cycle and thereby conditions when the ice has removed the upper regolith layers. In addition, by modelling many objects, many different depths of regolith are considered.		
I 115 Flooding (localized, short-term surface flooding)	Flooding of terrestrial areas may lead to transport of radionuclides from the water to terrestrial areas. This is included in the radionuclide model (SKB R-13-46) by the use of a specific flooding coefficient.		
I 235 Precipitation (wet deposition)	See NEA FEP A 3.039.		
I 292 Surface water bodies (physical/chemical changes)	Physical and chemical changes of water bodies are considered in the radionuclide model (SKB R-13-46). For example, in the radionuclide model, changes in chemistry are considered by the use of different parameter sets for marine and limnic stages of the aquatic objects and physical changes are considered by the use of time specific values of the geometry of the objects.		
J 5.26 Erosion on surface/sediments	Erosion leads to transport of sediments and soils. In addition erosion may affect depths of the regolith layer which influence recharge and discharge. The extent of erosion has formed the present topography which is included in the radionuclide model (SKB R-13-46). For the future landscape, erosion is considered in the landscape development model (SKB R-13-27, SKB TR-14-06), and the radionuclide model (SKB R-13-46).		
J 6.09 River meandering	See NEA FEP A 3.086.		
K 8.05 Radionuclide accumulation in sediments	Radionuclide accumulation in sediments is considered in the radionuclide model (SKB R-13-46). Deposited material may accumulate in soils and organic debris. This is considered in the radionuclide model both as deposition and permanent accumulation.		
K 8.06 Radionuclide accumulation in soils	Radionuclide accumulation in soils is considered in the radionuclide model (SKB R-13-46). Deposited material may accumulate in soils and organic debris. This is considered in the radionuclide model both as deposition and permanent accumulation.		
K 8.09 Uptake by crops	Uptake by crops of radionuclides is included in the radionuclide model by the use of concentration ratios (SKB R-13-01).		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
K 8.22 Erosion/ deposition	See NEA FEP K 10.11.		
K 8.23 Sedimentation	Sedimentation is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46).		
K 8.24 Soil formation	Soil formation is included in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46).		
K 8.29 Precipitation	Precipitation is considered in hydrological modelling (SKB R-13-19 and water balances that are used to derive input parameters (SKB R-13-18) to the radionuclide model (SKB R-13-46).		
K 10.11 Fluvial erosion/sedimentation	Erosion and sedimentation are considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and in the radionuclide model (SKB R-13-46).		
K 10.12 Surface denudation	Denuding of the site may remove the upper regolith and thereby affecting the dispersion of radionuclides. This is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46) since we consider a glacial cycle and thereby conditions when the ice has removed the upper regolith layers. In addition, by modelling many objects, many different depths of regolith are considered.		
K 10.14 Glacial erosion/sedimentation	See NEA FEP K 10.11.		
K 10.15 Glacial–fluvial erosion/ sedimentation	See NEA FEP K 10.11.		
M 1.3.02 Extremes of precipitation, snow melt, and associated	Flooding which is caused by extremes in snowmelt or precipitation is considered in the hydrological model (SKB R-13-19), and in the radionuclide model (SKB R-13-46).		
M 1.4.02 Denudation	See NEA FEP K 10.12.		
M 1.4.03 River, stream, channel erosion	River erosion and channel erosion are considered in the radionuclide model (SKB R-13-46). At the site, the regolith consists of till and rivers are relatively small, which gives a low potential for any substantial river erosion of the river banks. In the radionuclide model, no long-term accumulation is assumed to occur in streams and thereby the annual sedimentated material is assumed to be resupended (eroded) and transported downstream, i.e. the sizes of the rivers are assumed to remain throughout the modelled time period.		
M 1.4.04 River meandering	See NEA FEP A 3.086.		
M 1.4.05 Freshwater sediment transport and deposition	Sediment transport and deposition are included in several aspects, e.g. the radionuclide model (SKB R-13-46), sediment and resuspension parameters (SKB R-13-18), the sediment model describing infilling of marine basins and lakes with time, and ecosystem mass balances.		
M 1.4.06 Coastal erosion and estuarine development	Erosion in marine basins is considered in the landscape development model (SKB R-13-27, SKB TR-14-06), e.g. distribution of accumulation and erosion bottoms is described.		
M 1.4.07 Marine sediment transport and deposition	See NEA FEP K 10.11.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
M 1.5.01 River flow and lake level changes	Changes in river flows and lake levels are considered in the radionuclide model (SKB R-13-46) as future objects have different sizes of catchment areas (thereby different amounts of water passing). Moreover, terrestrialisation affects lake depths and lake levels. Changes in lake levels and sea levels are also considered in the transition from marine basins to lakes.		
M 1.6.12 Accumulation in soils and organic debris	Deposited material may accumulate in soils and organic debris. This is considered in the radionuclide model (SKB R-13-46).		
M 2.4.03 River rechannelling	River erosion and channel erosion are considered in the radionuclide model (SKB R-13-46). At the site, the regolith consists of till and rivers are small, which gives a low potential for any substantial river erosion of the river banks. In the radionuclide model, no long-term accumulation is assumed to occur in streams and thereby the annual sedimentated material is assumed to be resuspended (eroded) and transported downstream, i.e. the sizes of the rivers are assumed to remain throughout the modelled time period.		
W 1.043 Aeolian erosion	Erosion is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46). Erosion leads to transport of sediments and soils. The extent of erosion has formed the present topography and will form the future landscape.		
W 1.044 Fluvial erosion	See NEA FEP K 10.11.		
W 1.046 Aeolian deposition	See NEA FEP A 3.039.		
W 1.047 Fluvial deposition	See NEA FEP A 3.092.		
W 1.048 Lacustrine deposition	See NEA FEP A 3.092.		
W 1.058 River flooding	Flooding of terrestrial areas may lead to transport of radionuclides from the water to terrestrial areas. This is considered in the radionuclide model by the use of a specific flooding coefficient (SKB R-13-18).		
W 1.059 Precipitation (for example, rainfall)	Precipitation is considered in hydrological modelling (SKB R-13-19) and water balances.		
W 1.066 Coastal erosion	See NEA FEP M 1.4.06.		
W 1.067 Marine sediment transport and deposition	Sediment transport and deposition in marine basins is included in the radionuclide model (SKB R-13-46) and in the landscape development model (SKB R-13-27, SKB TR-14-06).		
W 2.103 Accumulation in soil	Deposited material may accumulate in soils and organic debris. This is considered in the radionuclide model both as deposition and permanent accumulation (SKB R-13-46).		

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Table A14-30. SR-PSU FEP Bio35 Export.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
K 8.41 Hunter/ gathering lifestyle	Gathering life style is considered in the radionuclide model (SKB R-13-46), gathering of food is only considered within biosphere objects and neither humans nor food are exported out from the model area. This is a cautious assumption since gathering life style would most likely dilute dose to humans due to humans gathering food from a larger area than the contaminated biosphere objects.		
K 8.43 Removal mechanisms	Removal mechanisms are considered in the radionuclide model (SKB R-13-46). In the radionuclide model, export is considered as transport of dissolved and particulate matter in water flow out from objects, as transport of gas in the atmosphere and as removal of primary producers by natural processes such as export of aquatic pelagic organism or as harvesting of e.g. animal feed.		
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Table A14-31. SR-PSU FEP Bio36 Import.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
K 8.41 Hunter/ gathering lifestyle	Gathering life style is considered in the biosphere interaction matrix. In the radionuclide model, gathering of food is only considered within biosphere objects and neither humans nor food are imported into the model area (SKB R-13-46). This is a cautious assumption since gathering life style would most likely dilute dose to humans due to humans gathering food from a larger area than the contaminated biosphere objects.		
K 8.44 Consumption of uncontaminated products	Consumption of all available sources is considered in the biosphere interaction matrix. The food supply in the radionuclide model is cautiously considered to be derived exclusively from the model area, i.e. being contaminated with radionuclides.		
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SR-PSU FEP Bio37 Interception

No NEA Project FEP is associated with this SR-PSU FEP.

Table A14-32. SR-PSU FEP Bio38 Relocation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.14 Dams	Dam constructions may influence hydraulic heads and may affect surface water flows. Dams are made by artificial thresholdings.	Artificial thresholdings are not considered in SR-PSU. Such thresholdings would enlarge present lakes and the flat landscape of Forsmark would not encourage larger dam constructions.	
A 3.042 Dispersion	Dispersion refers to the movement of radionuclides away from its source and includes advection, diffusion, water and air transport. These processes are considered in the radionuclide model (SKB R-13-46).		
A 3.046 Erosion - lateral transport	Erosion is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46). Erosion leads to transport of sediments and soils. The extent of erosion has formed the present topography and will form the future landscape.		
A 3.047 Erosion (wind)	Erosion is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46). Erosion leads to transport of sediments and soils. The extent of erosion has formed the present topography and will form the future landscape.		
A 3.052 Flooding	Flooding of terrestrial areas may lead to transport of radionuclides from the water to terrestrial areas. This is included in the radionuclide model (SKB R-13-46) by the use of a specific flooding coefficient.		
A 3.058 Greenhouse food production	Greenhouse food production may influence the location of radionuclides if irrigation is performed. Irrigation may increase radionuclide concentrations in crops and therefore irrigation is included in the radionuclide model (SKB R-13-46).		
A 3.074 Lake infilling	Lake infilling is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46) where lakes are gradually infilled due to succession.		
A 3.092 Sedimentation in water bodies	Sedimentation of radionuclides is dependent on the sorption/desorption of radionuclide to particles. This is included in the radionuclide model (SKB R-13-46) as modelled sedimentation (in dry weight per area and year) and K_d values.		
A 3.105 Suspension in air	One pathway for radionuclides from soil and water to become part of the air is by degassing. This is included in the radionuclide model (SKB R-13-46).		
A 3.108 Terrestrial surface	The type of terrestrial area, forest, outcrops, grasslands are important for the transport and accumulation of radionuclides. A regolith model (SKB R-13-22) is used to predict the type of future landscape at Forsmark and the occurrence of wetlands and forest are mapped over time for the entire model area which is included in the radionuclide model (SKB R-13-46).		
A 3.118 Wind	Wind affects the transport of radionuclides by affecting soil erosion, degassing and dilution and transport of radionuclide by wind. Accordingly, wind speed is considered in the radionuclide model and parameterisation.		
E GEN-29 Erosion and weathering	See NEA FEP A 3.046.		
H 2.2.1 Changes in geometry and driving forces of the flow system	Changes in geometry changes the flow pattern. This is considered in the safety assessment where shoreline-displacement is included and flow to different objects is calculated for each time step in the radionuclide model (SKB R-13-46).		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
H 2.4.1 Generalised denudation	Denuding of the site may remove the upper regolith and thereby affecting the dispersion of radionuclides. This is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46) since we considered a glacial cycle and thereby conditions when the ice has removed the upper regolith layers. In addition, by modelling many objects, many different depths of regolith are considered.		
H 2.4.2 Localised denudation	See NEA FEP H 2.4.1.		
H 4.1.2 Solid discharge via erosional processes	See NEA FEPs A 3.046 and H 2.4.1.		
H 4.2.3 Sediment transport including bioturbation	Transport of elements including bioturbation is included in the radionuclide model (SKB R-13-46) where processes such as resuspension and deposition are parameterised (SKB R-13-18).		
I 085a Dams (filling, draining)	Dam constructions may influence hydraulic heads and may affect surface water flows. Dams are made by artificial thresholdings.	Artificial thresholdings are not considered in SR-PSU. Such thresholdings would enlarge present lakes and the flat landscape of Forsmark would not encourage larger dam constructions.	
I 112b Denuding of the site	Denuding of the site may remove the upper regolith and thereby affecting the dispersion of radionuclides. This is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46) since we considered a glacial cycle and thereby conditions when the ice has removed the upper regolith layers. In addition, by modelling many objects, many different depths of regolith are considered.		
I 292 Surface water bodies (physical/chemical changes)	Physical and chemical changes of water bodies are considered in the radionuclide model (SKB R-13-46). For example, in the radionuclide model, changes in chemistry are considered by the use of different parameter sets for marine and limnic stages of the aquatic objects and physical changes are considered by the use of time specific values of the geometry of the objects (SKB R-13-18).		
I 305 Topography (changes)	Changes in topography and landscape development (e.g. transformation from lake to wetland) are considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46).		
J 5.26 Erosion on surface/sediments	See NEA FEP A 3.046.		
J 5.27 Human induced actions on groundwater recharge	Human induced changes in land use that affect recharge are not considered in the hydrological modelling (SKB R-13-19). Contamination through irrigation is considered in the radionuclide model (SKB R-13-46), but not as recharge in the flow modelling.		
K 8.22 Erosion/deposition	See NEA FEPs A 3.046 and A 3.092.		
K 8.38 Ploughing	Ploughing is considered in the radionuclide model (SKB R-13-46) where ploughing depth is included in the calculations.		
K 9.07 Erosion/denudation	Erosion is considered in the, landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46).		
K 10.11 Fluvial erosion/sedimentation	See NEA FEP A 3.046.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
K 10.12 Surface denudation	Denuding of the site may remove the upper regolith and thereby affecting the dispersion of radionuclides. This is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46) since we considered a glacial cycle and thereby conditions when the ice has removed the upper regolith layers. In addition, by modelling many objects, many different depths of regolith are considered.		
K 10.14 Glacial erosion/sedimentation	See NEA FEP A 3.046.		
K 10.15 Glacial–fluvial erosion/sedimentation	See NEA FEPs A 3.046 and A 3.092.		
M 1.4.01 Land slide	Land slide could relocate soils in the landscape.	Land slide is not applicable due to the low topography of the Forsmark area.	
M 1.4.02 Denudation	See NEA FEP K 10.12.		
M 1.4.03 River, stream, channel erosion	River erosion and channel erosion are considered in the radionuclide model (SKB R-13-46). At the site, the regolith consists of till and rivers are relatively small, which gives a low potential for any substantial river erosion of the river banks. In the radionuclide model, no long-term accumulation is assumed to occur in streams and thereby the annual sedimentated material is assumed to be resupended (eroded) and transported downstream, i.e. the sizes of the rivers are assumed to remain throughout the modelled time period.		
M 1.4.07 Marine sediment transport and deposition	See NEA FEPs A 3.046 and A 3.092.		
M 2.4.03 River rechannelling	See NEA FEP M 1.4.03.		
M 2.4.10 Qurries, near surface extraction	Extraction from Quarries may give rise to external exposure. External exposure is considered in the radionuclide model (SKB R-13-46). The external dose is considered by all sources.		
W 1.043 Aeolian erosion	See NEA FEP A 3.047.		
W 1.044 Fluvial erosion	See NEA FEP A 3.046.		
W 1.045 Mass wasting	Mass wasting (the downslope movement of material caused by the direct effect of gravity) is important only in terms of sediment erosion in regions of steep slopes. Erosion and subsequent deposition of material are considered in the radionuclide model (SKB R-13-46).		
W 1.049 Mass wasting	See NEA FEP W 1.045.		
W 1.066 Coastal erosion	See NEA FEP A 3.046.		
W 3.050 Coastal water use	Water use is the use of water for other purpose than drinking. Coastal waters are available for recreational utilisation, and industrial uses. Although this may pose exposure to humans, it is assumed to be insignificant compared to internal exposure due to ingestion, and also smaller than external exposure from terrestrial ground and therefore this is not further considered in the radionuclide model (SKB R-13-46).		
W 3.051 Sea water use	Water use is the use of water for other purpose than drinking and is considered in the biosphere interaction matrix. Sea waters are available for recreational utilisation, shipping etc. Although this may pose exposure to humans, it is assumed to be insignificant compared to internal exposure due to ingestion, and also smaller than external exposure from terrestrial ground and therefore this is not further considered in the radionuclide model (SKB R-13-46).		

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Table A14-33. SR-PSU FEP Bio39 Resuspension.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.026 Colloids	Colloids in water, i.e. particulate matter are included in the radionuclide model as these influence sorption/desorption and thereby transport and accumulation of radionuclides (SKB R-13-46).		
A 3.029 Critical group - agricultural labour	Inhalation of dust by farmers is included in the radionuclide model (SKB R-13-46).		
A 3.042 Dispersion	Dispersion refers to the movement of radionuclides away from its source and includes advection, diffusion, water and air transport. These processes are considered in the radionuclide model (SKB R-13-46).		
A 3.046 Erosion - lateral transport	Erosion is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46). Erosion leads to transport of sediments and soils. The extent of erosion has formed the present topography and will form the future landscape.		
A 3.047 Erosion (wind)	Erosion is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46). Erosion leads to transport of sediments and soils. The extent of erosion has formed the present topography and will form the future landscape.		
A 3.063 Household dust and fumes	Inhalation of contaminated dust and fumes is included in the exposure pathway (SKB R-13-46 Gases and aerosols are considered as a source dissolved in water in the radionuclide model (SKB R-13-46).		
A 3.077 Outdoor spraying of water	Water and dust intake are handled in the radionuclide model (SKB R-13-46).		
A 3.086 Rivercourse meander	River meandering may result in agriculture on former stream beds. River meandering is not considered, but the result would be similar to agricultural use of former lake beds (which is included in the radionuclide model) and thus the effect of this process is considered (SKB R-13-46).		
A 3.088 Saltation	Saltation is considered in the radionuclide model where dust particles are included (SKB R-13-46).		
A 3.091 Sediment resuspension in water bodies	Resuspension is considered in the radionuclide model (SKB R-13-46).		
A 3.092 Sedimentation in water bodies	Sedimentation of radionuclides is dependent on the sorption/desorption of radionuclide to particles. This is included in the radionuclide model as modelled sedimentation (in dry weight per area and year) and K_d values (SKB R-13-46).		
A 3.102 Space heating	Space heating when burning contaminated materials such as trees may contribute to external exposure. External exposure is included in the radionuclide model, but has limited importance for a few and non-dominating radionuclides (SKB R-13-46). The external dose is considered by all sources.		
A 3.105 Suspension in air	One pathway for radionuclides from soil and water to become part of the air is by degassing. This is considered in the radionuclide model (SKB R-13-46).		
A 3.118 Wind	Wind affects the transport of radionuclides by affecting soil erosion, degassing and dilution and transport of radionuclide by wind. Accordingly, wind speed is considered in several parts of the radionuclide model (SKB R-13-46).		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
H 2.4.1 Generalised denudation	Denuding of the site may remove the upper regolith and thereby affecting the dispersion of radionuclides. This is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46), since we considered a glacial cycle and thereby conditions when the ice has removed the upper regolith layers. In addition, by modelling many objects, many different depths of regolith are considered.		
H 2.4.2 Localised denudation	See NEA FEP H 2.4.1.		
H 4.2.3 Sediment transport including bioturbation	Transport of elements including bioturbation is included in the radionuclide model (SKB R-13-46) where processes such as resuspension and deposition are parameterised.		
H 4.2.4 Sediment/ water/gas interaction with the atmosphere	Exchange over the air–water interface and the exchange of 14-C is included in the radionuclide model (SKB R-13-46).		
I 009 Sediments (in water bodies)	The sorption/desorption of radionuclides to particles is considered in the radionuclide model by K_d values for different radionuclides. In addition, the transport of particles between the water column and the sediment is dependent on sedimentation/resuspension processes, which is also included in the radionuclide model (SKB R-13-46).		
I 112b Denuding of the site	Denuding of the site may remove the upper regolith and thereby affecting the dispersion of radionuclides. This is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46), since we considered a glacial cycle and thereby conditions when the ice has removed the upper regolith layers. In addition, by modelling many objects, many different depths of regolith are considered.		
I 211 Outdoor spraying of water (atmospheric dose pathway)	See NEA FEP A 3.077.		
I 292 Surface water bodies (physical/ chemical changes)	Physical and chemical changes of water bodies are considered in the radionuclide model (SKB R-13-46). For example, in the radionuclide model, changes in chemistry are considered by the use of different parameter sets for marine and limnic stages of the aquatic objects and physical changes are considered by the use of time specific values of the geometry of the objects (SKB R-13-18).		
J 5.26 Erosion on surface/sediments	See NEA FEP A 3.046.		
J 6.09 River meandering	See NEA FEP A 3.086.		
K 8.22 Erosion/ deposition	See NEA FEP A 3.046.		
K 8.23 Sedimentation	See NEA FEPs A 3.091 and A 3.092.		
K 9.07 Erosion/ denudation	See NEA FEPs A 3.046 and I 112b.		
K 10.11 Fluvial erosion/sedimentation	See NEA FEPs A 3.046, A 3.091 and A 3.092.		
K 10.12 Surface denudation	See NEA FEP I 112b.		
K 10.14 Glacial erosion/sedimentation	See NEA FEPs A 3.046, A 3.091 and A 3.092.		
K 10.15 Glacial–fluvial erosion/ sedimentation	See NEA FEPs A 3.046, A 3.091 and A 3.092.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
M 1.3.02 Extremes of precipitation, snow melt, and associated	Flooding which is caused by extremes in snowmelt or precipitation is considered in the hydrological model (SKB R-13-19), and in the radionuclide model (SKB R-13-46).		
M 1.4.02 Denudation	See NEA FEP I 112b.		
M 1.4.03 River, stream, channel erosion	River erosion and channel erosion are considered in the radionuclide model (SKB R-13-46). At the site, the regolith consists of till and rivers are relatively small, which gives a low potential for any substantial river erosion of the river banks. In the radionuclide model, no long-term accumulation is assumed to occur in streams and thereby the annual sedimentated material is assumed to be resupended (eroded) and transported downstream, i.e. the sizes of the rivers are assumed to remain throughout the modelled time period.		
M 1.4.04 River meandering	See NEA FEP A 3.086.		
M 1.4.05 Freshwater sediment transport and deposition	Sediment transport and deposition are included as several aspects, e.g. the radionuclide model (Sediment and resuspension parameters), the sediment model describing infilling of marine basins and lakes with time, and ecosystem mass balances.		
M 1.4.06 Coastal erosion and estuarine development	Erosion in marine basins is considered in the modelling of future development of marine basins (e.g. distribution of accumulation and erosion bottoms is described).		
M 1.4.07 Marine sediment transport and deposition	See NEA FEPs A 3.046 and A 3.091.		
M 1.5.01 River flow and lake level changes	Changes in river flows and lake levels are included in the radionuclide model (SKB R-13-46) as future object have different sizes of catchment areas (thereby different amounts of water passing). Moreover, terrestrialisation affects lake depths and lake levels. Changes in lake levels and sea levels are also considered in the transition from marine basins to lakes.		
M 2.4.03 River rechannelling	River erosion and channel erosion are considered in the radionuclide model (SKB R-13-46). At the site, the regolith consists of till and rivers are small, which gives a low potential for any substantial river erosion of the river banks. In the radionuclide model, no long-term accumulation is assumed to occur in streams and thereby the annual sedimentated material is assumed to be resupended (eroded) and transported downstream, i.e. the sizes of the rivers are assumed to remain throughout the modelled time period.		
W 1.043 Aeolian erosion	See NEA FEP A 3.047.		
W 1.044 Fluvial erosion	See NEA FEPs A 3.046, A 3.091 and A 3.092.		
W 1.066 Coastal erosion	See NEA FEPs A 3.046, A 3.091 and A 3.092.		
W 1.067 Marine sediment transport and deposition	Sediment transport and deposition in marine basins are included in the radionuclide model (SKB R-13-46) and in the model describing development of the landscape in Forsmark.		

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Table A14-34. SR-PSU FEP Bio40 Saturation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
H 4.2.1 Soil moisture and evaporation	This process is considered in the hydrological modelling (SKB R-13-19) that calculates input parameters to the radionuclide model (SKB R-13-46).		
K 10.02 Effective moisture (recharge)	In the surface hydrology modelling, meteorological input is used and evapotranspiration processes are quantified explicitly by the model (SKB R-13-19).		

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Table A14-35. SR-PSU FEP Bio41 Radioactive decay.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.037 Crop storage		When crop is stored, radionuclide concentration may increase if seepage or flooding wet the crop. Decay of radionuclides in the stored crop may also decrease the exposure. If crop is wetted it is most likely discarded as food and decay of radionuclides is only important for short-lived isotopes considering the length of storage of crops. For radionuclides entering from a deep repository this is thus irrelevant.	
A 3.082 Radioactive decay	Radioactive decay and daughter nuclides are included in the radionuclide model (SKB R-13-46).		
I 045 Progeny nuclides (critical radionuclides)	The decay chain and decay products are included in the radionuclide model (SKB R-13-46).		
I 082 Crop storage		See NEA FEP A 3.037.	
K 8.45 Radon pathways and doses	Radon emission is considered in the biosphere interaction matrix but not included in the radionuclide model (SKB R-13-46).		

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Table A14-36. SR-PSU FEP Bio42 Exposure.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.004 Animal grooming and fighting	Animal fighting and grooming may lead to exposure if the animals take up radionuclides that have been attached to their fur/skin during fighting. This is indirectly considered as concentration ratios are estimated based on measurements on wild animals (SKB R-13-01). These animals have due to a natural life style experienced grooming and fighting.		
A 3.006 Ashes and sewage sludge fertilizers	Ashes and sewage sludge may increase crop yield. In the radionuclide model, values of crop production from fertilized land are used to calculate production of food and thereby this process is indirectly included. Ashes of burned peat may concentrate radionuclides in the soil. In the safety assessment, each object is assumed to receive the entire radionuclide release and thus radionuclides are already present within the object and ashes will not introduce an extra source of contaminants. This is also handled in a separate calculation case.		
A 3.013 Biotoxicity		In terms of the behaviour and transport of radionuclides in the environment, biotoxicity can lead to the disruption of food webs. For human dose prediction, such disruptions need not be considered quantitatively because ignoring their effects on food webs would lead to over-estimates of dose. In addition, the human dose limit is a small fraction of the natural background dose and this will likely exclude any possibility of biotoxic effects.	
A 3.015 Building materials	Wood etc used as building material may expose humans to external exposure. External exposure is included in the radionuclide model (SKB R-13-46), but has limited importance for a few and non-dominating radionuclides. The external dose is considered by all sources.		
A 3.030 Critical group - clothing and home furnishings	Clothing, furniture etc. may expose humans to external exposure and is considered in the biosphere interaction matrix. External exposure is included in the radionuclide model (SKB R-13-46). The proportion of external exposure compared to internal is very small and therefore the effect of different materials in clothing and furniture has not been further explored.		
A 3.032 Critical group - house location	The location of house may be important for the exposure of humans. In the radionuclide model, all members of the critical group are assumed to live within the model object, and thereby be exposed to external exposure.		
A 3.033 Critical group - individuality	Critical group is considered in the radionuclide model (SKB R-13-46).		
A 3.034 Critical group - leisure pursuits	Activities such as hockey, curling on contaminated ice or swimming in contaminated water may expose humans to external exposure. In the radionuclide model, the concern is mainly long-lived radionuclides and these give the highest external dose from ground, and time spent in lakes swimming or on ice skating has not to be considered. Instead, as a cautious assumption, humans are assumed to spend their entire time (100%) outdoors receiving external exposure from the ground.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.035 Critical group - pets	If the fur of pets is contaminated by radionuclides, humans may be exposed to external exposure. Pets are not specifically considered in the radionuclide model, but external exposure is included in the radionuclide model (SKB R-13-46). External exposure has limited importance for a few and non-dominating radionuclides. The external dose is considered by all sources.		
A 3.036 Crop fertilizers and soil conditioners	Fertilizers and soil conditioners increase the yield from agricultural land, but may also dilute the concentration of radionuclides in the crop if radionuclides that are essential elements are diluted with uncontaminated elements in the fertilizers. In the safety assessment, values of crop production from fertilized land are used to calculate production of food and thereby this process is considered. As a cautious assumption, fertilizers are not considered when estimating concentration of radionuclides in the crop, but then all elements are assumed to be taken up from the soil.		
A 3.040 Dermal sorption (except tritium)	Dermal sorption is considered in the biosphere interaction matrix. Dermal sorption in general is likely of minor importance for humans, compared to the direct ingestion and inhalation of radionuclides. Cautious assumptions built into these major pathways could readily include dermal sorption, and therefore, no explicit quantitative treatment of dermal sorption is required.		
A 3.041 Dermal sorption (tritium)	See NEA FEP A 3.040.		
A 3.048 Fires (agricultural)	Fires are considered in the biosphere interaction matrix, but not included in the radionuclide model (SKB R-13-46). Although fires may give rise to high concentration in the atmosphere on a short time scale the contribution to dose on a 50 year perspective is assumed to be small.		
A 3.049 Fires (forest and grass)	See NEA FEP A 3.048.		
A 3.056 Gas leakage into basements	Gas leakage into buildings is considered in the biosphere interaction matrix, but was screened out (see SKB R-14-02).	Exposure from the biosphere object all year around is regarded to be higher than exposure inside a house.	
A 3.060 Groundshine	Groundshine is part of the external exposure and is included in the radionuclide model.		
A 3.062 Herbicides, pesticides and fungicides	Herbicides, pesticides and fungicides may stimulate crop production and increase the yield from agricultural land. This is considered in the radionuclide model as values of crop production are from conventional agricultural land where herbicides, pesticides and fungicides are used. In FEP A 3.062 it is suggested that agricultural chemicals can become contaminated and pass contaminants onto plants and into various food chains. However, in the radionuclide model (SKB R-13-46), objects are assumed to receive the entire radionuclide release and thus, no extra import of radionuclides is assumed to occur via addition of pesticides, fungicides and herbicides.		
A 3.063 Household dust and fumes	Inhalation of contaminated soil dust is included as an exposure pathway and thus volatilisation/aerosol/dust is included in the assessment. Re-volatilisation is considered in the matrix and models.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.064 Houseplants	External exposure is included in the radionuclide model (SKB R-13-46), but has limited importance for a few and non-dominating radionuclides. The external dose is considered by all sources although contribution from household plants is assumed to be small.		
A 3.083 Radiotoxic contaminants		In terms of the behavior and transport of radionuclides in the environment, radiotoxicity can lead to the disruption of food webs. For human dose prediction, such disruptions need not be considered quantitatively because ignoring their effects on food webs would lead to overestimates of dose. In addition, the human dose limit is a small fraction of the natural background dose and this will likely exclude any possibility of radiotoxic effects.	
A 3.095 Smoking		Tobacco is not cultivated at Forsmark at present and this FEP is not considered in the radionuclide model (SKB R-13-46). However, any contribution to dose from smoking is likely to be minor compared to the amounts ingested through food and water.	
A 3.112 Urbanization on the discharge site	Whether humans are urbanized or rural influence the exposure. In the safety assessment, as a cautious assumption, human populations are assumed to be rural and to only feed on products produced within the biosphere objects, i.e. the contaminated area (SKB R-13-46).		
A 3.114 Water leaking into basements	Water leaking into basements could lead to an increased external exposure. However, this exposure would still be small in comparison to ingestion of contaminated water and food and this pathway has been considered negligible in the radionuclide model (SKB R-13-46).		
H 4.4.1 Human exposure: External	External exposure is included in the radionuclide model (SKB R-13-46).		
H 4.4.2 Human exposure: Ingestion	Human exposure due to drinking and feeding is included in the radionuclide model (SKB R-13-46). Drinking is the uptake from surface water and water extracted from the well. Ingestion of food is further described in the biosphere synthesis report (SKB TR-14-06).		
H 4.4.3 Human exposure: Inhalation	Human exposure due to inhalation is considered in the radionuclide model (SKB R-13-46) as inhalation of dust.		
I 010 Recycling process (biomass)	Ashes and sewage sludge may increase crop yield due to an extra supply of essential elements. In the safety assessment, values of crop production from fertilized land are used to calculate production of food and thereby this process is considered.		
I 074a Lake exposure scenario	Humans may be exposed to contaminants as a result of their activities associated with a lake. This is considered both in the radionuclide model (SKB R-13-46), where ingestion of food from lakes and usage of lake water in agriculture is included.		
I 074b Well exposure scenario	Humans may be exposed to contaminants as a result of their activities associated with well. This is considered both in the radionuclide model (SKB R-13-46), where drinking of water from wells is included.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 074c Swamp exposure scenario	Humans may be exposed to contaminants as a result of their activities associated with a lake. This is considered both in the radionuclide model (SKB R-13-46), where ingestion of food from wetlands is included.		
I 074d Combination exposure scenario	Humans may be exposed through a combination of exposure pathways. This is considered in the radionuclide model (SKB R-13-46) where exposure from different ecosystems is considered as well as external exposure and inhalation of dust.		
I 074e Artificial lake exposure scenario		Radionuclide discharge from the repository is assumed to enter low points in the environment, i.e. lakes or wetlands. Thus, the highest dose to humans is assumed to come from natural lakes and wetlands and artificial lakes are not further considered.	
I 090 Dermal sorption (tritium and others)	See NEA FEP A 3.040.		
I 102 Ecological successions	Succession is considered in the landscape development model (SKB R-13-27, SKB TR-14-06) and radionuclide model (SKB R-13-46). Marine basins are developed to lakes and thereafter to mires. The latter can thereafter be used as agricultural land.		
I 128 Gas leakage into basements	See NEA FEP A 3.056.		
I 139 Groundshine	See NEA FEP A 3.060.		
I 150 Household plants (dose pathway)	See NEA FEP A 3.064.		
I 227 Urbanization (demographics)	See NEA FEP A 3.112.		
I 276 Smoking (dose pathway)		See NEA FEP A 3.095.	
K 0.3 Gaseous and volatile isotopes	C-14 is handled in the radionuclide model (SKB R-13-46).		
K 8.13 Exposure pathways	Exposure pathways are considered in the radionuclide model (SKB R-13-46). Ingestion of various food sources, water inhalation of dust and external exposure are considered.		
K 8.14 Human lifestyle	Human lifestyle will influence the exposure pathways to man. In the radionuclide model the cautious assumption that humans are gaining all their food and spend all their time in the contaminated biosphere object is applied.		
K 8.27 Atmosphere	The atmosphere is considered in the radionuclide model (SKB R-13-46).		
K 8.42 Contaminated products (non-food)	Material products used for other purposes than food may be contaminated. This is considered in the radionuclide model (SKB R-13-46) as external exposure.		

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SR-PSU FEP Bio43 Heat storage

No NEA Project FEP associated with this SR-PSU FEP.

Table A14-37. SR-PSU FEP Bio44 Irradiation.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.082 Radioactive decay		Too low radionuclide levels to affect regolith and water in regolith by irradiation.	Other aspects are handled in SR-PSU FEP Bio41.
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Table A14-38. SR-PSU FEP Bio45 Light-related processes.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.090 Seasons	In the radionuclide model, annual mean values are used for parameterisation. These values are based on site specific measurements considering seasonal variations (SKB R-13-18).		
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SR-PSU FEP Bio46 Radiolysis

No NEA Project FEP associated with this SR-PSU FEP.

Table A14-39. SR-PSU FEP Bio47 Radionuclide release.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 3.056 Gas leakage into basements	Gas leakage into buildings is considered in the biosphere interaction matrix, but was screened out (see SKB R-14-02).	Exposure from the biosphere object all year around is regarded to be higher than exposure inside a house.	
A 3.084 Radon emission	Radon emission is considered in the biosphere interaction matrix but not included in the radionuclide model (SKB R-13-46).		
E GEN-31 Radionuclide reconcentration	Remobilization of radionuclides due to changed conditions, e.g. shore-level displacement, bioturbation and draining is considered in the radionuclide model (SKB R-13-46).		
I 128 Gas leakage into basements	See NEA FEP A 3.056.		
K 0.3 Gaseous and volatile isotopes	C-14 is handled in the radionuclide model (SKB R-13-46).		
K 8.12 Radionuclide volatilisation/aerosol/dust production	Volatilisation/aerosol/dust is considered in the radionuclide model (SKB R-13-46). Inhalation of contaminated soil dust is an exposure pathway and thus volatilisation/aerosol/dust is considered in the radionuclide model (SKB R-13-46).		
K 8.21 Dilution of radionuclides in surface water (aquifer, river, lake etc.)	The dilution of radionuclides in water bodies is considered in the radionuclide model (SKB R-13-46), where the radionuclide release is assumed to become completely mixed within the receiving water bodies.		
K 8.27 Atmosphere	The atmosphere is considered in the radionuclide model (SKB R-13-46).		
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Table A14-40. SR-PSU FEP Bio48 Changes in rock surface location.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
I 305 Topography (changes)	Change in topography is considered in the DEM (SKB R-12-03), landscape development model (SKB R-13-27) and in the radionuclide model (SKB R-13-46) with altered geometries for each time step in the model (e.g. geometry of marine basins) (SKB R-13-18).		
K 9.07 Erosion/ denudation	Erosion and denudation are considered in the landscape development model (SKB R-13-27) and radionuclide model (SKB R-13-46). Denuding of the site may remove the upper regolith and thereby affect the dispersion of radionuclides. In the radionuclide model, a glacial cycle is modelled and thereby conditions when the ice has removed the upper regolith layers (denudation) are considered.		
K 10.11 Fluvial erosion/sedimentation	Erosion and sedimentation are considered in the landscape development model (SKB R-13-27), the radionuclide model (SKB R-13-46) and in the ecosystem-specific parameters (SKB R-13-18).		

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Table A14-41. SR-PSU FEP Bio49 Sea-level change.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.59 Sea-level change	Sea level changes are considered in the landscape development model (SKB R-13-27, SKB TR-14-06), in the radionuclide model (SKB R-13-46), hydrological modelling (SKB R-13-19) and in the Ecosystem-specific parameters (SKB R-13-18). At the start of the modelling of the Forsmark landscape, the entire area is situated below sea level and at the end of the modelling period the entire area is situated above sea level.		
E GEN-33 Sea-level changes	Same as NEA FEP A 2.59.		
H 2.2.1 Changes in geometry and driving forces of the flow system	Effects of shoreline displacement, wave erosion and sedimentation of Quaternary deposits are considered in the landscape development model (SKB R-13-27, SKB TR-14-06), Changes in precipitation, permafrost and temperature affects the groundwater flow and thereby the solute transport. These are considered in the modelling of surface hydrology and near-surface hydrogeology (SKB R-13-19).		
I 143 Groundwater (redirection of)	Effects on hydrology of changes in topography and regolith stratigraphy are addressed in the hydrological modelling (SKB R-13-19). Redirection of flow under permafrost and glacial conditions are considered in the hydrogeological modelling (SKB R-13-19).		
I 266 Sea-level (rising)	See NEA FEP A 2.59.		

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
J 5.31 Change in sea level	See NEA FEP A 2.59.		
M 1.4.03 River, stream, channel erosion	At the site, the streams are relatively small and mainly situated in till areas, which mean a low potential for any substantial river erosion of the river banks. In the radionuclide model, no accumulation of radionuclides is assumed to occur in streams (SKB R-13-46) and thereby the annual sedimentated material is assumed to be resupended (eroded) and transported downstream to the nearest lake, i.e. the sizes of the rivers are assumed to remain throughout the modelled time period.		
S 081 Sea level changes	See NEA FEP A 2.59.		
S 087 Surface water chemistry	Changes in the chemistry are accounted for in the probabilistic approach where the potential changes in important parameters are included in ecosystem-specific parameters and CR and K_d values (SKB R-13-18).		
W 1.068 Sea level changes	See NEA FEP A 2.59.		
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Table A14-42. SR-PSU FEP Bio50 Thresholding.

NEA FEP	Aspects of the FEP addressed:	Aspects of the FEP not addressed because:	Comments
A 2.14 Dams	Dam constructions may influence hydraulic heads and may affect surface water flows. Dams are made by artificial thresholdings.	Artificial thresholdings are not considered in SR-PSU. Such thresholdings would enlarge present lakes and the flat landscape of Forsmark would not encourage larger dam constructions.	
I 085a Dams (filling, draining	See NEA FEP A 2.14.	See NEA FEP A 2.14.	
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